Implementation Variation and Fidelity in an Inquiry Science Program: Analysis of GLOBE Data Reporting Patterns

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Received 25 June 2002; Accepted 5 March 2003

Abstract: This article examines variations in patterns in the enactment of a large-scale kindergarten through Grade 12 science inquiry program. Student data reports in the GLOBE program provide a useful measure of implementation because key design elements in the program are student collection and reporting of local environmental data. We examined associations among teachers' responses to survey items to patterns in GLOBE data reporting to develop hypotheses about important contextual factors related to program implementation. Implications for the study of science inquiry programs are discussed. © 2004 Wiley Periodicals, Inc. J Res Sci Teach 41: 294–315, 2004

Researchers of educational innovations have long been concerned with studying variations in the implementation or enactment of educational innovations. Evaluators in particular have advocated the collection of data on within-program variability in program implementation, because the scale, depth, and fidelity of implementation cannot be assumed ahead of time when designing an evaluation (Patton, 1979; Rossi & Freeman, 1989; Scheirer, 1994). Data on variation in program implementation are critical both to understanding the limits of a program's applicability or flexibility and to explaining within-innovation variations in effectiveness (Lipsey & Cordray, 2000). In addition, such data can help identify competing hypotheses for observed effects (Schiller, 2001) and possible flaws in the assumptions that underlie the program design (Goodson, Layzer, St. Pierre, Bernstein, & Lopez, 2000).

Researchers differ in their interpretations of the significance of implementation variation. Some are concerned with measuring implementation fidelity—that is, the extent to which teachers enact innovations in ways that either follow designers' intentions or replicate practices developed elsewhere (Loucks, 1983). These researchers often cite evidence from large-scale studies of innovations such as the Comer School Development Program, Success for All, and the New American Schools scale-up that implementation fidelity is often strongly related to program

Contract grant sponsor: NSF; Contract grant number: ESI-9802033.
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DOI 10.1002/tea.20002
Published online in Wiley InterScience (www.interscience.wiley.com).

effectiveness (Millsap, Change, Obeidallah, Perez-Smith, Brigham, Johnston, Cook, & Hunt, 2000; Stringfield, Datnow, & Ross, 1998; Bodilly, 1998). Other researchers have argued that focusing on implementation fidelity ignores the important role teachers have in adapting and transforming innovations to be effective in different contexts. They can point to evidence from studies of policy implementation that demonstrate the central importance of teachers' views and understandings of policy goals in shaping the outcomes of innovations (e.g., Cohen & Hill, 1998).

However, few studies to date provide a context for studying innovations in which both variation and fidelity are important dimensions of implementation to designers. Earlier research has focused primarily on programs and innovations in which reformers believed it was particularly valuable or important that teachers adhere to a particular design for teaching and learning (e.g., Stringfield, Datnow, & Ross, 1998). Alternately, research has examined curriculum adaptation and enactment in situations where codevelopment of the innovation with teachers was part of the original design of the innovation (e.g., Brown & Edelson, 1998). There are, however, a number of innovations developed to encourage kindergarten (K) through Grade 12 teachers to incorporate science resources and inquiry activities into their teaching that are concerned to some degree with both fidelity of implementation and teacher choice in the use of particular materials. The Full-Option Science System (FOSS), Science Education for Public Education Program (SEPUP), various regional and nationwide "river watch" programs, and the program that is the subject of this article, GLOBE, are just a few such science inquiry initiatives.

To date, however, few of these programs have collected much empirical data on whether and how the resources and instructional strategies promoted in the workshops actually get implemented in classrooms. The GLOBE program provides a rich context for examining issues concerning implementation of inquiry-oriented, scientist-driven educational programs because the program has both a history of collecting evaluation data on implementation and mechanisms for capturing program activity as it occurs. As part of its evaluation activities, SRI International researchers have collected data from teachers about their own implementation practices and perceptions of the program since 1996. Considered together with data on program activity derived from program activities involving a Web-based data archive, the teacher reports offer an opportunity to examine implementation from the perspectives of both implementation fidelity and program adaptation.

GLOBE as a Context for Investigating Assumptions about the Enactment of Inquiry Science Teaching

GLOBE is an international environmental science and science education program focused on improving student understanding of science by involving young people in the collection of data for real scientific investigations. The program is organized into investigation areas, each focused on a particular topic in environmental science and headed by a GLOBE scientist selected through a competitive, peer-reviewed proposal process. Each scientist has developed a set of data collection protocols for his or her investigation area which K–12 students are expected to follow in measuring characteristics of their local atmosphere, bodies of water, soil, and land cover. Local GLOBE partner organizations, typically universities, provide training to teachers in the use of these protocols and of the set of accompanying learning activities included in the GLOBE teacher's guide; in turn, GLOBE-trained teachers select protocols and learning activities to use with their students. Students collect data according to the protocols and record their measurements using forms provided in the teacher's guide.

One feature of the GLOBE program that makes it a particularly compelling example of inquiry-based science education is that GLOBE students are not just collecting data as part of an isolated laboratory experience but as contributors to actual scientific studies. Students report data to the program's website, a large repository of environmental science data worldwide. GLOBE scientists use these student-collected data in their own investigations of such phenomena as the verification of remotely sensed global precipitation (Postawko, Morrissey, Greene, & Mirsky, 2001), accuracy assessment of Landsat images (Congalton, Rowe, & Becker, 2001), and modeling of relationships among Earth systems (Robin, Levine, & Riha, 2001).

From its inception, GLOBE's scientific and educational goals have been inseparable. The GLOBE program was formed in 1995 with funding and collaboration from multiple federal agencies with missions that span the fields of science and education: the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), the Environmental Protection Agency (EPA), and the Departments of Education and State. NASA and NOAA scientists in particular have been heavily involved in helping to shape the scientific activities of GLOBE and have loaned staff to manage the program's activities. By Fall 2002, the program had achieved considerable success toward realizing its scientific and educational mission. The Program reached 104 countries, such that nearly every biome on Earth was represented in GLOBE. Students have submitted over 8 million measurements to the GLOBE Web site. The program has reached thousands of teachers and hundreds of thousands of students from across the world. As of July 2002, more than 20,000 teachers from more than 12,000 schools have completed GLOBE training. According to recent teacher surveys, it is estimated that the reach of GLOBE is between 153,000 and 244,000 students among schools that have reported data to the GLOBE website in the past 3 years (Penuel, Korbak, Lewis, Shear, Toyama, & Yarnall, 2002).

Like other science inquiry programs, GLOBE has a kind of program logic model or "theory of change" (Connell & Kubisch, 1999) that underpins its design. Within this model, there are a number of important assumptions, four of which are discussed below and analyzed in this study. Each assumption sets GLOBE apart from some other programs, but each assumption is one that one or more other science education programs like GLOBE has adopted. Analyzing how well these assumptions stand up to data on GLOBE program implementation is a chief aim of our evaluation research.

Assumption 1: Classrooms Can Carry Out GLOBE Data-Reporting Activities with Fidelity, Following the Protocols and Reporting Data Consistently

To meet its scientific mission, the GLOBE program needs data that are scientifically useful. A key assumption of the program is that students and teachers can collect scientifically useful data. For the data to be useful to scientists, they must be collected according to the protocols and reported consistently over time. GLOBE scientists are therefore genuinely concerned with the fidelity of teachers' and students' implementation of the scientific data collection protocols and persistent and reliable reporting of the collected data.

Although nothing prevents teachers who have undergone GLOBE training from using GLOBE resources and learning activities without submitting data to the database, students' involvement in collecting and reporting scientific data is at the core of the GLOBE concept. The GLOBE Data Archive, the place where student-collected data are stored and can be reviewed, is a key element of the GLOBE infrastructure and program design. As the GLOBE teacher's guide makes clear:

> Data reporting is the step that makes the GLOBE collaboration [between schools and scientists] real. Through GLOBE, members of the science community provide content, support, and mentoring to the primary, middle, and secondary education community. However, scientists get nothing for these efforts unless student observations are reported and included in the GLOBE archive. (GLOBE Program, 2002, p. xiii)

The shared repository for GLOBE data (the Student Data Archive) provides a record of every data submission going back to the program's beginning in 1995. This record has provided scientists with a means for determining the usefulness of the data for their own studies. In their own review of the Data Archive, scientists have found that the data available are of good quality—comparable to other available data sets on the environment—but that schools were not reporting data consistently enough (Becker, Congalton, Budd, & Fried, 1998; Lawless & Rock, 1998; Levine, 1998; Means et al., 1998). Atmosphere or weather data, the GLOBE data type most commonly collected by schools, must be reported every day including weekends and summers, according to the GLOBE protocols. However, most GLOBE schools do not report data in the summer months (Means et al., 2001). This article focuses largely on consistency and persistence in data reporting because these qualities are requirements for building a data set that is useful for purposes of environmental research.

In its emphasis on data reporting and scientific accuracy, GLOBE is similar to a number of so-called network science programs that have become widely available to educators in the past 10 years. Such programs have drawn on networked technologies such as the Internet to create virtual communities that engage students not just as learners but as scientists themselves, collecting and analyzing data that are part of larger scientific investigations (Feldman, Konold, & Coulter, 2000). In all of these network science programs, as in GLOBE, the role of data reporting is central because investigations, whether conducted by students or by scientists, depend on large quantities of student-collected data and the efforts of many data collectors. The extent to which teachers and students really do contribute to the networked data archive of such programs is a potentially limiting factor for program success. In this respect, GLOBE's large data archive, coupled with SRI evaluation data, is a valuable source of evidence concerning the factors that shape the extent to which schools contribute to a network science program's success.

Assumption 2: Teachers' Choices about GLOBE Enactment Will Not Undercut the Scientific Aims of the Program

Unlike many of the programs that have provided the context for studying fidelity of implementation (e.g., Bodilly, 1998; Millsap et al., 2000; Stringfield, Datnow, & Ross, 1998), GLOBE's philosophy has always been one of providing resources and leaving decisions concerning curriculum and pedagogy to teachers. In some ways it would be a mistake to treat GLOBE as a program in any strict sense because teachers' adaptations shape GLOBE's potential to promote student learning in such fundamental ways. Teachers are permitted to select which investigation areas within GLOBE they implement with students, how much time they devote to GLOBE activities, which learning activities to use, and in what order to introduce different protocols or activities.

Each of these teacher decisions could have an influence on the enactment of the program as well as the program's effectiveness. Yet a core implicit assumption of the GLOBE program is that teachers' choices are not threats to the program's scientific and educational goals, but are instead assets. The authenticity of the data collected for later use by scientists is expected to stimulate learning and actually encourage innovation (GLOBE Program, 2002). The program staff believe that teachers are in the best position to help students make connections between GLOBE data collection efforts and their own experience. For example, teachers are actively encouraged to ‘‘stimulate and reinforce their students’ natural interests in their surroundings’’ and help students answer ‘‘questions that they want to answer’’ (GLOBE Program, 2002, p. xiii).

The Global Learning and Observations to Benefit the Environment’s encouragement of teachers to adapt the program to reflect students’ own interests and questions is consistent with inquiry approaches to science education emphasized in many other programs and in most state and national standards documents. The Global Lab curriculum, for example, was designed to foster students’ inquiry abilities by having them design and conduct scientific investigations using data collected from their own and peers’ schools (TERC, 1997). The Kids as Global Scientists program, developed at the University of Michigan, offers a somewhat more structured approach to scaffolding student inquiry but still strongly emphasizes the importance of student questions and student-directed investigations of environmental phenomena (Songer, Lee, & Ham, 2001). Like GLOBE, each of these programs makes the assumption that some degree of local adaptation is not only necessary for teachers but also desirable, to enhance student engagement and develop more advanced thinking skills in students.

Assumption 3: Local Partners Can Provide Follow-up Support to Increase the Likelihood That Schools Will Report Data

All teachers who wish to become GLOBE teachers, regardless of the level they teach, must attend GLOBE training. To deliver training, GLOBE has relied nearly exclusively on partner organizations in the past 4 years. Under this partnership model, the GLOBE Program enters into a no-exchange-of-funds partnership with a university, school district, science center, or other nonprofit entity interested in providing GLOBE training in its service area. The GLOBE Program provides train-the-trainer programs to the partnerships. In the past, these training sessions have focused heavily on teaching how to implement the scientific protocols. GLOBE’s partners also provide follow-up support services to teachers who have completed training, such as on-site coaching, participation incentives, and listservs.

A key assumption behind the partnership model is that partners are better able to provide more effective follow-up support to teachers. The GLOBE program’s budget does not permit its staff to observe individual teachers after training in any given year (more than 1000 teachers are trained each year). By contrast, a partner organization with a base in a particular region of a state, metropolitan area, or single school district could, in principle at least, keep in closer contact with teachers after training even making follow-up site visits to teachers’ schools from time to time. Such a partner might have a stronger influence on teacher enactment because that partner would have a better understanding of the particular supports and barriers to enactment for individual teachers.

The partnership structure of GLOBE is designed to facilitate local follow-up by putting educators who are experienced with the program in closer proximity to novice teachers, a professional design feature that has been recommended by a number of reform groups (see, for example, CEO Forum, 1999). Research suggests that schools in which teachers interact with each other about what and how they teach have greater capacity for implementing innovations than those in which teaching is a ‘‘private practice’’ (Ancess, 1997; Marks, Secada, & Doane, 1996). In fact, networks of teachers and peer study groups are perceived by teachers to be significantly more effective forms of professional development than traditional classes and workshops in transforming classroom practice, according to two recent studies (Garet et al., 2001; NCES, 2000).

Assumption 4: Demonstrating Alignment of Existing Materials with Locally Defined Learning Objectives Increases the Chances That GLOBE Schools Will Report Data

As part of its commitment to supporting partnerships and teachers in adapting the program to meet local needs, GLOBE emphasizes the need for teachers to see its existing protocols and learning activities as well-aligned with district and state standards. The program recognizes that the mapping between GLOBE and local standards may not be easy to make; therefore, program materials have been developed to make it easier for teachers to see how the program can help them accomplish the instructional objectives set forth by their district or state. The program has provided online tools to help teachers interpret the alignment of GLOBE activities with their local standards. Links between GLOBE activities and objectives of several textbooks that are widely used at different levels are also included in the GLOBE website. In addition, the new version of the teacher's guide, to appear online, will contain mappings between GLOBE objectives and the National Science Education Standards, which form the basis of many state standards documents. The newer version of the teacher's guide makes much more explicit the specific skills that are involved in participating in learning activities or collecting data, as well as the conceptual understandings that are presumed or promoted within these activities. In addition, in at least two states GLOBE has adopted the strategy of partnering with policy makers to help develop state science standards that are closely aligned with GLOBE objectives (Penuel & Crawford, 2001).

Concern with standards alignment has become important to many inquiry science programs that are independent of statewide or districtwide reform initiatives. When programs are intended to augment rather than replace the science curriculum by providing materials, structured activities, and ideas that help meet teachers' (and others') goals for student science learning, program designers must present a case for teachers to enact their programs. Programs such as GLOBE and Project WET (http://www.montana.edu/wwwwet), another environmental science program intended to be used as a curriculum supplement, have adopted the approach of making explicit links to standards, posting them on their websites, and encouraging local partners to make sure teachers know how GLOBE can fit within their existing curricula.

Our investigation of the assumptions that underlie the design of the GLOBE program in this research study is intended to help inform the design of other, similar science programs. Each of the individual assumptions above is made by at least one other major science inquiry program now being implemented on a state or national scale; therefore, a deep analysis of how well the assumptions stand up in one particular program can foster an understanding of what it takes to enact science inquiry programs successfully. To be sure, no other single program is likely to make the same combination of assumptions that GLOBE does, which makes it necessary to examine these results carefully in light of how other contexts and program designs might differ from GLOBE's. Still, it is hoped that by investigating these assumptions in the context of GLOBE, we will advance the field's understanding of the enactment of reformed teaching in science classrooms.

Methodology

To investigate implementation fidelity and variation with respect to data reporting, we used data from the GLOBE Student Data Archive matched with survey data collected from a large sample of GLOBE teachers as part of SRI's Year 5 evaluation of GLOBE. The data used and analyses performed are described below.

Data Reports in 1999–2000

In Spring 2000, SRI downloaded data from the GLOBE Student Data Archive that would allow researchers to create a file that showed school reports by month. A spreadsheet was created with columns to indicate whether a school reported data for each month between August 1999 and July 2000. Schools were then divided into four groups according to data reporting levels: nonreporters, periodic reporters (reported data during 1 or 2 months out of the year), average reporters (reported 3–6 months), and steady reporters (reported ≥7 months). Nonreporters can easily be identified by comparing the GLOBE Student Data Archive with the list of all GLOBE schools, which is available in another program database.

Data Reports in 2000–2001

The same procedure was used in July 2001 to download data reports by school for the 2000–2001 school year. A spreadsheet was created with columns to indicate whether a school reported data for each month between August 2000 and July 2001. Schools were then divided into the same four groups as were used for 1999–2000. This file was then merged with the file for data reporting in 1999–2000 and with data from the GLOBE database of schools that included information on whether schools were elementary or secondary schools.

Variation in data reporting within GLOBE can be measured along two dimensions: consistency and persistence. The GLOBE Student Data Archive provides a window into how GLOBE implementation at a school changes over time. SRI's teacher surveys are administered on an annual or biennial basis but student data are collected and reported throughout the school year and can be compared across years. Using data reporting as an indicator, we can investigate consistency in GLOBE implementation in any given year (i.e., the extent to which data are reported every month) as well as persistence in GLOBE implementation from year to year. From GLOBE scientists' point of view, it does not matter which individual teachers or students report data, only that a school reports data. Therefore, we have used school-level reporting of data as the dependent variable for most of our analyses.[1]

To evaluate consistency of data reporting, we define two terms used throughout this article. We refer to schools that report GLOBE during 1 or 2 months out of the year as periodic reporters.[2] We refer to schools that report ≥7 months out of the year as steady reporters. We also present analyses of schools that fall in the middle: that is, schools that report data during 3–6 months out of the year, but many of the contrasts we draw focus on the implications of schools' being periodic versus steady reporters.

To examine persistence in data reporting from year to year, we have analyzed data reporting patterns in 2000–2001 from schools that had reported data at least once in 1999–2000. Although we recognize that some schools may skip a year of data reporting, we wanted to have some reliable index connected to our teacher survey data from Year 5 of the GLOBE evaluation, to understand better the factors associated with persistence in implementing GLOBE over time.

Analysis of the consistency of GLOBE implementation was conducted using the proportion of reporters in each group from 2000–2001 as an index. We conducted an analysis of persistence in GLOBE by selecting schools that had reported data in 1999–2000 from the file and comparing their 1999–2000 and 2000–2001 reporting levels. The first part of the Results section of this article presents these findings for GLOBE schools overall, as well as for schools at different grade levels (elementary versus secondary). Because many schools' grade levels are not indicated in the GLOBE database, the separate analyses by grade level involve much smaller samples than the analysis of GLOBE schools overall and must be viewed with caution.

GLOBE Year 5 Teacher Survey Data

In the second part of the Results section of this article, we focus on understanding factors associated with variation in program implementation. For the analyses that form the basis of our discussion, we merged the data file we used to analyze consistency and persistence in GLOBE implementation with the data file of US teacher survey responses we used in Year 5. This survey includes information about barriers to program implementation as well as information about supports teachers accessed after GLOBE training. The surveys were sent to two samples of schools: 1000 schools that had teachers who received GLOBE training between June 1998 and August 1999, and 500 schools that regularly submitted data on at least four scientific protocols from the Atmosphere Investigation Area to the GLOBE website from December 1999–2000. The composite response rate for the survey was 60.1%.

Differences between schools from which survey responses came and the remainder of US GLOBE schools in the GLOBE database are statistically significant. Moreover, the way the sample of active teachers was selected means that the sample was skewed toward more consistent data reporters. Nearly 36% of schools returning surveys had reported GLOBE data for ≥7 months in 1999–2000, compared with 11% of GLOBE schools not completing a survey. Moreover, the schools in the survey were more likely to report data consecutively for 2 years in a row. Among survey respondents' schools, 43% reported data in both 1999–2000 and again in 2000–2001, compared with just 14% of the remainder of US GLOBE schools. The analyses that form the basis for our conclusions about important factors in data reporting must therefore be considered to be valid primarily for schools that are generally active in GLOBE and more likely than the general population of schools with teachers who have attended GLOBE training to persist in data reporting from year to year.

However there was considerable variability within this sample with respect to consistency of data reporting and GLOBE implementation. Such variability is the most important feature of the sample because GLOBE scientists in the Atmosphere Investigation Area seek consistency in data collection, and therefore would prefer that most schools be steady rather than periodic reporters. Table 1 shows the distribution of data reporting levels within survey respondents' schools.

The teachers whose surveys we analyzed also varied with respect to the attention they gave GLOBE within their classes. For example, the active teachers within the sample reported giving significantly greater emphasis to Atmosphere protocols than did the trained teachers whose survey data were used in the analysis, $t = 6.514$, $p < .0005$, $df = 749$. This variability gives us an opportunity to see the degree to which influences on classroom-level implementation variation are associated with differences in data-reporting levels.

Data from the teacher surveys on barriers and supports to GLOBE implementation were analyzed to determine whether there were significant relationships between specific barriers and supports and levels of data reporting. To test for the significance of the findings, in each case a chi-square test was used to determine whether the schools' data reporting levels were influenced by access to a particular posttraining support or experience of a particular factor as a barrier to implementing GLOBE. As part of our analyses for this article, we also merged data on the number

Table 1
GLOBE data-reporting consistency for U.S. schools, 1999–2000

Data-Reporting Level	Survey Respondents		All U.S. Schools	
	1999–2000	2000–2001	1999–2000	2000–2001
0 months (nonreporters)	324 (41%)	437 (55%)	623 (25%)	676 (27.2%)
1–2 months (periodic reporters)	48 (6.1%)	56 (7.1%)	252 (10%)	236 (9.5%)
3–6 months	138 (17%)	95 (12%)	327 (13%)	301 (12%)
≥7 months (steady reporters)	281 (36%)	203 (26%)	369 (15%)	358 (14%)

of GLOBE teachers at the school and the date when the newest GLOBE teacher at a school was trained, both of which may be factors affecting data-reporting patterns.

Results

Periodic Versus Steady Data-Reporting Schools in GLOBE

Of schools that report GLOBE data, many more are steady reporters than periodic reporters. In fact, in 1999–2000 and again in 2000–2001, there were almost twice as many steady reporters (684) as periodic reporter (377), as shown in Figure 1.

Although many more elementary schools than secondary schools are steady reporters, the percentages of schools that are steady and periodic reporters at each grade level are representative of GLOBE implementation more broadly, compared with the national database of all schools with GLOBE-trained teachers. In other words, it does not appear that elementary schools, for example, are disproportionately more likely than secondary schools to be steady reporters. Past surveys have found that just under half of all GLOBE teachers tend to be elementary school teachers; roughly one quarter are middle school teachers and another quarter are high school teachers (Means, Korbak, Lewis, Michalchik, Penuel, Rollin, & Yarnall, 2000).

Persistence in GLOBE Data Reporting

In the second year of the GLOBE evaluation, SRI examined persistence in data reporting from the first to the second year of GLOBE implementation. During that period, 68% of all GLOBE schools that had reported data in 1995–1996 reported again in 1996–1997. Today, the percentage of schools that persist in reporting data from one year to the next is similar. As Figure 2 shows, about 64% of schools that reported data in 1999–2000 also reported in 2000–2001. Figure 2 also shows that the proportion of nonreporters had not changed substantially since the beginning of the GLOBE program.

As with steady data reporting, it does not appear that elementary and secondary schools differ with respect to the likelihood that they will persist from year to year in reporting data.

Relationship between Data-Reporting Levels and Persistence

Closer examination of the GLOBE Student Data Archive shows that consistency and persistence in data reporting are closely related. In fact, schools that are steady reporters in one year are more than twice as likely as periodic reporters to report data the next year. More than four fifths (84%) of schools that were steady reporters in 1999–2000 reported data in 2000–2001, compared with just two fifths (40%) of periodic reporters (Figure 3).

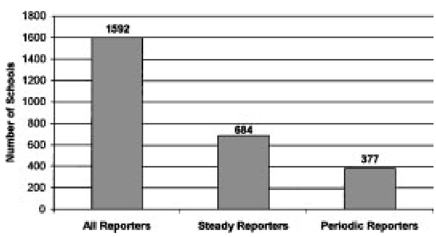

Figure 1. Number of steady and periodic GLOBE data reporters in 2000–2001.

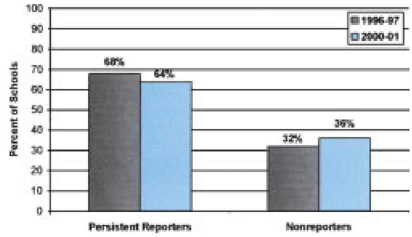

Figure 2. Persistence in GLOBE data reporting from 1999–2000 to 2000–2001.

It appears that the relationship between being a steady reporter and persistence in data reporting the following year is greater at the elementary level than at the secondary level. It may be more significant, in terms of predicting persistence in data reporting, for an elementary school to report data consistently than for a secondary school to report data consistently throughout the year. Whereas less than one third of periodic reporters at the elementary level reported data the next year, just over half of secondary school periodic reporters reported data the next year (see Figure 4, next section).

Teachers' Decisions about GLOBE Implementation and Consistency in Data Reporting

The GLOBE program gives teachers responsibility for choosing the aspects of the program to implement. It is up to teachers to determine the particular protocols they implement, the learning activities they use, and the kinds of analyses of GLOBE data they conduct with students. To a certain extent, most initiatives depend on teacher choices about what aspects of the program they enact; however, initiatives differ widely in their specificity—how much direction program designers give concerning implementation (Porter, Floden, Freeman, Schmidt, & Schwille, 1988)—and in their elaboration—how much detail is given to teachers about classroom implementation (Ball & Cohen, 2001). Compared with other science education initiatives, the specificity of GLOBE is fairly low in that little about how GLOBE is to be integrated into the teacher's curriculum is specified. As such, the program makes an implicit assumption that teachers' selections of activities to use with students will not undercut the desire for consistent and persistent data reporting.

Not surprisingly, those GLOBE-trained teachers who report deciding to engage their students in GLOBE data collection and reporting activities have schools reporting GLOBE environmental data at higher levels than those who say they do not engage in these activities. Less obviously, teachers' decision to engage their students in discussing and analyzing GLOBE data is associated with more consistent data reporting and with telecommunicating through e-mail with other GLOBE schools, as is the decision to implement learning activities with students (Table 2). There were no significant associations between consistency in data reporting and teachers'

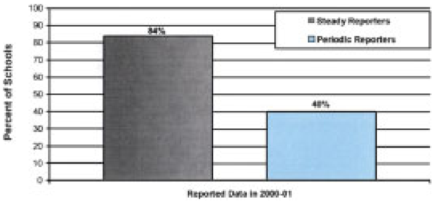

Figure 3. Persistence in GLOBE: steady reporters versus periodic reporters.

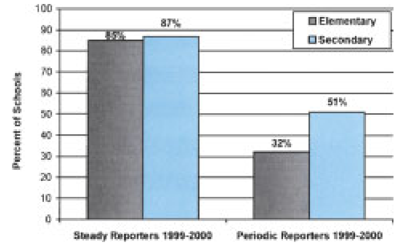

Figure 4. Persistence in GLOBE data reporting, by school level.

decisions to engage students in extended investigations with GLOBE data or in collaborative projects with other GLOBE schools.

Some implementation choices teachers make in one year are also associated with persistence in data reporting, that is, the likelihood that schools report the next year again, and at high levels. Consistent with the finding that schools that report at high levels one year are likely to report again next year, teachers who made the decision to report data in 1999–2000 were more likely to report again the next year (Table 3). Teachers' decisions to have students communicate by e-mail with other GLOBE schools or engage in collaborative projects with other schools in one year similarly predict persistence in data reporting in the next year. However, engaging in data analysis activities and learning activities, which are associated with reporting level in the same year teachers choose to implement these aspects of GLOBE, do not appear to predict persistence in GLOBE data reporting.

Impact of Posttraining Supports on Consistency and Persistence in GLOBE Data Reporting

Many GLOBE partners offer additional resources to teachers after their initial training sessions. These resources are intended to support teachers' efforts to implement GLOBE protocols and report data. They include:

- Communications through such methods as listservs, newsletters, meetings and conferences, and contact with GLOBE partner staff or other GLOBE teachers via telephone or e-mail.
- Mentoring during school visits by GLOBE partner staff or experienced GLOBE teachers.
- Supplementary materials, such as tips for implementation.
- Follow-up or refresher training sessions.
- Participation incentives, such as equipment or recognition for reporting certain types or amounts of data.

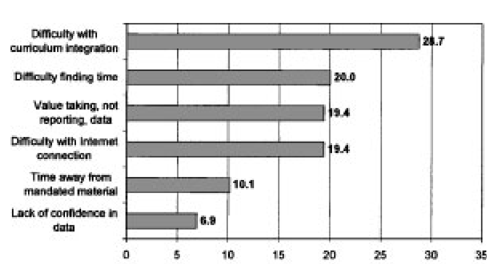

Figure 5. Difference between nonreporters and steady reporters, by barriers to reporting.

Table 2

Percentage of teachers reporting implementing aspects of GLOBE program, by number of months data were reported, 1999–2000

Implementation Activity	No. Months Data Were Reported 0 ($n = 130$)	1–2 ($n = 30$)	3–6 ($n = 106$)	≥7 ($n = 256$)	χ^2
Taking measurements (data collection)	22.3	70.0	91.5	95.3	263.97**
Reporting data	22.3	70.0	91.5	95.3	263.97**
Analyzing and discussing GLOBE data	46.2	53.3	74.5	74.2	36.15**
Telecommunicating with other GLOBE schools	10.0	3.3	17.9	30.0	28.37**
Conducting GLOBE learning activities	77.7	53.3	75.5	76.6	8.40*
Conducting student investigations with GLOBE data	37.7	30.0	41.5	45.7	4.22
Engaging in collaborative projects with other GLOBE schools	6.9	3.3	9.4	10.2	2.32

*$p < .05$.
**$p < .001$.

On the teacher survey, we asked teachers about which of these supports their school had received. SRI used responses to the Year 5 teacher survey in an analysis of which supports are most likely to be associated with consistency and persistence in GLOBE data reporting. Table 4 presents two aspects of those results. First, it shows which supports teachers access most frequently. The communications line at the top of the graph indicates that communication resources are most often used, being available to 70% of respondents. Least often provided are incentives, the line at the bottom of the graph, which were available to 15% of respondents.

Table 3

Percentage of teachers reporting implementing aspects of GLOBE program whose schools persist in GLOBE data reporting

Implementation Activity	Mean % of Teachers from Persistent Schools Enacting ($n = 289$)	Mean % of Teachers from Nonpersistent Schools Enacting ($n = 103$)	t ($df = 390$)	p
Taking measurements (data collection)	98%	96%	0.998	.32
Reporting data	95%	85%	2.51	.03
Exploring GLOBE website				
Analyzing and discussing GLOBE data	74%	69%	1.00	.32
Telecommunicating with other GLOBE schools	30%	10%	4.2	<.001
Conducting GLOBE learning activities	76%	70%	1.19	.23
Conducting student investigations with GLOBE data	46%	37%	1.57	.12
Engaging in collaborative projects with other GLOBE schools	11%	5%	2.23	.03

Table 4
Percentage of teachers reporting using posttraining support, by number of months data were reported, 1999–2000

Type of Support	No. of Months Data Were Reported 0 ($n = 324$)	1–2 ($n = 48$)	3–6 ($n = 138$)	≥7 ($n = 281$)	χ^2
Communications (e.g., newsletter)	69.8	64.6	69.6	74.4	2.90
Mentoring	21.6	27.1	43.5	45.9	46.18*
Materials and supplies	29.6	39.6	44.9	43.1	15.57*
Refresher training	19.4	18.8	20.3	27.8	6.96
Participation incentives	9.9	4.2	21.0	23.1	26.99*

*$p < .001$.

Table 2 also displays the relationship of supports accessed to consistency of reporting in 1999–2000. From this table, we can infer which kinds of support were most important in predicting consistency in data reporting and which ones did not appear to make a difference. The difference between those who did not report data (nonreporters) and those who reported data for ≥7 months (steady reporters) indicates which supports are likely to contribute to consistent data reporting. Of the supports provided, mentoring, materials, and incentives appear to have a significant effect on data reporting. Of the respondents for whom mentoring support was provided, fewer than a quarter (22%) were nonreporters and almost half (46%) were steady reporters. Similarly, of those for whom supplementary materials were provided, 30% were nonreporters compared with 43% who were steady reporters. When incentives were provided, 10% of respondents still did not report data, whereas 23% were steady reporters.[3] Communications activities, the support most commonly offered by GLOBE partners, did not appear to have a significant relationship to steady reporting.

We also analyzed whether there were significant associations between the use of these various posttraining supports for 1 year and reporting persistence. We did not conduct a second survey in Spring 2001, so we do not know whether teachers accessed these supports in 2000–2001, the year of data reporting we used for this particular analysis. Table 5 shows the relationship between posttraining supports and persistence in data reporting for that subset of schools that had reported data in 1999–2000. One pattern that is evident is that none of the posttraining supports predicted persistence in data reporting, including those that were significantly associated with data reporting in the year the supports were accessed. Only mentoring and supplementary materials approached significance in their association with data reporting levels after 1 year.

Table 5
Percentage of teachers reporting using posttraining support, by number of months data were reported, 2000–2001

Type of Support	No. of Months Data Were Reported 0 ($n = 130$)	1–2 ($n = 51$)	3–6 ($n = 85$)	≥7 ($n = 201$)	χ^2
Communications (e.g., newsletter)	70.0	76.5	68.2	73.6	1.62
Mentoring	36.9	37.3	41.2	49.8	6.48*
Materials and supplies	43.1	35.3	34.1	49.3	7.16*
Refresher training	17.7	21.5	25.9	29.4	6.12
Participation incentives	17.7	21.6	17.6	23.4	2.11

*$p < .10$.

Table 6
Percentage of teachers reporting difficulty with curriculum integration, by reporting consistency

	No. of Months Data Were Reported				
	0 ($n = 137$)	1–2 ($n = 27$)	3–6 ($n = 102$)	≥7 ($n = 231$)	χ^2
Curriculum integration is a barrier to implementing GLOBE	77.1	93.1	71.4	48.4	7.20
Curriculum integration is not a barrier to implementing GLOBE	22.9	6.9	18.6	51.6	

Barriers to Data Reporting

The GLOBE teacher survey poses questions to teachers about a number of barriers they face in reporting data to the GLOBE website.

An analysis of responses to the Year 5 teacher survey in relation to data reporting in both 1999–2000 and 2000–2001[4] indicated that both nonreporters and steady reporters encounter the same barriers to reporting, but that some of these conditions are likely to be perceived as more serious barriers by nonreporters. The greatest difference in the reported effect of barriers to data reporting is the difficulty teachers face in integrating GLOBE with the curriculum (Table 6). Fewer than half of steady reporters (48%) considered this a barrier, compared with more than three quarters of nonreporters (77%).

Another commonly experienced barrier to reporting data is the difficulty teachers face in finding time to report data (Table 7). The pattern in the data suggests that for teachers who were able to implement GLOBE at all, time was a factor in the level of data reporting. Of those schools reporting data just 1–2 months of the year, 81% of teachers reported that finding time to report data was a barrier, compared with 59% of steady reporters.

One of the reasons teachers implement the GLOBE program is to teach students to take measurements accurately. For some teachers, this goal may influence their view of the value of reporting data. Some teachers believe that the value for their students lies in taking GLOBE measurements, not in reporting them. This belief again was viewed as a larger barrier by non-reporters than by steady reporters (Table 8). One quarter of nonreporters cited this as a reason for not reporting data, compared with just 9% of steady reporters.

A final barrier to reporting that affected nonreporters more than steady reporters is problems with Internet connectivity (Table 9). About 57% of nonreporters experienced these problems, compared with just over half of the steady reporters (52%). Although GLOBE schools have

Table 7
Percentage of teachers saying difficulty finding time to report data is a barrier, by reporting consistency

	No. of Months Data Were Reported				
	0 ($n = 81$)	1–2 ($n = 26$)	3–6 ($n = 63$)	≥7 ($n = 125$)	χ^2
Finding time is a barrier to implementing GLOBE	63.0	81.8	69.8	59.2	13.36*
Finding time is not a barrier to implementing GLOBE	37.0	19.2	30.2	40.8	

*$p < .05$.

Table 8
Percentage of teachers saying value is in taking (not reporting) data, by reporting consistency

	No. of Months Data Were Reported				
	0 ($n = 78$)	1–2 ($n = 27$)	3–6 ($n = 63$)	≥7 ($n = 113$)	χ^2
Value is in taking but not reporting data is a barrier to implementing GLOBE	25.6	22.2	21.6	8.8	16.83*
Value is in taking but not reporting data is not a barrier to implementing GLOBE	74.4	77.8	79.4	91.2	

*$p < .05$.

Internet connections, the convenience of access for a particular class and the reliability of the connection are persistent problems at many schools.

Figure 6 displays these barriers together, showing the percentage difference between nonreporters and steady reporters. Each bar on the graph displays the difference in the percentage of teachers who reported a barrier to be significant in hampering implementation of GLOBE. The display allows us to see the association of a particular barrier on consistency of data reporting. The largest associations are contributed by barriers for which the difference scores are greatest.

Although each of the barriers is experienced by both nonreporters and steady reporters, four of those barriers have a much greater impact on nonreporters than on steady reporters: difficulty integrating GLOBE with their curriculum, finding time to report data, valuing the taking but not the reporting of data, and difficulties with Internet connections.

These results are supported by independently conducted research that also investigated barriers to data reporting. Conroy (2001) analyzed lack of time as a barrier in greater detail and found that computer access is often at the heart of the time barrier. Teachers find it more difficult to report data when there are no computers for this purpose in their classrooms. Arranging to take some or all of the students to computers located elsewhere, such as in a computer lab, is more complicated than sending students to computers within the classroom. Finding a convenient time to use computers outside the classroom is not always possible, especially in schools where there is a high demand for limited computer access.

Conroy also found that submitting data is not always valued as highly as data collection. Some teachers said that students find submitting data repetitive. Given that data reporting is seen as time-consuming, teachers find that they allow the level of student interest to influence the consistency of data reporting. Others said that collecting data for scientists is not necessarily a

Table 9
Percentage of teachers saying difficulty with Internet connection is a barrier, by reporting consistency

	No. of Months Data Were Reported				
	0 ($n = 85$)	1–2 ($n = 28$)	3–6 ($n = 64$)	≥7 ($n = 125$)	χ^2
Difficulty with Internet connection is a barrier to implementing GLOBE	57.6	60.7	73.4	52.0	18.26*
Difficulty with Internet connection is not a barrier to implementing GLOBE	42.4	39.3	26.6	48.0	

*$p < .01$.

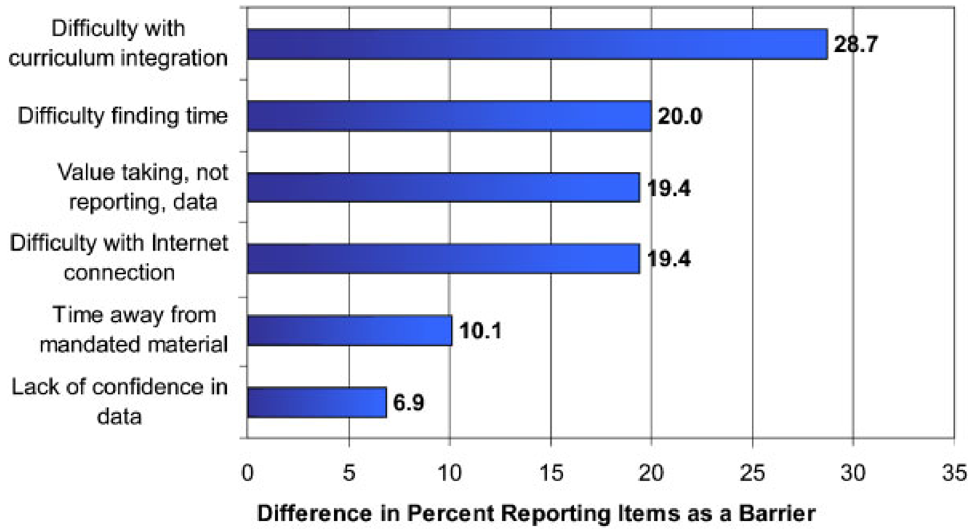

Figure 6. Difference between Nonreporters and Steady Reporters, by Barriers to Reporting.

motivating aspect of the program for teachers. These results complement SRI's findings and suggest areas to target in efforts to increase data reporting.

Discussion

The data analyzed for this study provide some support for the assumptions the GLOBE program makes about implementation fidelity, but it also suggests areas in which these assumptions, as articulated in the introductory section of this article, may need revision. In this section of this report, we review the evidence presented in our analysis of GLOBE data reporting patterns about the GLOBE program's assumptions and consider some of the limitations of our data set for interpreting results.

It appears that, whereas it is possible for teachers in real classrooms to ensure that data reporting happens consistently and can be maintained across years, this objective is difficult to achieve for just over half of GLOBE schools. Many of the schools that do not report data consistently do provide data to the GLOBE website but their data are less likely to be useful to scientists because they are not collected every day. Moreover, students in these schools are not getting the realistic picture of the nature of scientific investigation that an extended, authentic collection of GLOBE environmental data is intended to provide. Many schools that report one year do not report again the next year, especially if their reporting was not consistent in the first place.

To be sure, many schools do report data consistently, as GLOBE program designers intended. Nearly half of all schools that reported GLOBE data in Year 6 were steady reporters, submitting data during at least 7 months from August 2000 through July 2001. Consistent with scientists' findings about the quality of student data, the feasibility of using student-collected data for scientific investigations is supported by these data, even if only a portion of GLOBE schools' data can be used.

Analyses performed with data from the teacher survey and the Student Data Archive also underscore the significance of consistency in data reporting for persistence in GLOBE among schools active in the program. Schools that report consistently in one year are twice as likely to report data again the next year, according to analyses of data reporting from 1999–2000 and

2000–2001. Interestingly, this pattern is more pronounced among elementary schools than among secondary schools. An analysis of the Student Data Archive does not tell us why steady reporting seems to be less important at the secondary level. We can only speculate that secondary schools' inconsistent reporting of data may mask a consistency in teachers' using GLOBE to support particular topics each year in their curriculum. Future studies would need to investigate this relationship more systematically.

Interestingly, teachers' decisions to do more than just collect and report data are associated with more consistent data reporting, but they do not predict schools' persistence in data reporting over multiple years. On the one hand, our data suggest that engaging in GLOBE data analysis activities with students contributes to more consistent data reporting. However, these same activities conducted in one year do not predict a school's persistence in data collection the next year. Only the more infrequently enacted activities show a significant relationship to persistence: telecommunicating with other GLOBE schools and engaging in joint projects with other schools. This particular pattern of results may indicate that some other underlying predictor—namely, enthusiasm for GLOBE and commitment to implementing as many aspects of the program as possible—could explain both the depth and persistence of implementation. If this is the case, GLOBE's decision to leave most implementation decisions up to teachers may be mostly well supported, provided that the program does an adequate job of developing commitment to the program on the part of its teachers.

Analyses examining the relationship between data reporting and posttraining supports point to the central importance of mentoring and material support to teachers. Our finding that incentives, mentoring, and other on-site support to teachers have the greatest impact on data-reporting levels suggests that GLOBE training providers may succeed in their efforts to sustain GLOBE teachers' involvement in the program by providing more access to such supports. At present, these supports are less common than listservs and e-mail communication with teachers after GLOBE training. In posttraining teacher mentorship programs, the close attention paid to local school contexts and how they shape possible forms of GLOBE implementation seem to pay off. The payoff, moreover, may help to shape teachers' pedagogical content knowledge with respect to implementing GLOBE in their particular schools and with their unique groups of students.

There is evidence that alignment with local learning objectives makes a difference in data-reporting consistency, lending support to the program's assumptions about the importance of ensuring that teachers see how GLOBE can help them improve student learning. The congruence of teachers' beliefs about what is important in GLOBE with designers' intentions, for example, shows a significant relationship to data-reporting levels. Those teachers who saw the value of GLOBE as being connected more closely to students' data collection activities than to students' data reporting activities were more likely to report data reporting as a barrier to GLOBE implementation. However, technology infrastructure was also a significant predictor of data reporting, a factor that goes beyond concerns with alignment. Many teachers say they still have limited access to technology for data reporting, and this limited access has proven a barrier to more consistent data reporting.

The researchers have relied on self-report data, and it is possible that teachers who do not report GLOBE data are more likely than those who do to say that they encountered these barriers, regardless of the objective level of the problem at their schools. Given this fact, it is useful to compare barriers against each other, and examine where differences are greatest between nonreporters and more frequently reporting schools. When the data are analyzed from this perspective, curricular alignment issues appear to be even more strongly associated with data reporting. The difference between teachers' reports of curriculum integration as a barrier to implementation between steady reporting schools and nonreporting schools is 28%, much higher than any other barrier analyzed from the survey results.

The data analyses presented here do not permit us to draw strong conclusions about whether the significant relationships are causal. Although it is logical to assume that tests of association between contextual variables and implementation variables are predictive, it may be that some other, underlying factor is influencing both the contextual factor measured and the implementation level (data reporting) measured. It may also be that teachers who report less are more likely to say that they have limited access to posttraining support, technology, or some other facilitator of implementation. Future studies planned for the GLOBE evaluation will examine longitudinal trends in persistence over multiple years. In addition, we plan to replicate analyses of teacher survey data to be collected in Spring 2004 and attempt to triangulate survey data with case study research in selected GLOBE schools.

Implications

The results of this study pose some challenges for the design of programs which, like GLOBE, have scientific and educational aims that are intertwined. The results of the study provide evidence that teachers' choices about implementation do not necessarily undercut implementation fidelity. At the same time, it is less clear whether fidelity of implementation in such programs matters to student learning, a chief concern of many designers of educational innovations. The scientific aspects of programs may need greater attention in preparing teachers to implement them because data collection according to protocols established by scientists is not typically a part of classroom practice for science teachers. Making use of training and posttraining support activities for programs such as GLOBE may be especially important because, as this study suggests, in focusing on alignment of program activities with teachers' own goals for student learning, training and posttraining support can boost fidelity of implementation for GLOBE's science components while meeting educational aims.

Designers of educational innovations often fear that in deciding not to implement some aspects of an innovation or by altering instructional materials, individual teachers may reduce students' opportunities to learn important concepts that designers intend students to master (Brown & Edelson, 1998). In GLOBE, the program stresses implementation fidelity with respect to its scientific aspects more than with respect to its educational ones. If students report high-quality environmental data consistently over time, the program can judge teachers' implementation fidelity to be adequate. In this respect, our data show that although persistence in data collection is challenging for many schools, some are successful in helping GLOBE meet its scientific mission. By contrast, teachers vary widely in the degree to which they implement learning activities or engage students in analyzing data as part of their GLOBE experiences.

These learning activities may be important with respect to meeting the educational mission of programs such as GLOBE. One potential benefit of such programs is that students learn valuable inquiry skills in the context of data collection activities by participating in real inquiry. Students could, in the course of their participation in such programs, have the opportunity to pose their own questions of data, collect data, analyze it, and formulate explanations from their analyses. However, in a review of GLOBE-like programs that emphasize students doing real science in the context of data collection for science investigation, Feldman et al. (2000) found that students had significant difficulties in making sense of the data they had collected. Students in these programs had difficulty understanding the reasons behind their data collection efforts, and they rarely recognized that they could pose questions of the data they were collecting to pursue lines of inquiry on their own. Students did not have many opportunities to analyze data as part of their learning experiences, either; data collection was a primary focus of teaching and learning in these programs. Recently analyzed student assessment data collected as part of the GLOBE evaluation suggest that the frequency of GLOBE data analysis activities in a classroom is a significant predictor of students' understanding of scientific concepts and their skill in performing inquiry tasks (Penuel et al., 2002).

Even if inquiry-related activities are important for student learning, our data do not support the conclusion that requiring teachers to engage in data analysis would make a difference in promoting the scientific aims of the program. The emphasis within GLOBE training on data collection and data reporting, rather than on data analysis, appears to be warranted. Many of the data collection protocols are challenging for teachers to implement and represent a significant departure from their current practice; emphasizing these elements in the training may therefore help to increase the likelihood that teachers will implement GLOBE (Ball & Cohen, 2001; Tyack & Cuban, 1995). Given the centrality of data reporting for meeting the scientific aims of the program, it might be ill-advised for the program to reduce significantly its emphasis on learning to use the scientific protocols.

The data from this study point to possible ways to address the problem. Posttraining supports, especially providing on-site mentoring and supplementary educational materials, are opportunities for GLOBE partner staff to help teachers structure learning opportunities around GLOBE activities. We found such activities were significantly associated with consistency in data reporting activities. Some, especially providing supplementary materials, address the curricular needs of teachers directly. In future studies of GLOBE, we plan to investigate these supplementary materials in greater detail to learn more about their content and what teachers find useful about them.

Training and posttraining support activities are also opportunities for staff to emphasize the ways that GLOBE activities are aligned with teachers' local curricular goals, whether they are defined at the state, district, or classroom level. Teachers' perceptions about curricular alignment may have both an educational and a scientific benefit. Teachers that said curriculum integration was not a barrier were much better represented among schools that report data with high levels of consistency. Student assessment data from GLOBE suggest that teachers' beliefs about GLOBE's efficacy in meeting their own goals for student learning are strongly associated with student achievement in the program as well (Penuel et al., 2002).

Our suggestions about the potential of training and posttraining supports in programs that have intertwined science and education goals are consistent with those recommended by Feldman et al. (2000). They posited four elements of infrastructure important for improving implementation fidelity: providing training in which desired activities and approaches to teaching to learning are modeled, providing ongoing face-to-face support, ensuring access to a sound technology infrastructure, and ensuring that teachers have local support to take the time they need to become comfortable with the new program. We suggest that for GLOBE and other programs in which scientific protocols that are unfamiliar to many teachers are to be followed, modeling of teaching and learning processes must not sacrifice a focus on the most challenging content and procedures that are integral to the program.

Students and adult citizens may come to have increasingly important roles in environmental science activity, especially monitoring the environment. Already, amateur networks of citizens are responsible for much of the weather data reported across the United States, data that could be collected by any GLOBE school. For such programs to succeed as opportunities for learning and as opportunities to contribute to our understanding of the earth, we need ongoing investigation of program implementation, seeking to identify points where educational and scientific goals can meet and support one another.

An earlier version of this article was presented at the annual meeting of the American Educational Research Association, New Orleans, Louisiana. This research was made possible through a grant from the National Science Foundation (ESI-9802033). All opinions expressed here are the sole responsibility of the authors.

Notes

[1]In addition, analyses of survey data indicate that for GLOBE schools with more than one teacher, only 3–5% of teachers report that another teacher implements Atmosphere protocols but they do not.

[2]Each of these differences was statistically significant at $p < .05$.

[3]Data from 1999–2000, the year of the full teacher survey, are presented in this section. Data from 2000–2001, the year of the mini–telephone survey, mirror those results.

[4]Periodic reporters are distinguished from nonreporting schools, which are registered as GLOBE schools but do not report data in a particular year.

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