ENDNOTES

1. See, for example, Berenfeld (1993), Feldman (1994), Hunter (1993), Julyan (1988, 1990, 1991, 1993), Lenk (1989), Tinker (1987a, 1987b, 1988, 1989, 1990, 1993a, 1993b).

2. Among the most prominent of these curricula were *Elementary Science Study* (Walcott, Hawkins, and Naiman), *Science: A Process Approach* (American Association for the Advancement of Science Commission on Science Education Mayor and Livermore), and *Science Curriculum Improvement Study—SCIS* and *SCIIS—(Karplus)* for elementary grades; *Intermediate Science Curriculum Study* (Berkman, Redfield, and Dawson), *ERC—Life Science Investigations—Man and Environment* (Day and Harvey), *Foundational Approach in Science Teaching* (Pottenger) for middle school; and *Physical Science Study Committee—High School Physics* (Zacharias), *Chemical Bond Approach* (Strong), *Biological Sciences Curriculum Study—High School Biology* (Mayer), *Chemical Education Materials Study* (Pimental, Ridgway), and *Introductory Physical Science* (Haber-Schaim) for high school.

3. These issues may be understood better when current network science projects have completed their own evaluations, but most of the existing studies have not been made available publicly.

4. The most important sources of data for the section on NGS Kids Network include an interview with Judy Vesel, TERC's project director and curriculum director for Kids Network, on January 13, 1998; an interview with Sharon Cowley, NGS Kids Network director, on August 17, 1999; an interview with Al Vincent, president of Kendall-Hunt, on September 7, 1999; Jimmy Karlan's e-mail to NGS and TERC of April 4, 1995 detailing his proposal for major revisions of Kids Network curriculum units; Karlan, Huberman, and Middlebrooks' research study (1997); many informal conversations with Vesel and other project staff; the experience of co-author Bob Coulter as a field-test teacher and consultant for the web-based units; NGS Kids Network curriculum materials, print and online; and project proposals.

5. This vignette and the two that followed are accounts of real teachers. The names have been changed to afford anonymity.

6. The most important sources of data for the case study of Global Lab include a formal, taped interview with former project director Leigh Peake on September 7, 1997; many informal conversations with Peake and other project staff; conversations with Robin Brown, TERC's development coordinator; observations in many Global Lab classrooms and conversations with Global Lab teachers; Global Lab curriculum materials, print and online; and project proposals.

7. In 1997, the Testbed for Telecollaboration project staff anticipated Global Lab's need for a streamlined system of authoring, publishing, and community communication. The Testbed had previously developed CLEO (Collaborative Learning Environments Online), a web-based tool that facilitated classroom research by allowing students to author and publish their own investigations. The Testbed worked with Global Lab project developers to reconfigure CLEO as GLOW, an online site for exchanging data.

8. The most important sources for data for the case study of Journey North include interviews with Elizabeth Howard on March 18, 1998, and Karen Leichtweis on March 19, 1998 (taped); contributions to the Network Science Conference by Joel Halvorson; the experience of coauthor Bob Coulter as a Journey North teacher and consultant; and the Journey North web site and teacher materials.

9. Access to messages from Global Lab teachers was provided courtesy of the Global Lab project at TERC.

10. Access to questionnaires from Classroom BirdWatch teachers was provided courtesy of Cornell Laboratory of Ornithology.

11. Wait times of 3 to 4 seconds may not seem like much, but Rowe (1983) suggested that increasing the time from 1 second to 3 seconds has a large effect on the length and types of responses students give.

12. Based on her research, Rowe (1983) recommended that even the more neutral verbal rewards such as fine and okay be used sparingly because higher rates of such rewards tend to be associated with lower quality explanations.

13. A synopsis of this research, broken down into various process and content areas, is included in chapter 15 of AAAS's (1993) *Benchmarks for Science Literacy*.

14. There are, in fact, several varieties of sociocultural perspectives on learning which we do not distinguish here. Cobb and Bauersfeld (1995) presented a concise overview of these as well as their interactionist view in which they preserve what they see as the merits of constructivist and sociocultural perspectives, depending on the problem under consideration.

15. For evidence of the pedagogical advantages of the use of controversy, see Johnson, Brooker, Stutzman, Hultman, and Johnson (1985). Fifth-grade students working in groups that debated different points of view about whether wolves should be a protected species learned more and had better attitudes about the experience than those who worked in groups with the goal of reaching a consensus on the same issue.

16. Preliminary research suggests that connecting learners who are otherwise isolated—and therefore do not have good face-to-face alternatives—may be an excellent use of online discussions.

17. Additional discussion of this issue can be found in chapter 3. See "Lesson 6: Online staff development cannot replace face-to-face communication."

18. Finzer is educational technology director at Key Curriculum Press and heads the development of the data analysis program *Fathom Dynamic Statistics* (1999) and accompanying curriculum materials for Grades 9 to 14 (see www.keypress.com/fathom).

19. We have inserted some of the plots they examined during their analysis.

20. This is an expansion of accounts found in Coulter (1997a and 1997b).

21. Coulter's background includes a doctoral degree in curriculum and teaching with a focus on integrating technology into elementary science programs and familiarity with methods of statistical analysis. Furthermore, he knew these students well, having had them in a class the previous year.

22. See Polman's (1997) dissertation for a long-term study of a high school teacher's struggle with learning how to design and manage students' projects effectively.

23. We do not mean to single out these projects. We could draw similar experiences from nearly every network science project.

24. We chose not to include a discussion of how software may help or hinder this problem. Network science classrooms that do use software for analyzing data typically use spreadsheets, and few teachers seem to be aware of how spreadsheets differ from data analysis software (Biehler, 1993). Although spreadsheets can be used to generate summary statistics and high quality graphics, they are ill equipped for the kind of visual investigation of statistical distributions that is the hallmark of exploratory data analysis (cf. Cleveland, 1993). There are a now a number of data analysis tools designed specifically for student use. However, even with the best of *these-Data Explorer* (Sunburst, 1998), *DataScope* (Intellimation, 1994), *Fathom Dynamic Statistics* (Key Curriculum Press, 1999), *NGS Works* (National Geographic Society, 1997), *Statistics Workshop* (Sunburst, 1992), *Tabletop* (Broderbund, 1995)students too frequently use them to search, often in trial-and-error fashion, for the right display plot (Grant, 1998) rather than explore the data.

25. For readers not familiar with these representations, the lines on either end are sometimes referred to as whiskers and the rectangle in the middle as the box. The plot partitions the data into quartiles. The left whisker extends from the smallest value to the 25th percentile. Thus, in the upper box plot for the cities along the 47th parallel, the left whisker indicates that the lowest value is about 2 and the 25th percentile is at 7 inches. The right whisker of the upper plot incorporates the upper 25% of the data, ending with the highest value of 27. The box extends from the 25th to the 75th percentiles, enclosing 50% of the data. The location of the median is indicated by the line within the box, which in the case of the upper plot is 11.

26. The example of snowfall in this chapter illustrates the conceptual difficulty of working with aggregate values. The January snowfall data are, in fact, 30-year averages for the years 1965 to 1994. This information changes how one views the data. Thinking the data were from one January, an expert might have wondered whether this had been a typical January. On learning that these are average values, an expert would take the apparent differences more seriously. However, many young students would be baffled by average snowfall. Should they still picture 6 inches of snow piled up over Reno? The risk would be that, being unsure about what averages values are, students would treat them as numbers only, stripped of their meaning.

27. Although these were the basic representations students used, the program also allowed students to form various groupings of data points. Using these capabilities, the students could, and did, partition data displayed as a stack plot into representations that were functionally equivalent to histograms and box plots.