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GLOBE YEAR 7 EVALUATION

Exploring Student Research and Inquiry in GLOBE

Prepared for:

The GLOBE Program
1800 G St NW, Suite 800
Washington, DC 20006

Prepared by:

Center for Technology in Learning

333 Ravenswood Avenue ● Menlo Park, CA 94025-3493 ● 650.859.2000

Primary report authors:

William R. Penuel
Christine Korbak
Amy Lewis
Linda Shear
Yukie Toyama
Louise Yarnall

With assistance from:

Christy Kim Boscardin, UCLA/CRESST
Katherine Masyn, UCLA
Bowyee Gong
Robert F. Murphy
Alexis Whaley

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1. Introduction

SRI International (SRI) prepared this evaluation research report for the GLOBE Program. This is the seventh in a series of annual evaluation reports provided to the GLOBE Program by SRI, which has been evaluating the Program since its inception. The Year 7 evaluation report focuses on student research and inquiry in GLOBE. Student research and inquiry have been part of the Program's vision from the beginning, but supporting students in developing their own research questions and investigating them by using GLOBE data has become an important focus of the Program's efforts. SRI's Year 7 report is designed to highlight issues related to implementing student research and inquiry in K-12 classrooms that use GLOBE and investigating the aspects of GLOBE implementation that contribute the most to the development of student inquiry skills.

We relied on data collected in the 2001-02 school year to study how student research and inquiry are being integrated into GLOBE classrooms. We conducted a survey of GLOBE teachers to learn more about the reach of GLOBE, as well as the breadth and depth of GLOBE implementation in their classrooms. We also conducted case studies of GLOBE schools that engage students in inquiry using GLOBE data. To supplement these case studies, we conducted interviews with both United States and international schools where students are engaged in student research projects, some of which engaged students from two or more countries. Finally, we conducted an assessment of student conceptual understanding and inquiry skills in the Atmosphere Investigation Area. In this assessment, we explored which aspects of GLOBE implementation were associated with deeper conceptual understanding and more sophisticated inquiry skills.

Program Description

The GLOBE Program, headquartered in Washington, D.C., has received support from several United States Government agencies: 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. Until 2002, the National Oceanic and Atmospheric Administration was the lead agency for the Program, having been recently replaced by NASA. As of July 2002, more than 20,000 teachers from more than 12,000 schools have completed GLOBE training, and students have submitted more than 8 million measurements to the GLOBE Web site. Also, as of July 2002, the Program reached 97 countries, such that nearly every biome on Earth is represented in GLOBE.

GLOBE is both an environmental science program and an education program. GLOBE scientists seek to enhance their understanding of the Earth by conducting research in four major investigation areas: Atmosphere, Hydrology, Soil, and Land Cover. They also conduct research on interactions among phenomena across these investigation areas to construct models of the Earth as a system. By collecting GLOBE data, K-12 students contribute to this research and gain valuable experience in carrying out data collection and analysis activities as part of their study of environmental science. As an education program, GLOBE prepares teachers with training, materials, and follow-up support to implement data collection protocols and learning activities designed to enhance students' environmental science achievement.

The goals of GLOBE are:

- To enhance the environmental awareness of individuals throughout the world.
- To contribute to scientific understanding of the Earth.
- To help all students reach higher levels of achievement in science and mathematics.

To meet these goals, GLOBE provides schools with a scientific framework for data collection and educational training and materials that teachers can adapt to their own classroom situations. The GLOBE Program is representative of a class of science reform initiatives structured around the principle of engaging students in real science investigations, rather than in reading about the products of science investigations or watching or mimicking demonstrations. Some of these programs that seek to engage students in authentic inquiry are designed as year-long curricula for teachers to use with students (see Ba et al., 2001); others are designed to scaffold students' developing explanations of phenomena that result from their inquiry into particular scientific controversies (Linn, Bell, & Hsi, 1998).

What makes GLOBE different from many of these other science reform initiatives is its simultaneous concern with teacher choice in implementing particular parts of GLOBE and with fidelity in implementing GLOBE's scientific protocols. The GLOBE Program's philosophy has always been one of providing resources and leaving decisions concerning curriculum and pedagogy to teachers. It therefore 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 fundamental ways. At the same time, GLOBE is both an education initiative and a science initiative in which student data are used in scientists' investigations of Earth systems. GLOBE therefore is concerned with the fidelity of teachers' and students' implementation with respect to data collection and reporting, even if teachers choose not to implement all the protocols or learning activities from the Teacher's Guide.

Program Evolution: Scaling Up and Scaling Out in GLOBE

Since its inception in 1995, the GLOBE Program has evolved considerably. To meet its core mission, the Program has had to be concerned with what education reformers call "scaling up" by finding partners to help reach more students and teachers. A chief strategy GLOBE has employed in scaling up has been to rely on other organizations to provide training to teachers. Under this partnership model, the GLOBE Program enters into a no-exchange-of-funds partnership with a country, and in the United States, with a university, school district, science center, or other nonprofit entity interested in providing GLOBE training in its self-determined service area. The model has allowed the Program to grow in reach, with GLOBE partners in nearly 100 countries (as of July 2002) providing training and follow-up support to teachers. The GLOBE Annual Conference in 2002 was planned and facilitated collaboratively by GLOBE partners and the GLOBE office.

In addition, GLOBE has sought to scale up in the United States by working closely with departments of education in states where science standards are closely aligned with GLOBE in order to improve the likelihood that trained GLOBE teachers will implement GLOBE protocols and learning activities. In most states, the emphasis placed on student academic standards has increased, making GLOBE's work at this level more important. Standards for science curricula in many states emphasize that students should learn how to conduct scientific inquiry with data they collect (see NRC, 1996, 2000). New science tests being considered in several states will attempt to measure these inquiry skills; new legislation passed by Congress will require states to report on students' progress in science in the coming years, adding pressure on schools to show results. In some states, such as North Carolina and New York, educators have used or are using GLOBE as one basis for standards development (Means et al., 2002; Penuel & Crawford, 2001). Other states are expected to do so, as well.

GLOBE is also "scaling out" by extending the scope of data collection protocols students can use, evolving the curricular resources of the Program, conducting outreach to historically underrepresented groups in science, and sharpening the Program's focus on student research and inquiry. Several data collection protocols have been added in just the last 2 years. In the Atmosphere Investigation Area, protocols for Relative Humidity, Aerosol, Ozone, Barometric Pressure, and Precipitation have been added or updated. The Automated Soil and Air Temperature Monitoring Protocol has been added to the Soil Investigation Area. In addition, the Hilton Pond Center for Piedmont Natural History worked with GLOBE to develop a new set of protocols focused on the behavioral ecology of ruby-throated hummingbirds. These protocols are the first to involve observations of vertebrate behavior. See Table 1.1 for a complete list of GLOBE data collection protocols.

Table 1.1
GLOBE Protocols

Atmosphere/Climate

- Air Temperature
- Clouds
- Precipitation
- Aerosol
- Surface Ozone
- Relative Humidity
- Barometric Pressure
- Automated Air Temperature Monitoring
- Digital Multi-Day Max/Min/Current Air and Soil Temperatures

Soil

- Soil Characterization Field Measurements
- Soil Characterization Lab Analysis
- Gravimetric Soil Moisture
- Soil Moisture and Temperature
- Soil Moisture Sensor
- Soil Infiltration
- Automated Soil Temperature Monitoring
- Digital Multi-Day Max/Min/Current Air and Soil Temperatures

Hydrology

- Transparency
- Water Temperature
- Dissolved Oxygen
- pH
- Electrical Conductivity
- Salinity
- Alkalinity
- Nitrate

Land Cover/Biology

- Qualitative Land Cover
- Quantitative Land Cover
- Biometry

Phenology

- Green-up / Green-down
- Ruby-throated Hummingbird

Special Measurements

- Budburst
- Lilac

* Adapted from: http://www.globe.gov/fsl/html/templ.cgi?measpage&lang=en&nav=1 (10/28/02).

A new Teacher's Guide was published on the GLOBE Web site in 2002. The Guide contains new versions of several chapters, including the introduction, the Atmosphere chapter, the GPS chapter, and the Toolkit. Draft versions of several GLOBE 2003 Teacher's Guide sections are also available in PDF format: Implementation Guide, Soil, and Earth as a System. The new Guide places more emphasis on the guiding concepts behind the protocols and includes an expanded collection of learning activities.

GLOBE also unveiled a new Web site in summer 2002. The new Web site is designed to provide easier access to GLOBE's educational resources and the GLOBE Data Archive. Educators, for example, can easily find directions for the new e-mail data submission procedure and spreadsheet templates for data entry. In addition, the Student Investigations section of the Web site has been revamped. GLOBE Student Investigations are reports of scientific projects conducted by GLOBE students that include the use of GLOBE data or protocols. The site now includes a rubric for judging the quality of student research reports; the rubric will be used to judge entries to the GLOBE Learning Expedition to be held in Croatia in summer 2003.

GLOBE has been scaling out by conducting outreach to groups historically underrepresented in the field of science. The GLOBE Program has helped facilitate the creation of partnerships with Historically Black Colleges and Universities (HBCUs) and with Native American tribal colleges (see Ford, 2001). The intent of these programs is to prepare teachers to implement GLOBE science protocols with students and adapt GLOBE learning activities and investigations to traditional community ways of knowing, thereby helping increase students' interest in science.

Perhaps the most significant way GLOBE has scaled out in recent years is in the increasing emphasis placed on student research and inquiry. GLOBE has always supported students' collecting and analyzing data about the environment; moreover, it has always had at its core a design that emphasizes collaboration between students and scientists. But in recent years, as local and state standards have come to emphasize inquiry skills and as GLOBE has sought to broaden its impact on student learning in science, GLOBE educators and staff have paid increasing attention to student research and inquiry.

Inquiry in Science Education

An understanding of the process of scientific inquiry is now recognized in many national and state standards as a core aspect of content learning in science, as well as being a core component of scientific literacy (AAAS, 1989, 1993; NRC, 1996; Olson & Loucks-Horsley, 2000). Inquiry-based science instruction is seen not only as a way for students to learn about the scientific inquiry process, but as an effective instructional approach for promoting deep mastery of core concepts and facts in all scientific domains. Inquiry-based science is often part of a “knowledge-centered” learning environment, which emphasizes students’ engagement with complex problems or questions and opportunities to “explore, explain, extend, and evaluate their progress” (NRC, 1999, p. 127). This approach to science learning and teaching is seen as beneficial because it emphasizes deep mastery of core scientific concepts, students’ motivated engagement with the “big ideas” in science, and “doing science” and “sense-making,” rather than facts and recall (NRC, 1999).

Definitions of *inquiry* from the American Academy for the Advancement of Science (AAAS) and the National Science Education Standards (NSES) make clear that inquiry-based instruction involves more than simply collecting original data. These data must be connected in meaningful ways to a research question that drives the inquiry. Analyzing data, understanding data patterns, understanding how well data can address a question, drawing conclusions based on data, and understanding how the data collection process may limit the degree to which data can provide evidence to answer a question—these are all crucial aspects of inquiry-based instruction. According to the NSES:

> *Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations.* (NRC, 1996, p. 23)

There is evidence that inquiry-based instruction leads to better student outcomes than traditional science instruction. Shymansky, Kyle, and Alport (1983) conducted a meta-analysis of 105 experimental studies involving more than 45,000 students and 27 innovative science curricula. Results of the meta-analysis showed that, across all innovative curricula, students in inquiry-rich classrooms performed better than students in traditional courses in general achievement, analytic skills, process skills, and related skills (e.g., reading, mathematics, social studies, and communication). At the same time, students in inquiry-rich classrooms developed a more positive attitude toward science.

To be sure, not all teachers are prepared to provide their students with inquiry-based science learning experiences. Many have conceptions of science as a received body of knowledge, rather than as an active process of systematic exploration; many teachers are unsure how to manage classrooms where students explore questions of their own choosing. Teachers need opportunities to practice inquiry in the context of their preservice and inservice training (NRC, 2000). They need professional development with a strong subject matter focus (Cohen & Hill, 1998). They also need to experience this professional development as part of a coherent strategy of science education reform (Garet et al., 2001). To address student questions, science teachers need to know how to draw on students' everyday sense-making strategies and build toward scientific practices (e.g., Bureau of Indian Affairs, 1998; Snively & Corsiglia, 1998; Warren et al., 2001).

Inquiry in the Scaling Out of GLOBE

The GLOBE Program is committed to preparing teachers to implement GLOBE in a way that promotes student research and inquiry. A core assumption of the Program is that students are capable of more than memorizing science facts; students can themselves inquire into the scientific phenomena observable in their environment:

> *[T]he study of the environment provides an area of scientific research that is accessible to students at an early age. Students can do science. They can begin with curiosity and questions, observe, measure and analyze, and reason their way to logical conclusions supported by their data. This process is student inquiry, and it can bring the excitement of scientific research to the sometimes routine activities of data collection.* (GLOBE, 2002, p. xiv)

GLOBE students have shown that their GLOBE research can be important outside of their school settings. In 2002, nine GLOBE students from the Gallaudet Model Secondary School for the Deaf in Washington, D.C., attended a meeting of the American Geophysical Union. At the meeting, earth and space scientists presented their research to the group, and students from Gallaudet presented theirs. Similarly, students in Alabama have been conducting research on Mobile Bay, taking Hydrology measurements to investigate the presence of effluvium from the Mobile River at different spots along the bay's shore.

Nonetheless, such projects are not yet common at GLOBE schools. A few teachers have tried to integrate data analysis activities into GLOBE, but many more have focused primarily on having students collect data and on conducting learning activities. In 2001-02, GLOBE has increased the number of educational materials it provides for student research and inquiry and is transforming its approach to teacher training in an effort to increase the likelihood that teachers will incorporate inquiry into their GLOBE implementation.

The educational materials added in Year 7 provide examples of ways in which teachers can use GLOBE data for student research projects. A CD developed in 2001 provided data analysis activities for teachers to use with particular GLOBE data sets. The Implementation Guide chapter in the forthcoming 2003 Teacher's Guide includes tips on how to use GLOBE to support student research and inquiry. The new Guide will include learning activities for data analysis and data visualization, spatial analysis of data, measures of central tendency and variation in data analysis, and planning an investigation. The Guide will also include learning activities on advanced research techniques, such as creating and testing models and working with large data sets.

Inquiry is also reflected in the new training model used since fall 2002. Before being introduced to data collection protocols, educators are first introduced to a local environmental issue and how scientists are investigating it, as a way to model student inquiry. Educators are provided with opportunities to pose their own questions and explore how GLOBE data might be used to investigate those questions. More attention is being placed on the reasons for taking particular measurements and their significance within Earth's systems.

As GLOBE seeks to increase the number of classrooms that integrate student research and inquiry into data collection, more research is needed about the particular challenges teachers face in implementing inquiry. Research is also needed to identify aspects of GLOBE that support the development of student inquiry skills. The Year 7 evaluation research efforts have been dedicated to these two tasks, and this report presents our findings from several implementation and outcome studies.

The report is organized into eight chapters. Chapter 2 describes the methods used for each of the implementation and outcome studies conducted. Chapter 3 describes the Program's growth, as a context for investigating how GLOBE has scaled "up" and "out." Chapter 4 describes GLOBE activities internationally. Chapters 5 outlines how a broad sample of teachers are implementing GLOBE, using results from a survey conducted in the United States in spring 2002. Chapter 6 presents results from our student assessment, in which we investigated which aspects of GLOBE implementation are associated with greater inquiry skills. Chapter 7 profiles student research and inquiry using GLOBE in case study classrooms in the United States. Finally, in Chapter 8 we discuss implications of the findings presented in this report for future support from the GLOBE Program to teachers implementing inquiry-based science.

2. Evaluation Research Methods

In conducting its evaluation of the GLOBE Program each year, SRI International uses a variety of research methods, each designed to address a core set of research questions. This chapter describes the research questions we investigated in Year 7 (2001-02) and the methods used in detail. In subsequent chapters, only general descriptions of research methods are included.

We continued to collect basic evaluation data on the GLOBE Program's reach, implementation patterns, and growth in Year 7, but we also focused on developing a better understanding of student research and inquiry with GLOBE. We investigated how frequently teachers reported implementing different aspects of science inquiry in their classrooms. We also sought to understand how case study schools implemented inquiry with GLOBE in different communities, paying close attention to the barriers and supports to implementing the Program in this way. Finally, we sought to understand better those aspects of GLOBE implementation that supported the development of inquiry skills among middle and high school students.

Research Questions

SRI researchers worked with GLOBE Program staff to generate a set of research questions to guide our investigations in Year 7. These questions were:

1. What is the rate of growth in terms of GLOBE teacher training and implementation of GLOBE activities?
2. How many students does the GLOBE Program reach?
3. How frequently do teachers implement protocols and conduct learning activities with their students?
4. What are the barriers to GLOBE implementation and data reporting?
5. What are the effects of GLOBE training on teachers' practice?
6. How frequently do teachers engage students in inquiry and research with GLOBE?
7. What are the supports and barriers to conducting inquiry and student research with GLOBE, in the United States and among international GLOBE schools?

8. What aspects of GLOBE implementation contribute to students' science achievement?

Using these questions as a guide, SRI queried the GLOBE Data Archive, administered a large-scale teacher survey, conducted interviews with GLOBE teachers at their schools, and administered a student assessment in GLOBE classrooms. The sections below describe our strategies for collecting and analyzing data from these sources.

Investigating the Growth and Reach of GLOBE

Data on the growth of GLOBE in Year 7 are presented in Chapter 3 of this report. GLOBE's growth has been measured each year by using a variety of data sources. The GLOBE Program maintains records of all teachers trained in the Program. The GLOBE Data Archive is the repository for the measurement data collected by students. Growth is summarized in Chapter 3 using descriptive statistics about the number of schools reporting data, the frequencies and types of data reported, and the number of teachers trained. Data on the Program's retention rate or persistence in data reporting are also drawn from the GLOBE Data Archive and summarized. Program trends are examined in terms of data reporting practices through comparison with other years' data.

The reach of GLOBE was estimated from results of a large-scale teacher survey (Appendix A), administered to a stratified random sample of GLOBE-trained teachers in spring 2002. Because we have found in the past that data reporting influences teacher response rates and is related to implementation, we divided the population of GLOBE-trained teachers into three groups: teachers from schools that had never reported data to the GLOBE Data Archive, teachers from schools that had reported data only between 1995 and 1998, and teachers from schools that had reported data since 1999. We then drew, at random, subsamples of schools to target through our teacher surveys. Our overall sample size was determined in collaboration with the GLOBE office. In our decision-making, we considered the effects of sample size both on the reliability and validity of our estimate and on the evaluation budget, particularly the cost of follow-up with nonrespondents. Follow-up in the form of telephone calls to teachers who do not respond initially to surveys is costly; it was estimated, moreover, that follow-up for the schools in the never-reported category would be required for up to 90% of the teachers.

As expected, extensive follow-up was required for the sample of schools that had never reported data; initial response rates were less than the 10% expected for this group. Response rates were also low for the middle category of schools, those that last reported data between 1995 and 1998. Extensive follow-up was conducted for these schools. Response rates are shown in Table 2.1.

Table 2.1
Survey Response Rate, by Data Reporting Category

	Number of Schools in Category	Number of Teachers Sampled for Teacher Survey*	Effective Response Rate**
Never reported data	5,696	520	19%
Last reported data during 1995-1998	1,278	119	19%
Reported data since 1999	3,130	316	60%

* If more than one GLOBE-trained teacher was present at a school, schools were asked to identify the most active GLOBE teacher to complete the survey.

** The effective response rate is the rate after adjusting for attrition. Attrition was verified by researchers and refers to teachers who had left their GLOBE schools, leaving the school without a GLOBE-trained teacher.

The estimate of the reach of GLOBE reported in Chapter 3 is based solely on results from the third subsample, schools that have reported data since 1999, because this subsample was the only one for which we obtained an adequate response rate. At each school, the most active GLOBE teacher filled out the survey, estimating answers for fellow GLOBE teachers so as to characterize the reach of GLOBE in each school. Researchers used the descriptive statistics resulting from the survey data to calculate estimates of the reach of GLOBE. We report a range of values, rather than an absolute number, for this estimate because if we were to conduct the survey again, we would obtain a different answer to the question “How many students does GLOBE reach?” We know this in part because each school reaches a different number of students, and different schools might respond to our survey on a subsequent survey administration. The ranges reported represent the values between which we are 95% confident that the “true” reach of GLOBE is included.

Analyzing Training and Implementation

Our teacher survey asked about areas in addition to how many students were reached by GLOBE. The first section of the survey asked all teachers to provide general demographic information about their schools and their perceptions of GLOBE teacher training. It also asked nonimplementing GLOBE teachers to characterize their reasons for suspending the Program and their views of the barriers to GLOBE implementation. The second section asked detailed information about implementation of protocols, learning activities, and specific instructional activities and inquiry tasks in the GLOBE classroom of only those teachers who had implemented GLOBE in the 2001-02 school year. The second section also queried these teachers on perceived barriers to using the Program, the influence of changing state, district, and schoolwide priorities on their decision to implement GLOBE, their perceptions of the educational impact of GLOBE, and the types of GLOBE resources they used in carrying out classroom activities.

The analyses we conducted proceeded in three ways, depending on the structure of the data. We calculated frequencies and descriptive statistics (mean, median, standard deviation) to characterize overall implementation trends in GLOBE. We conducted a range of statistical significance tests to examine relationships between teachers' perceptions of some features of the Program and their implementation practices. In cases where the independent variables were categorical (e.g., grade level) and the dependent variables were continuous (e.g., summed variables characterizing how much teachers engaged in GLOBE protocols and learning activities), we conducted ANOVAs with F tests of significance. In cases where both independent and dependent variables were categorical or perhaps one was collapsed into a categorical variable (e.g., transforming a 3-point rating scale into a dichotomous variable), we conducted chi-square analyses to determine significant associations.

We conducted additional exploratory analyses to understand the degree to which factors such as teachers' beliefs about GLOBE's effectiveness, grade level, and perceptions of training were associated with implementation. The results presented in Chapter 5 were calculated by using Pearson product moment correlation tests. These tests should be interpreted with caution, however. The association of teacher characteristics and beliefs and grade-level contexts with particular types of implementation does not imply causality here. Rather, these correlations should be viewed as suggestive of relationships that could be further elaborated in a theoretical model of GLOBE implementation, explored more systematically through experimental methods, or triangulated with other data sources to gain greater understanding about the association.

Assessment of Student Learning

The GLOBE Program evaluation includes an assessment of student learning. The assessment is designed to measure the ways participation in different GLOBE activities is associated with higher levels of science achievement. In Year 7, two assessments were used, one for the Atmosphere Investigation Area and one for the Hydrology Investigation Area. In this section, we describe the sampling procedure, the instruments used to measure student outcomes, the instrument used to measure implementation, and analyses of data conducted.

Sample. Two samples of GLOBE schools were recruited for the assessment study: one for Atmosphere and another for Hydrology. Schools that had reported data during the 1998-99 school year in the investigation area being tested were first grouped into three categories: high schools, middle schools, and North Carolina middle schools. North Carolina middle schools were oversampled as part of SRI's ongoing research partnership with GLOBE in that state (see Year 6 report). GLOBE schools in California, Florida, Puerto Rico, and Hawaii were excluded from the Atmosphere sample because one assessment involved extended analysis of snowfall data, something with which many students in these states would be unfamiliar.

Schools were then selected at random from within these three groups. Roughly 9% of schools contacted met the criterion of implementing at least some aspect of GLOBE with their students and were willing to participate in the study. A total of 20 different classrooms participated in the Atmosphere assessment, but missing data from teachers caused us to eliminate 5 classrooms from the study. A total of 294 students from 15 classrooms were included as part of the Atmosphere study. Nine classrooms participated in the Hydrology study; 7 with complete data were used in the analysis, for a total of 105 students participating in that study. Additional characteristics of the samples are shown in Table 2.2.

Table 2.2
Characteristics of Students in the Assessment Samples

	Atmosphere Sample	Hydrology Sample
Gender	51% Male 49% Female	56% Male 44% Female
Age	Median: 13 Range: 10-19	Median: 16 Range: 14-18
Class size (number of students)	Mean: 23.1 SD: 11.7 Range: 9-60	Mean: 16.3 SD: 7.8 Range: 3-28

Assessment instruments. Four different assessment instruments were used in Year 7: a test of students' background knowledge of key concepts in the Atmosphere Investigation Area, a performance task requiring students to demonstrate their science inquiry skills using Atmosphere data, a test of students' background knowledge of key concepts in the Hydrology Investigation Area, and a performance task requiring students to demonstrate their science inquiry skills using Hydrology data. Students took only the tests relevant to the investigation area their respective teacher had implemented (either Atmosphere or Hydrology).

The concepts targeted on the background tests were first reviewed by the GLOBE office for validity and for their perceived salience in students' GLOBE experience. The tasks measuring inquiry skills were developed by using a template created by SRI for classroom assessment in GLOBE. The GLOBE office also reviewed these tasks. A factor analysis performed on results of the assessment indicated that the data fit a two-factor model, with the background knowledge responses comprising one factor and the inquiry skills responses comprising a second factor.

In addition, information about student demographics (e.g., age and gender) and about students' attitudes toward science was collected.

Implementation instrument. Teachers and students from each classroom that participated in the assessment task also completed a survey of their GLOBE implementation practices. There was a low ($r = 0.35$) correlation between teachers' and students' estimates about GLOBE implementation. Therefore, responses from the teacher survey were used to characterize the frequency of GLOBE activities. Using the teacher responses is consistent with practices adopted by other researchers studying implementation of educational innovations (Herman & Klein, 1997).

To strengthen the reliability of the implementation measures, a number of survey items were combined to create different indices of implementation. The composite implementation variables and the questions that made up the scales appear in Table 2.3.

Table 2.3
Survey Items Comprising the GLOBE Implementation Indices

	Atmosphere Survey Items	Hydrology Survey Items
Breadth of Protocol Implementation	Frequency of engaging in GLOBE Atmosphere protocols and in Cloud Observation learning activity	Frequency of engaging in GLOBE Hydrology protocols and in Water Walk learning activity
GLOBE Data Collection Activities	Frequency of GLOBE protocol activity, weighted by frequency of participation in science activities	Frequency of GLOBE protocol activity, weighted by frequency of participation in science activities
GLOBE Data Reporting Activities	Frequency of GLOBE data reporting activity, weighted by frequency of participation in science activities	Frequency of GLOBE data reporting activity, weighted by frequency of participation in science activities
GLOBE Data Analysis Activities	Frequency of GLOBE data analysis activity and participation in GLOBE learning activities	Frequency of GLOBE data analysis activity and participation in GLOBE learning activities
Frequency of Inquiry Activities with GLOBE	Frequency of participation in science activities	Frequency of participation in science activities

In addition to indices for implementation measures, we established indices for other factors that we hypothesized (on the basis of previous evaluation results) might have a direct or indirect influence on student performance on our assessment tasks. These indices and their component questions appear in Table 2.4.

Table 2.4
Survey Items Comprising Other Possible Influences on Learning

	Survey Items
Content Coverage (in Investigation Area)	Frequency of study of atmosphere concepts
Teachers' Beliefs about GLOBE's Effectiveness	Teacher goals for GLOBE activities
Teachers' Perceptions of Alignment with Standards	Congruence of GLOBE with applicable standards

Analysis of results. Results of the survey were then analyzed in concert with the student performance results, using two-level hierarchical linear modeling (HLM). Because of the multilevel nature of the data—students nested within classrooms—HLM provided a systematic way to investigate how teachers' implementation of the GLOBE Program influenced student learning. Using HLM, we examined the relationship between classroom differences in GLOBE implementation and student scores on our assessments. In addition, HLM was used to control for other possible classroom-level influences on student learning and individual characteristics.

Because of the small number of teachers in the Atmosphere sample, each predictor at the classroom level (HLM level 2) was examined individually. It is important to note that this small sample size results in greatly reduced power for detecting effects at the classroom level and that the inability to include more than one classroom predictor at a time may result in biased estimates of effect. Each of the three outcomes—knowledge, inquiry, and attitude—was also examined separately. Results from the Hydrology sample are not reported here because of insufficient sample size.

Several details of the models tested are important to note. First, each of the two-level models tested included three individual student characteristics as covariates: age, gender, and attitudes toward science. Second, the implementation variables used in the models may not be independent; implementation variables are likely to be highly correlated and therefore their effects would not be additive. Third, results of HLM do not in and of themselves indicate causal relationships between variables. Implementation variables *are* strong predictors of results, but they may themselves be caused by something else. For example, a teacher's broad implementation of GLOBE protocols might be a predictor of better learning scores, but that implementation might be caused by the teacher's disposition to innovate. In that case, any number of innovations in science education might produce positive learning effects, given a sufficient opportunity for students to learn the concepts and skills being tested.

Chapter 5 reports simplified representations of results of the analysis in an effort to make them more accessible. Appendices B and C, however, include details about the models that are more technical in nature and format.

Investigating Supports and Barriers to Student Research and Inquiry

We relied on case study methods to gather data on the supports and barriers to student research and inquiry with GLOBE. Case studies serve several purposes. They allow researchers to enrich quantitative data with illustrations of students and teachers engaged in GLOBE activities. Case studies cannot be broadly generalized, but they do help to explain trends in participation with real-life examples and to provide data on the facilitators and challenges that shape implementation in richer ways than surveys can offer. Case studies put evaluation researchers in direct contact with GLOBE participants and give them a forum for discussing research findings and getting informal input from participants for future research.

As in previous years, case studies in Year 7 were confined to schools in the United States. However, this year, a new theme was explored. Sites chosen for case study were those where GLOBE teachers were also trying to implement inquiry in student research, whether as part of GLOBE or as part of the broader science curriculum. Finding sites in which students were conducting inquiry projects using GLOBE data proved difficult because student inquiry is not a common practice in science classrooms, and many GLOBE teachers and partners are just beginning to explore using this approach with GLOBE. Inquiry activities differ from traditional teaching practices, and teachers typically are not trained to implement inquiry effectively.

Sources for identifying sites included GLOBE partners and schools identified as GLOBE Stars on the Program Web site. The most active GLOBE partners, in terms of teacher training and support activities, were asked to nominate potential teachers and schools. Partners active in teacher training were identified using the GLOBE database.

Partners active in teacher support activities were identified from the 1999 partner survey. The most active partners were asked because of the likelihood that they would know more about the instructional practices of their GLOBE teachers than would less active partners. Researchers reviewed the GLOBE Stars on the Web site to identify those schools that might be integrating GLOBE with an inquiry approach. Researchers then conducted a telephone screening interview with 26 teachers identified by partners and 4 teachers identified on the GLOBE Web site. The interview included questions about the teachers' GLOBE activities generally and about student inquiry in their science classes.

Twelve teachers contacted for screening did not wish to be considered further as potential participants in the study. Most of these teachers had either discontinued their GLOBE activities or were not engaged in inquiry with GLOBE. The rest of the teachers contacted were considered for either site visits or telephone interviews. Ultimately, researchers traveled to three schools for case study visits, and an additional nine teachers were interviewed by telephone. This combination of in-person and telephone interviews provided data to explore the intersection of GLOBE activities with student inquiry in science. The case study visits also included observation of students engaged in GLOBE and inquiry activities, and interviews with other school personnel as appropriate.

We developed structured protocols for teacher and principal interviews, classroom observations, and student focus groups to use on the site visits. We spent a minimum of an hour interviewing the teacher we would observe at each site, gathering data about the teacher's background and classroom practices, goals for and use of GLOBE, integration with curriculum and standards, other challenges faced, and student outcomes observed, with a particular focus on the use of GLOBE for student inquiry and on ways in which GLOBE materials were tailored to increase personal relevance to students. Where possible, we also interviewed the principal and other adults who were involved in the GLOBE projects we sought to understand (e.g., a local partner who had designed the research project at the site, or other GLOBE teachers). At each school, we observed one or two classrooms using GLOBE, trying to time our visits to see students engaging in data analysis or other project work beyond traditional data collection and reporting. At two schools, we conducted student focus groups, asking about their collective experiences with science and with GLOBE. A modified version of the teacher interview protocol was used for telephone interviews. Each site visit and telephone interview was then summarized by using a structured data capture form, which facilitated the aggregation of data for analysis and reporting. Findings from the case studies are reported in Chapter 7.

We gathered information from selected international GLOBE partners to identify ways that countries outside the United States were implementing student research in GLOBE. We focused on collaborative, multinational research projects that had been presented at the 2002 GLOBE Conference held in Chicago, Illinois. An SRI researcher reviewed conference proceedings and spoke with Country Coordinators to identify prospective sites and gather basic information about the projects. A second researcher from SRI later contacted Coordinators via e-mail to ask more targeted questions about their research projects with students and learn more about these projects' status. Our findings from these e-mail surveys are reported in Chapter 4.

3. Program Growth

SRI has tracked the growth of the GLOBE Program since its inception using two indicators: the number of teachers trained and the number of data reports for each of the investigation areas. In Year 7, SRI explored a third indicator, the number of student participants in 2001-02, to assess how many students GLOBE has potentially reached. These three indicators *approximate* rather than *measure* Program activity, for two reasons. First, teachers who complete GLOBE training decide for themselves how they will implement GLOBE with their students. As a result, teachers' implementation of the Program varies; some focus on data collection and reporting, while others use GLOBE learning activities and do data collection only periodically. Therefore, the GLOBE Data Archive—where students report the data they have collected—does not represent all GLOBE activity in classrooms. Second, the number of students who participate in GLOBE activities depends on how the teacher uses GLOBE in the classroom. In some schools, where data are collected daily, a small group of students is responsible for conducting protocols, not the entire class. On the other hand, GLOBE learning activities typically involve all students in the classroom. Therefore, the number of teachers trained does not provide a complete measure of how many students the Program reaches through trained teachers.

This chapter summarizes trends in the growth of the Program, as shown by teacher training and GLOBE Data Archive data. We present comparisons for Years 3 through 7 of GLOBE when data are available, to provide a picture of Program growth over time. Our interpretations are validated, in some cases, by patterns and trends found in other data sources or reported by the GLOBE office and partners. In other cases, we offer interpretations of phenomena that require further investigation to validate. This chapter also describes the results of the first effort to calculate the number of students reached by GLOBE.

Data Sources for Growth Indicators

The number of GLOBE teachers is comparatively easy to track, since it is defined by the number of teachers who have attended GLOBE training. Although there may be teachers who do GLOBE activities without having attended training, the official count of teachers includes only those who have been trained.

The reach of GLOBE, defined as the number of student participants across all years, thus far has not been possible to track. In Year 7, quantifying the number of student participants became a priority. Therefore, when SRI conducted its biennial teacher survey in spring 2002, questions about the number of student participants were included. Teachers were asked to estimate the number of students who participated in GLOBE in the 2001-02 school year, whether by collecting, reporting, or analyzing data or by engaging in a GLOBE learning activity.

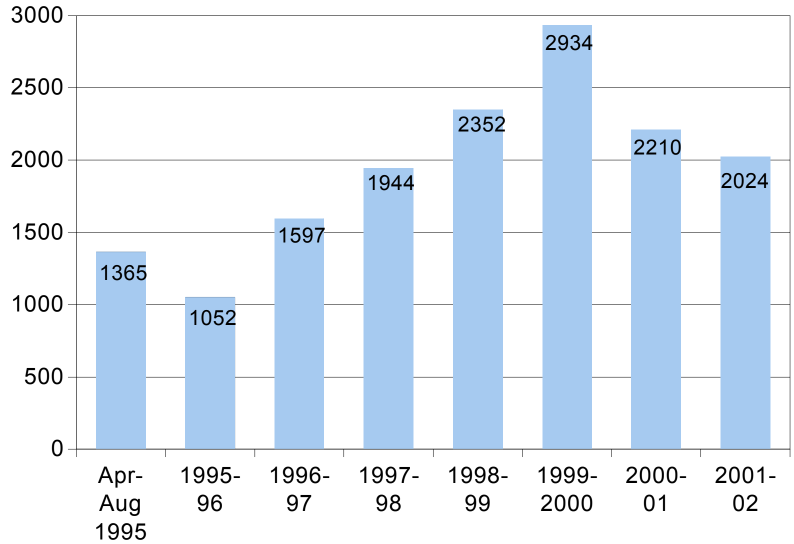
Trends in GLOBE data reporting provide evidence of the growth of GLOBE, but data reporting is what researchers call a "lagging indicator" of growth, because increases in the numbers of schools reporting GLOBE data will lag behind increases in GLOBE training and data collection activities. Moreover, for some investigation areas, the breadth or geographic spread of schools reporting data is as important as the number of schools reporting data. In the Soil and Land Cover Investigation Areas, for example, scientists are concerned with obtaining measurements that cover particular geographic areas (often at a particular time), so that they can test models of Earth processes that have been developed in other research.

Number of Teachers Trained[1]

United States partners in the GLOBE Program trained fewer teachers in 2001-02 than they trained in 2000-01. Except in 1999-2000 when the number of teachers trained reached a record high of 2,934, the number of teachers trained has been relatively stable since 1997-98 (see Figure 3.1).

[1] The Year 6 evaluation report presented incorrect data for number of teachers trained due to a query of the GLOBE database that accessed incomplete records. A correction for Year 6 data is available at http://www.globe.gov/fsl/html/templ.cgi?evaluation&lang=en&nav=1. The corrected data for Year 6 are presented in this report.

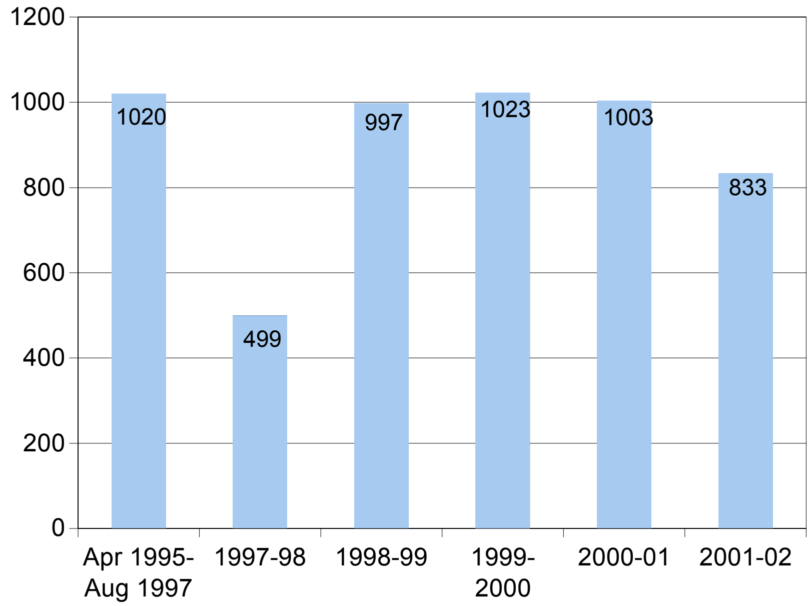
Figure 3.1
Number of Teachers Trained in the United States, by Year*



* Bars depict 12-month (September-August) training totals, except as noted in 1995.

Internationally, the number of teachers trained also remained relatively stable (833 in Year 7, compared with 1,003 in Year 6; see Figure 3.2).

Figure 3.2
Number of Teachers Trained Internationally, by Year*



*Bars depict 12-month (September – August) training totals, except as noted in 1995-97.

More teachers were trained per training session in Year 7 than in Year 6. Partners in the United States held 193 training sessions for teachers in Year 7, compared with 180 in Year 6. The mean number of teachers attending each training session in Year 7 was 10 teachers, an increase of 2 teachers over the previous year. Training more teachers at the same time may help to make delivery of training more efficient for GLOBE partners.

It is important to note that all teacher training, except for special "Train-the-Trainer" sessions in the United States, is offered solely through GLOBE partners. According to the GLOBE Web site, as of September 2002, there are 238 GLOBE partners in the United States. Not all of these partners, however, are active every year in training new GLOBE teachers, and not all are equally active in preparing teachers to implement GLOBE (Conroy, 2001). United States partners that trained the largest numbers of teachers in Year 7 (Sept. '01-Aug. '02) were GLOBE in Alabama, Huntsville (87 teachers); NASA John C. Stennis Space Center in Mississippi (64); Iowa Academy of Science (53); University of Idaho (56); and University of North Carolina at Chapel Hill (46). Each of these partners has been active in GLOBE for a number of years and has strong links to other local educational initiatives. These links are one possible explanation for their success and will be explored in SRI's evaluation activities beginning in 2002-03.

Reach of the Program among Active GLOBE Schools

As part of our teacher survey in spring 2002, SRI asked teachers to identify how many students had been reached by GLOBE in the 2001-02 school year. By "reach," we mean participation in any GLOBE activity, whether students have engaged in learning about protocols; collected, reported, or analyzed GLOBE data; or completed a GLOBE learning activity. Although our survey targeted all GLOBE schools, regardless of whether students had reported any data, only schools that had reported data since 1999 had a response rate that was sufficient (60%) to draw inferences about the reach of GLOBE.

The low response rate does not necessarily mean that teachers who were trained in the early years of GLOBE are not using GLOBE activities with students. We expected that teachers who are not using GLOBE would not be motivated to complete our survey; on the other hand, there may be GLOBE-trained teachers who have left a GLOBE school but are implementing GLOBE with students in the next school. If these teachers are not reporting data and their schools are not listed as GLOBE schools, they would not be included in our survey population. The percentage of teachers who are no longer teaching at the school where they were when they received GLOBE training is, in fact, high. Among those schools that last reported data at some point since 1999, nearly a third (29%) no longer had a GLOBE teacher at the school.

Table 3.1 shows the results of our efforts to calculate the reach of GLOBE. Among the 3,130 schools that have reported data since 1999, we estimate that the reach of GLOBE is between 153,000 and 244,000 students. Each GLOBE school reaches, on average, from 49 to 78 students. The actual reach of GLOBE among all schools is likely to be much larger; because of the low response rate, the numbers calculated should be treated as a minimum estimate of reach.

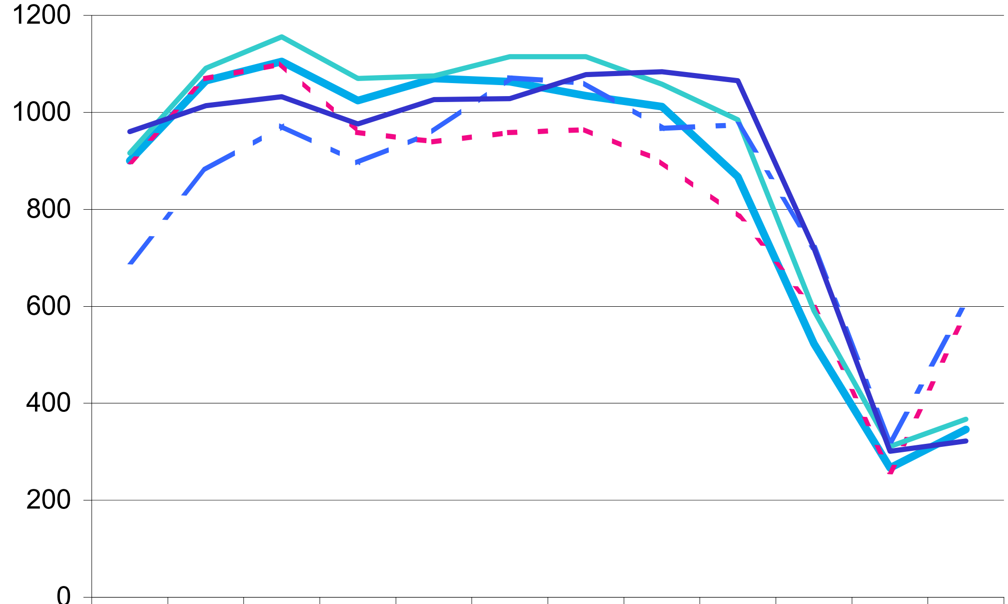
Table 3.1
Number of Students Reached by GLOBE, for Schools Reporting Data Since 1999

	Mean	Lower Limit (95% Confidence Interval)	Upper Limit (95% Confidence Interval)
Number of students per GLOBE school	66	49	78
Number of students overall	200,320	153,370	244,140

Trends in GLOBE Data Reporting

The overall number of GLOBE schools reporting data has been relatively stable in the past 5 years. Although the number of schools reporting data fell slightly in 2000-01, the number has grown in 2001-02 and is almost back to the levels of Year 5 (1999-2000), when it was at its peak (see Figure 3.3). A total of 1,848 schools reported data between September 2001 and August 2002 (Year 7), compared with 1,810 in Year 6.

Figure 3.3
Number of Schools Reporting Data Overall, by Month and Year

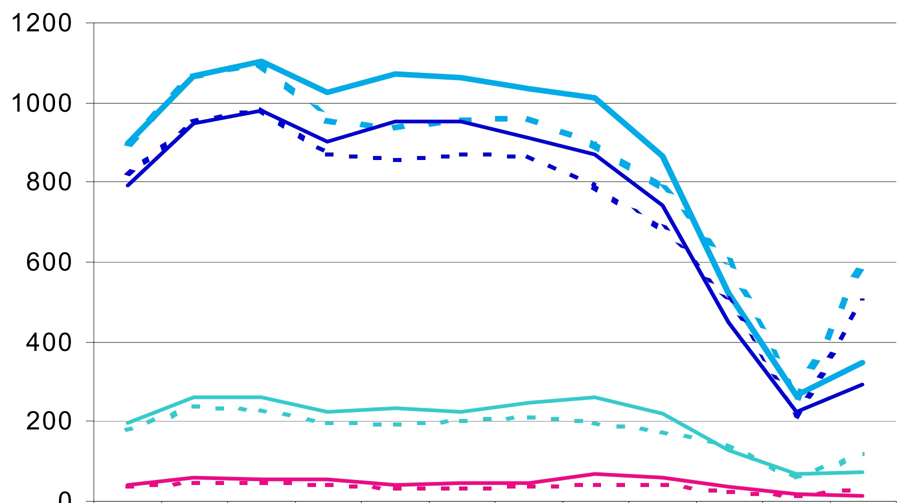


	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
2001-02	900	1065	1105	1024	1070	1063	1034	1012	867	523	267	346
2000-01	899	1069	1100	959	939	958	964	898	785	598	259	584
99-2000	916	1091	1156	1070	1075	1115	1115	1058	985	591	311	367
1998-99	692	882	972	896	961	1071	1060	967	974	721	323	604
1997-98	960	1014	1032	976	1026	1028	1078	1084	1065	720	301	322

In Year 6 (2000-01), we noted a decline in the number of schools reporting data in the spring compared with the fall, particularly in the reporting of Atmosphere data. This decline may have been due to the decrease in the number of teachers trained compared with previous years. The decline may also have been caused by other factors, such as teacher mobility, an increase in the lag time between teacher training and first data reported, and lack of class time due to mandated testing and competing curriculum demands.

Atmosphere remains the investigation area with the highest rate of data reporting, followed by Hydrology (see Figure 3.4). This finding is not surprising, since more teachers report implementing Atmosphere protocols than other protocols, and the Soil and Land Cover protocols are expected to be implemented less frequently. Figure 3.4 shows that in Year 7 (2001-02), schools again reported more consistently from fall to spring, but there was still a drop in spring Atmosphere reporting when compared with fall. It is possible that the increase in the number of teachers trained ameliorated the effects of factors affecting Year 6 (2000-01) data reporting, but that competing pressures on classroom time in the spring remain important factors in reducing data reporting during these months.

Figure 3.4
Number of Schools Reporting Data in Years 6 and 7, by Investigation Area

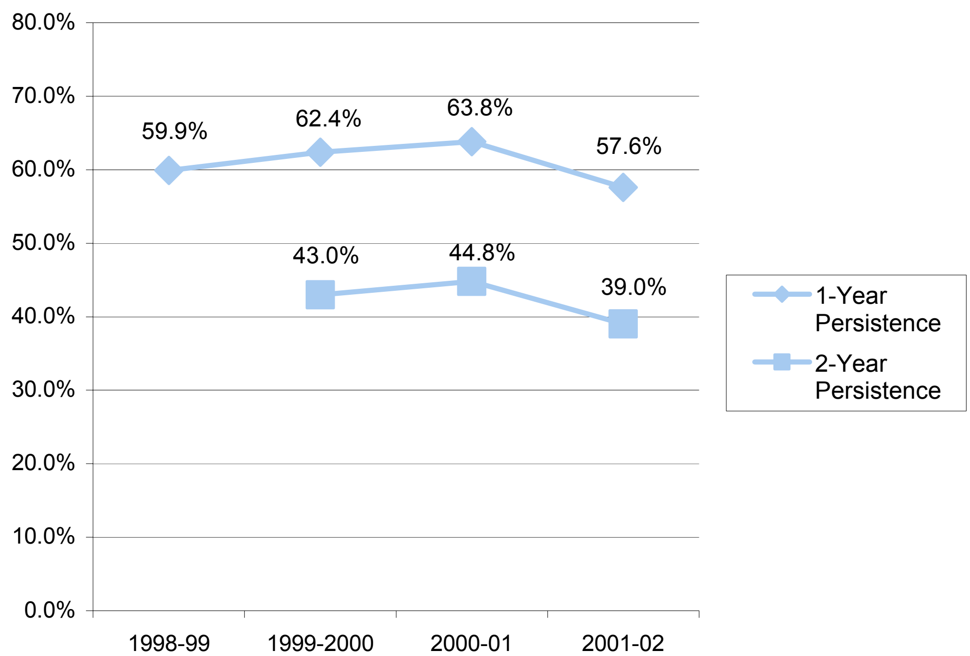


	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
All reports 2001-02	900	1065	1105	1024	1070	1063	1034	1012	867	523	267	346
All reports 2000-01	899	1069	1100	959	939	958	964	898	785	598	259	584
Atmos 2001-02	792	946	978	903	952	954	911	871	743	450	223	294
Atmos 2000-01	815	953	985	872	855	870	867	794	684	503	215	499
Hydro 2001-02	197	260	260	225	232	226	249	259	218	129	68	74
Hydro 2000-01	177	238	228	198	194	200	209	197	173	144	58	117
Soil 2001-02	43	58	54	54	42	48	47	68	61	36	19	16
Soil 2000-01	36	46	45	43	30	34	36	41	43	25	15	32

Reporting Persistence and Schools Reporting for the First Time

SRI began to investigate in Year 6 (2000-01) the effects of reporting level on persistence in GLOBE data reporting—that is, the likelihood that schools that report data in one year will report data in a subsequent year (Penuel et al., 2001). Persistence in GLOBE data reporting, especially for particular Atmosphere and Hydrology Investigations that have been conducted by scientists, is desirable to the extent that scientists need GLOBE data collected over time to test and validate models of change and variation in global climate. The rate of persistence in Year 7 reversed a positive trend, declining to 57.6% from 63.8% in Year 6, (see Figure 3.5). The 2-year retention rate has also declined almost 6 percentage points, from 44.8% in Year 6 to 39% in Year 7.

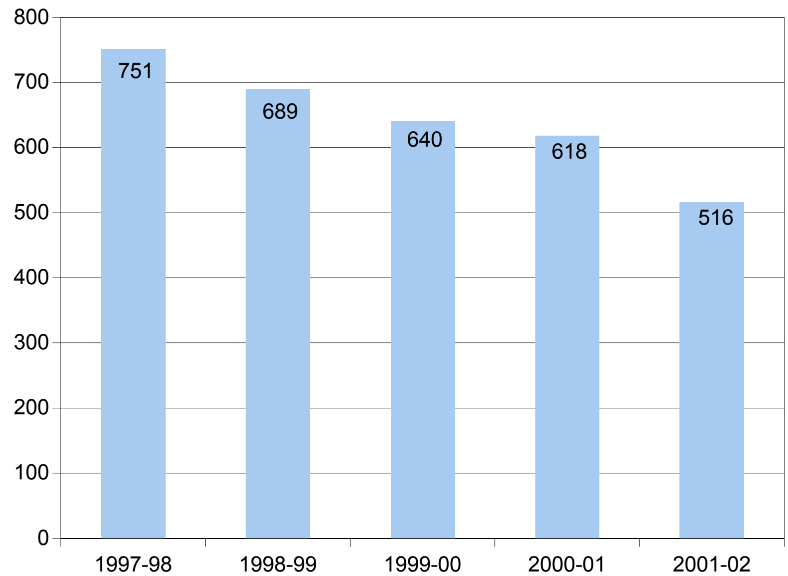
Figure 3.5
Percentage of Schools Reporting Data Persistently, by Year



We also calculated persistence among first-time data reporters for the past 3 years. Persistence rates (both 1-year and 2-year) were 5% and 15% lower for first-time data reporters than for all GLOBE data reporters. In other words, newer GLOBE schools are less persistent data reporters than GLOBE schools overall. As with GLOBE schools overall, the rate of persistence is also decreasing.

In addition to the decline in persistence of data reporting, there is a continuing downward trend in the number of schools reporting data for the first time (see Figure 3.6); nonetheless, the overall number of schools reporting data has been at approximately the same level from year to year. This leveling of the reporting pattern might be attributable to having a larger number of teachers trained.

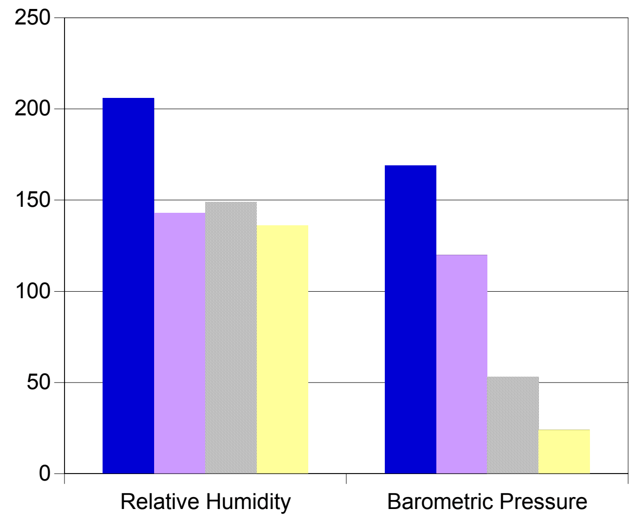
Figure 3.6
Number of Schools Reporting Data for the First Time, by Year



Reporting Patterns for Frequently Measured GLOBE Data Types

Data reporting for GLOBE Atmosphere protocols established at the start of the Program—Air Temperature, Cloud Cover, and Precipitation—was similar to reporting in Year 6; there was no significant increase or decrease in the number of schools reporting. Newer Atmosphere protocols, such as Relative Humidity, Barometric Pressure, Aerosols (previously Haze), and Ozone are starting to show signs of being adopted into more schools, as shown in Figure 3.7. These protocols were introduced in 2000.

Figure 3.7
Number of International and United States Schools Reporting Relative Humidity and Barometric Pressure Data, by Year



	Relative Humidity	Barometric Pressure
Int'l 2001-02	206	169
U.S. 2001-02	143	120
Int'l 2000-01	149	53
U.S. 2000-01	136	24

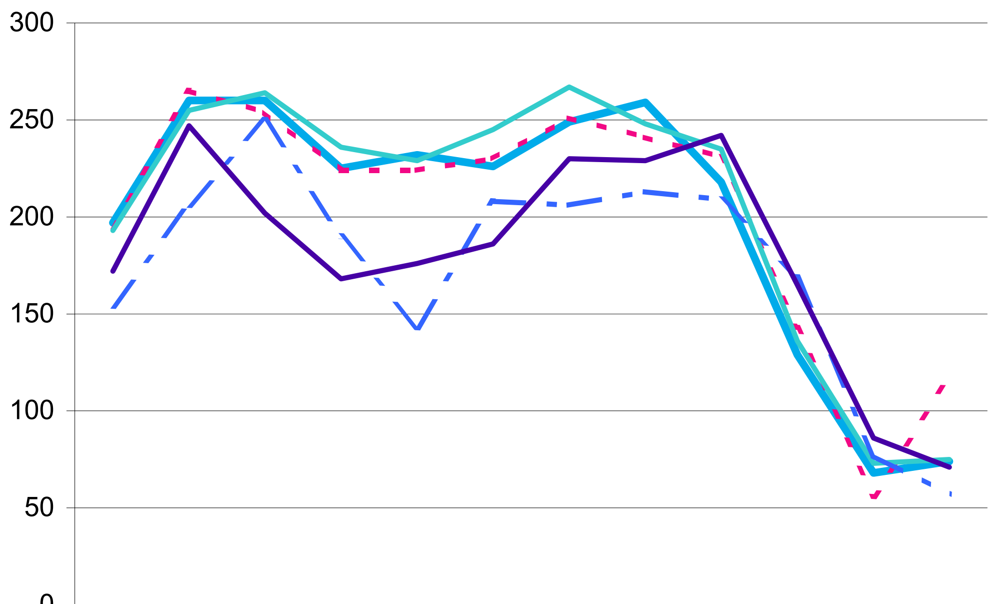
The Relative Humidity and Barometric Pressure protocols have been adopted by about one-third of schools that report data consistently. More international schools are reporting these measurements than schools in the United States. A breakdown by state of reporting schools shows that schools from 40 states reported Relative Humidity data during Year 7; California (18 schools) and Pennsylvania (13 schools) had the most schools reporting these data. For Barometric Pressure, 35 states were represented in Year 7 data, with California, Illinois, and Pennsylvania leading with school counts of 14, 12, and 11, respectively.

The Aerosols and Ozone protocols are being adopted much more slowly, perhaps in part because the protocols require more complex procedures and equipment. In addition, these protocols have only recently completed a pilot-testing phase in which procedures and instrumentation were finalized. As of August 2002, 18 schools reported Aerosols data—8 international and 10 United States schools (representing 9 states in the Midwest, East, and South). Eleven schools reported Ozone data in Year 6, and 27 schools

(7 international and 20 United States) reported this type of data in Year 7. The 20 United States schools that reported data represented 12 states, with 1 to 3 schools in each state. SRI will continue to examine how widely these protocols are adopted by schools.

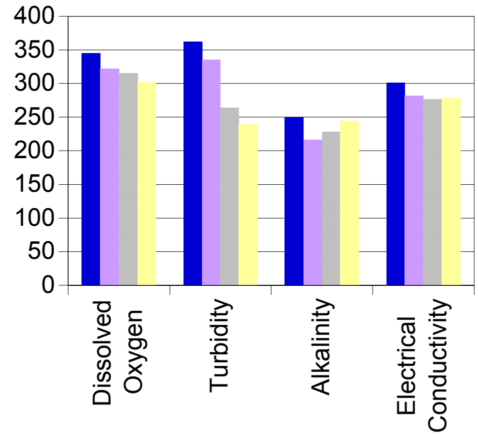
Hydrology data were reported in Year 7 at levels slightly above those of Years 5 and 6 for all protocols except Nitrates and Salinity, in which there was a small decrease in reporting. Twenty percent to 30% more schools reported Hydrology data than in Year 6. The pattern is consistent over 3 years and continues to be relatively smooth, with increased reporting in the fall and spring and modest drops during the winter. The spring reporting peak appeared a month later in Year 7, occurring in April rather than in March as in Years 5 and 6. (See Figures 3.8 and 3.9.)

Figure 3.8
Number of Schools Reporting Hydrology Data, by Month and Year



	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
2001-02	197	260	260	225	232	226	249	259	218	129	68	74
2000-01	195	265	254	224	224	230	251	241	231	143	56	117
99-2000	193	255	264	236	229	245	267	248	235	136	73	75
1998-99	154	206	250	190	143	208	206	213	209	169	77	57
1997-98	172	247	202	168	176	186	230	229	242	165	86	71

Figure 3.9
Number of Schools Reporting Water Quality Data, by Year



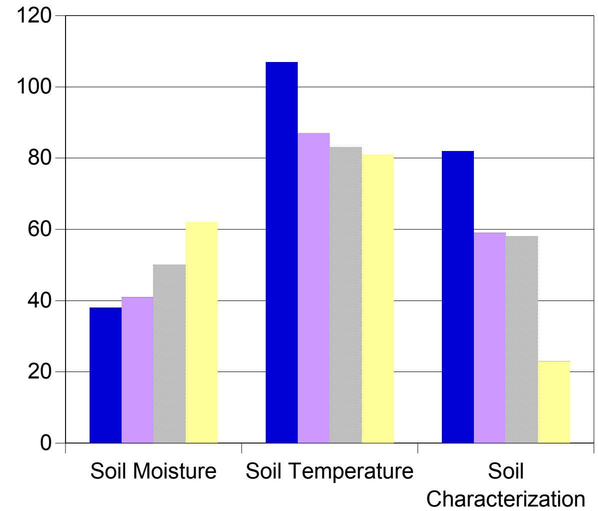
	Dissolved Oxygen	Turbidity	Alkalinity	Electrical Conductivity
2001-02	345	362	250	301
2000-01	322	335	216	282
1999-2000	315	264	228	277
1998-99	302	239	245	279

Reporting Patterns for Less Frequently Measured GLOBE Data Types

Some investigation areas require schools to collect data less frequently. Students might complete the Soil Characterization protocols only once at their site, for example. Similarly, students might classify the land cover of their study site only once in the lifetime of their Land Cover Investigation. In addition, protocols from these investigation areas tend to be less widely implemented, independent of the frequency with which particular schools implement them.

Two of the Soil protocols, Soil Characterization and Soil Temperature, were reported by an additional 20 schools in Year 7, compared with Year 6 (see Figure 3.10). The number of Soil Temperature reports should increase as more schools replace their current Min/Max Air Temperature thermometers with the new digital model that has an option of adding a probe to take soil temperature readings. Soil Moisture reports (38 schools) have remained at about the same level as in 2000-01. Few schools have ever reported Soil Moisture, perhaps because measurement requires a drying oven, which most schools do not have. In addition, Soil Moisture is a multistep protocol, meaning that teachers need to find more time to complete it, compared with other protocols. In addition, schools that are still using the Gypsum Block method for this measurement have to replace the blocks periodically to maintain accuracy in the readings.

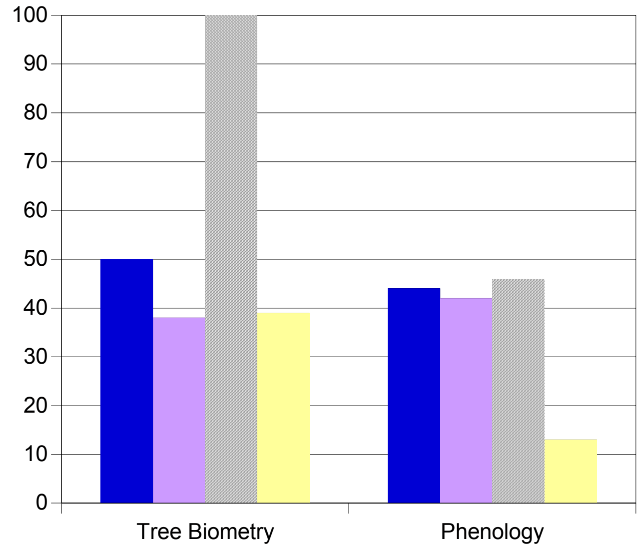
Figure 3.10
Number of Schools Reporting Soil Data, by Year



	Soil Moisture	Soil Temperature	Soil Characterization
2001-02	38	107	82
2000-01	41	87	59
1999-2000	50	83	58
1998-99	62	81	23

Figure 3.11 shows that the number of schools reporting Tree Biometry and Phenology data has increased very little. The relatively new Green-up/Green-down Phenology measurement was reported by 32 schools in Year 7. A new protocol in the Phenology Investigation Area has recently been introduced for students to make observations of the ruby-throated hummingbird. The specialized Lilac observation has been reported by 22 schools since its inception in 2000.

Figure 3.11
Schools Reporting Quantitative Land Cover/Biometry and Phenology

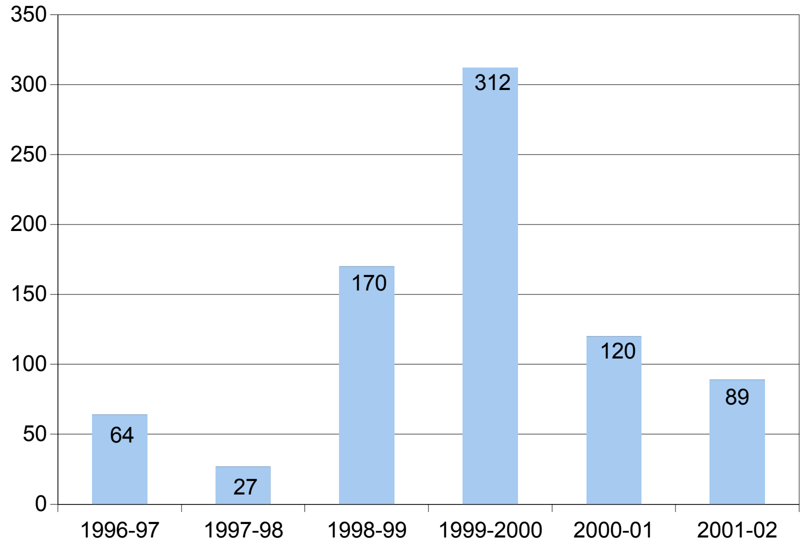


	Tree Biometry	Phenology
2001-02	50	44
1999-2000	38	42
1998-99	100	46
1997-98	39	13

Reports, by Year

Qualitative Land Cover data reporting (Modified UNESCO Classification or MUC) has been decreasing since Year 5 (1999-2000). Eighty-nine schools reported this Land Cover measurement in Year 7, compared with 120 in Year 6 and 312 in Year 5 (see Figure 3.12). Among the 89 schools reporting these data, 21 states and 33 schools in the United States were represented in Year 7, and among the 120 schools in Year 6, 27 states and 48 schools were represented. These data, as noted above, are typically recorded only once by a school, so new measurements are often indicators of new schools' involvement in Land Cover Investigations. Overall, 393 schools have reported Qualitative Land Cover data. Two hundred of these schools are in the United States, representing 41 states.

Figure 3.12
Number of Schools Reporting Qualitative Land Cover (MUC) Data, by Year



Discussion

For the first time, we have been able to make an estimate of the reach of GLOBE among schools that have reported data in the past 3 years. On the basis of the data collected from teacher surveys, we estimate that GLOBE reaches from 150,000 to 250,000 students in these schools. Although this estimate was calculated by using data from a subset of GLOBE schools, the percentage of schools that were implementing GLOBE but without reporting data since 1999 is likely to be small. Of the low percentage of schools in this category that responded to our teacher survey (19%), only 9% of schools that had never reported data and 5% of schools that reported data between 1995 and 1998 indicated that they were implementing GLOBE with their students. A conservative estimate would put the overall reach of the Program among all GLOBE schools at roughly 400,000 students. SRI will continue to estimate the reach of GLOBE among active schools, but our success is dependent on the extent that we are able to achieve high enough response rates to make reliable estimates of how many students are participating in the Program each year.

The number of teachers trained in GLOBE in Year 7 of the Program remained steady. The number of schools reporting data for the first time, however, fell for the second year in a row. The lag between training and first report of data can be quite long, as we have discovered in prior years' evaluation. We would expect to see a slight rise in first-time data reporters in Year 8, on the basis of previous studies of GLOBE Program growth.

One potentially troubling trend is the decrease in the percentage of schools that persist in data reporting from year to year. The overall rate of persistence is decreasing, as is the rate of persistence among new GLOBE schools. The rate of persistence among schools trained in the last 3 years, moreover, is more than 10% lower than that of schools trained since GLOBE's inception. On one hand, this pattern suggests that GLOBE schools that have been involved from the Program's early days are committed to GLOBE. At the same time, it would be useful to explore reasons why particular GLOBE schools that have stopped reporting data have done so, and whether they are also no longer engaging in other GLOBE activities with students.

Despite the drop in first-time data reporters and rate of persistence in data reporting, the overall number of schools reporting data did not decrease in Year 7. This pattern suggests that GLOBE schools that have reported in previous years may "skip" one or two years of subsequent data reporting. Future case study efforts will investigate reasons for this pattern.

4. Supports for Implementation and Student Research among GLOBE's International Partners

The GLOBE Program is gaining popularity among countries around the world as a hands-on science education program and as an international exchange program. With the entry of Saudi Arabia to the Program in September 2002, GLOBE had reached 99 international partners.[2] Partner countries have the flexibility to decide how to implement the Program, providing that GLOBE's standards for protocols, equipment, and training requirements are followed according to the country's bilateral agreement or memorandum of understanding with the Program. As with the GLOBE partners in the United States, GLOBE international partners continue to expand the Program to more students and schools, both within individual countries and across countries. This chapter reports[3] on recent developments in international partners' activities, particularly on innovative student projects involving scientific inquiry activities, which are implemented both within countries and across countries. The chapter also reports on challenges and support mechanisms in implementing GLOBE in partner countries, teacher training and supports, and local adaptations of the GLOBE Program.

Strategies of International Partners to Encourage GLOBE Implementation

Mobilizing and Sustaining Support

As reported in previous years, mobilizing and sustaining support and resources is one of the major challenges that international partners struggle with, but many are finding strategies to overcome this challenge. Beyond the typical initial sponsorship by a Ministry of Education or a Ministry of the Environment, other public partnerships are actively sought to assist with implementation of GLOBE. In developing countries, particularly in Africa, active partnerships exist with international aid agencies, such as the U.S. Peace Corps, the United Nations High Commissioner for Refugees (UNHCR), and

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[2] "The Kingdom of Saudi Arabia Joins GLOBE!" GLOBE Bulletin (October 3, 2002). Available at www.globe.gov/fsl/GB/Display.pl?page=gb03OCT2002_085829&lang=en&nav=1.
[3] Information in this chapter was obtained mainly from reports presented by Country Coordinators at the 7th Annual GLOBE Conference held in Chicago in July 2002, supplemented by contacting Country Coordinators by e-mail and phone, as well as by a review of resources available on the World Wide Web.

the U.S. Agency for International Development (USAID). In Europe, funding from the European Union (EU) is available for some of the international collaborative projects using GLOBE. The American embassies and GLOBE headquarters in the United States are also reported by countries to play significant roles in supporting the planning and introduction of the Program.

Partnerships have helped provide technology and telecommunications, equipment, and public relations. GLOBE in Chile provides an example of innovative partnering with private companies. Hewlett-Packard has agreed to refurbish older PCs and donate them to the country's underprivileged schools along with brand-new printers and ink supplies. Shell Chile has joined Hewlett-Packard's initiative, providing schools with the company's obsolete computers. In Nepal, GLOBE works in close cooperation with nonprofit organizations. King Mahendra Trust for Nature Conservation, one of the major environmental organizations in the country, for example, requested the Nepal GLOBE office to provide training in GLOBE protocols for teachers who are involved in its conservation project.

Some partners emphasize the importance of public relations. For example, on the basis of 6 years of GLOBE implementation, Diana Garasic, Country Coordinator for Croatia, points out that creating a positive public image of the Program is a key for developing interest in GLOBE among non-GLOBE schools and getting necessary supports for the new schools to join. According to Diana Garasic, workshops for new schools are organized in a way that teachers and principals understand GLOBE as "privilege rather than just obligation and extra work." She further explains, "Once they see it [GLOBE] as a privilege and good contributor to the school image, the procurement of necessary equipment, Internet access, and allocation of funds for GLOBE teachers' travel expenses do not stand as significant problems any more. Those headmasters usually take care to provide GLOBE training for more than one teacher, which is a very important step in retention insurance."[4]

International partners have also worked with partners in the United States to come up with innovative strategies to mobilize support for collaborative projects. The Southern

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[4] Country Report: Croatia, by Diana Garasic. The GLOBE Program Seventh Annual Conference. Available at http://www.globe.gov/fsl/html/templ.cgi?croatia_report_2002&lang=en&nav=1.

University and A&M College Partnership, Baton Rouge, Louisiana, for example, made significant efforts to obtain financial and political support for its international project involving several African countries. Having failed to win funding in the previous year, the Southern University Partnership organized an International Project Development Consultancy in June 2002, where not only program participants but also representatives from donor agencies were invited to a meeting. These representatives suggested improvements to the project plan from the donors' perspective and provided possible funding sources. A similar effort was made to gain political support in partner countries in Africa. During a Train-the-Trainer workshop held in Washington, D.C. in March 2002, the Southern University Partnership invited embassy representatives to a banquet. Having been informed of the goals of the GLOBE Program and of prospective collaborative projects, all of the embassy representatives declared support for the international collaborative project. As a result of these and other efforts, the Southern University Partnership successfully secured funding from several agencies, including United Negro College Fund Special Programs (UNCFSP) Corporation, USAID, and the United States Department of Agriculture.

Regional and International Collaboration for Teacher Training

Besides organizing teacher training regularly in their own countries, many partner countries have been actively collaborating to hold international or regional training workshops for teachers, educators, and other supporters. These workshops usually last for 7 days and are intended to transfer the experience and expertise of long-term GLOBE partners to relatively new partners and/or to enhance the network of teachers and trainers for international collaborations. The Train-the-Trainer workshop held in Washington, D.C. by the Southern University and A&M College GLOBE partners is an example that had both of these objectives. The workshop drew participants from Africa and the United States, focusing not only on training in GLOBE protocols but also on discussion and networking for possible collaborations. Ana Christina Ferro Marques, Country Coordinator for Cape Verde, reports that the workshop not only trained the country's very first teacher in GLOBE protocols, but also opened many doors for exciting future collaborations for research.

Similar workshops were held in other parts of the world. For example, in October 2000, the Asia Pacific International Teacher Training Workshop was held in Nepal, drawing 75 participants, mostly from Nepal and countries in the Asia-Pacific region. In India, a new partner that joined the Program in 2000, a relatively smaller regional training was held for teachers, educators, and scientists from India, Nepal, and Thailand. Most recently, in September 2002, a Train-the-Trainer Workshop was organized in Cyprus, involving more than 50 individuals from 14 countries around the world. Commenting on the significance of the international workshop, says Sawsan Abu Fakhreddine, a workshop participant and GLOBE Country Coordinator for Lebanon, "Besides the exciting program itself, I have found it valuable to meet so many others who will be doing GLOBE in their countries. It is also a good opportunity for me to learn from others' experience with the Program."[5]

Providing Support for Teachers and Students: Materials and Networking

Partner countries are continuing to support teachers and students in various ways. One strategy is to provide translated GLOBE materials, as well as guides and handouts on different topics that are made to fit local contexts. The Czech Republic's GLOBE office, for example, has published GLOBE worksheets containing various activities in the areas of Hydrology, Meteorology, and Biometry, to help students understand complex scientific concepts. Additional worksheets are being created on Soil Measurements. Likewise, having finished the translation of the GLOBE materials in Atmosphere and Hydrology, the Japan GLOBE office now plans to create educational materials for teachers and students to acquire skills in analyzing and interpreting GLOBE data to facilitate student inquiry. In Chile, a collaborative approach is being taken to produce a supplemental learning resource, called Weather and Tree Finder Pocket Guide. The Chile GLOBE office plans to facilitate collaborations for student investigations among teachers and students and bring together the work of all GLOBE schools in the country to publish the material.

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[5] "Cyprus Train-the Trainer Workshop," News and Events. Available at http://globe.gov/fsl/html/templ.cgi?cyprus_training&lang=en&nav=1.

Another support strategy some international partners are employing is promoting and sustaining a network of GLOBE teachers and students to share their experiences and ideas. This is being accomplished through publishing newsletters, forming online communities, or organizing face-to-face meetings. For example, Hungary's GLOBE office publishes a monthly electronic bulletin on its Web site, covering the latest news, programs, and announcements on student competitions. In the Czech Republic, a paper version of a GLOBE newsletter is published twice a year to reach many schools in the country that lack an Internet connection. The newsletter provides answers to frequently asked questions about the Program and a space for teachers and students to write about their experiences and ideas.

New Zealand tackles the same issue by creating regional networks of GLOBE schools. The country's GLOBE schools are grouped into 18 geographic clusters to maximize teacher retention and program support. Each cluster involves 7 to 10 teachers from primary, intermediate, and secondary schools in the region, who share ideas and solutions to problems of implementation, discuss interests in local environmental issues, and share resources and expertise. According to John Lockley, New Zealand's Country Coordinator, such geographic networks of teachers from different levels of schools can maintain continuity in GLOBE participation throughout students' schooling from primary school to high school. John Lockley plans to assign a greater role to an experienced teacher in each cluster to act as a mentor, delegating some of his monitoring and supporting tasks to the mentor. Negotiations have been taking place with the Ministry of Education to make funding available for paying these mentors for their greater involvement in the Program.

The e-Learning in Science and Environmental Education (e-LSEE) project in Europe provides an example of international collaboration in the creation of educational materials and communities of teachers across countries. The e-LSEE project, involving the Czech Republic, Estonia, the Netherlands, Norway, Poland, and the United Kingdom, aims to provide resources for teachers to find meaningful ways to use GLOBE data, to share materials and methodologies for computer-based learning in the classroom, and to promote communication among GLOBE teachers across participant countries. With funding from the EU's Socrates program, the member countries have started creating learning materials to be shared through an online database. The database also will be made available on a CD-ROM so that teachers can access it without an Internet connection.

Providing Support for Teachers and Students: Sustaining the Interest of Teachers and Students

International partners with more experience in GLOBE implementation report that keeping the interest and enthusiasm of experienced GLOBE teachers to prevent attrition is a major challenge. Sven Baerwalde, GLOBE Country Coordinator for Germany, states in his report that "to give experienced GLOBE teachers 'new aspects' for their work" is as challenging as "to get new trained GLOBE teachers started."[6] To overcome this challenge, the German GLOBE office provides advanced workshops on protocols. Sven Baerwalde identifies the following four objectives of such advanced workshops:

1. To provide more background information on particular topics.
2. To provide opportunities for teachers to interact with scientists.
3. To create networks of local school.
4. To offer special research projects based on GLOBE protocols.[7]

In addition to these strategies, Sven Baerwalde points out the need for some criteria—for example, a certain number of data points collected and reported each year—for schools to remain in the Program.

Diana Garasic, Croatia GLOBE Country Coordinator, also addresses the issue of school retention in her report, arguing that continued support and recognition for dedicated GLOBE teachers' work is key to teacher retention and program growth. In Croatia, the Ministry of Education and Sports sponsors meetings for GLOBE teachers at least twice during a school year, where teachers receive training in new protocols, science concepts, and pedagogy, and spend time refreshing their knowledge and computer skills. These meetings are carefully organized so that teachers feel comfortable and encouraged,

[6] Country Report: Germany, by Sven Baerwalde. The GLOBE Program Seventh Annual Conference. Available at http://www.globe.gov/fsl/html/templ.cgi?germany_report_2002&lang=en&nav=1.
[7] Ibid.

and find the training and interactions with other participants beneficial to their professional development.

Several Country Coordinators mentioned that the Chief Scientist's letters of recognition also play an important role in motivating GLOBE teachers and students. In fact, an evaluation study conducted in Cameroon found that congratulatory letters from the Chief Scientist enhanced the enthusiasm of the GLOBE teachers and students to continue collecting and reporting data.

Adaptations of the GLOBE Program

Many GLOBE Country Coordinators, teachers, and other supporters have been seeking ways to link GLOBE activities to issues of local or cultural importance in their varied contexts. For example, during the 2002 Train-the-Trainer workshop session in Washington, D.C., embassy officials from Mali pointed out that in their country, GLOBE can be used for research on malaria and other diseases that are influenced by climate patterns. Similarly, Ambassador Jose Brito, from Cape Verde, suggested that GLOBE can be used for current efforts to increase food production in a country where 90% of all food, materials, and supplies are imported.

In Senegal, the United Nations High Commissioner for Refugees (UNHCR) uses GLOBE in four refugee schools against a backdrop of increasing concerns for refugee camp situations characterized by deforestation, soil erosion and depletion, and degradation of water resources.[8] Refugee teachers were trained in GLOBE, and experiments and outdoor activities were developed for refugee children and parents to increase their awareness for environmental damages caused by clearing land for housing and farming in the refugee camp, as well as by cutting trees for building houses, for fuel, or for selling. Mamadou Ndiaye, Senegal's UNCHR Country Coordinator, notes in his report that the Program is attempting to increase student interest in science and mathematics, and many students are continuing their study of science in university.

In New Zealand, GLOBE has been adopted as a national program to help teachers meet requirements in the Ministry of Education's new guidelines for a curriculum initiative in Environmental Education. Although this national policy context has worked

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[8] The GLOBE Program signed an agreement with UNHCR in 1996 for cooperation in enhancing the environmental awareness of refugee children through GLOBE activities.

favorably for the introduction of GLOBE to the country, John Lockley, New Zealand Country Coordinator, points out that there has been criticism of GLOBE as being a “foreign” and “North American” program from some alternative environmental education programs that compete for governmental support. Under such circumstances, John Lockley and his colleagues put a lot of thought into the design of local adaptation of the GLOBE Program in the country through several strategies. First and foremost, the GLOBE Program is presented within an action research framework, which promotes the use of GLOBE protocols and activities to identify local environmental issues and make investigations that lead to actions to address local problems. This framework has been effective not only in making connections between GLOBE and local contexts, but also in differentiating GLOBE from other education programs, which, according to John Lockley, are often not action oriented.

The Program in New Zealand also encourages teachers to interact with various experts and stakeholders in local environmental issues, such as researchers from universities and research institutes, governmental officials, and leaders of local community organizations or cultural groups to find relevant research themes and approaches in their communities. At a teacher training session, several local experts and leaders gave talks on their perspectives of environmental issues, and a list of participants and speakers was distributed for future contact.

John Lockley plans to issue a press release covering successful examples of local adaptations of the GLOBE Program in early 2003. The press release will highlight not only the examples of GLOBE localization within the action research framework, but also GLOBE’s growing international network that provides students with global perspectives on environmental issues.

GLOBE as a Catalyst for Student Research

Continuing the trend from Year 6, many GLOBE countries are finding extended use of GLOBE activities for student research projects an effective way to enrich student learning. The examples below exemplify some of the international partners’ efforts to facilitate student research activities that go beyond systematic and continuous data collection and reporting.

Science Fairs and Workshops for Students

Many countries reported that they held science fairs, competitions, or GLOBE expeditions to promote GLOBE for extended research by teachers and students. Such face-to-face meetings provide teachers and students an opportunity to interact with their peers and gain new ideas for research projects or collaborations. At most of these events, awards are given to groups of students and teachers who present outstanding work. For example, the Program in Croatia organizes an annual nationwide GLOBE conference for students and teachers with funding from the Ministry of Education and Sports. Each school presents its activities and findings by posters or electronically. At the end of the conference, awards are given to outstanding presentations and activities.

In Japan, a student conference was held in January 2002 for the first time since GLOBE began there in 1995. GLOBE students participated in oral or poster presentations, in measurement and observation activities guided by scientists, in a group meeting for students to get to know each other and exchange ideas and experiences, and in a nature game session. Tadayasu Tsuji and Toshihiko Higuchi, Japanese GLOBE Country Coordinators, state in their report that the student conference was a success because students expressed enthusiasm for their presentations at the conference, as well as eagerness to try some of the ideas gained from other students' experiences for their future research projects. The conference also enhanced a sense of community among GLOBE students. Said a participant student, "I want to know more about GLOBE and natural environments through new friends."[9]

GLOBE Thailand organized a special workshop for students and teachers from 10 schools that had reported data most regularly and continuously to interact with each other, as well as with local scientists. At the workshop, the participants discussed ways to interpret data and come up with research questions, and shared ideas for student research projects as well as for student-scientist research collaborations.

In Estonia, where student research, educational use of GLOBE data, and international collaboration were the main focus of the 2001-02 implementation, middle school students (ages 12 to 14) were given special training in how to obtain and use numeric and graphic

[9] "Results of GLOBE Japan Student Conference," Education and Implementation Panel Report, by Tadayasu Tsuji and Toshihiko Higuchi. The GLOBE Program Seventh Annual Conference. Available at http://www.globe.gov/fsl/html/templ.cgi?japan_conference&lang=en&nav=1.

information and maps from the GLOBE Web site for research purposes. This training was given by a GLOBE teacher in January 2002, right before students started work on their research projects for a science competition organized by the Ministry of Education.

Regional Collaborations

GLOBE partner countries also collaborate in implementing research projects with students. These collaborative projects often address common environmental issues among participant countries, such as water quality in a shared ocean or in comparable local bays or gardens. Country Coordinators report that having partner countries working on issues of common interest motivates students and teachers to learn about the situations of other countries and facilitates their understanding of the regional or global dimensions of environmental issues. In addition, cultural understanding and a sense of global community are enhanced. A comment by Johann Gudjonsson, who is Iceland's Country Coordinator and also a local teacher, summarizes the outcomes of GLOBE for collaborative research activities:

> *We use the GLOBE data as a working tool in statistical investigation. We ask many questions about the differences between countries, especially those countries we have a relationship with. It has been great. … I think the main result is cultural understanding. Our students think in some ways as do the students of Poland, but they are different in other ways.*[10]

The Hydrology Project in the Middle East is now in full swing, increasing teachers' and students' involvement in and understanding of the significance of research. In Year 6, almost 100 students and 8 teachers from 8 schools in 3 countries (Bahrain, Jordan, and Lebanon) took local seawater measurements in waters of the Arabian Gulf, the Red Sea, and the Mediterranean Sea. After 3 to 4 months of local investigations, students from the three countries gathered at a regional conference held in Lebanon, where they discussed and compared their data and findings. Country Coordinators involved in the project report that students are taking more initiative in the research process, taking their research activities and understanding of the scientific process and science content knowledge to a greater depth. "The students did everything, and they gained a lot of insight. It was a very valuable experience all around, because they

[10] SRI e-mail communication with Johann Gudjonsson on October 6, 2002.

discussed the weakness of some of their methodology and are going back to correct it"[11] states Zakeya Ali, Bahrain's Country Coordinator and one of the coordinators of the project. The project coordinators are considering ways to involve scientists and experts in the project to further strengthen the process of student research, as well as to find better ways to disseminate findings from the student research to a wider audience in each participant country. In addition, the project plans to expand its geographic coverage, as well as the research areas: Egypt and possibly Cyprus will join the project, and Land Cover and MUC-a-Thon will be included in the investigations.

Similar collaborative research projects are implemented or planned mainly in Europe. The GLOBE-Arctic project, involving 15 schools from countries in the Arctic (Iceland, Norway, Sweden, Finland, Russia, Canada, USA/Alaska) in an investigation of persistent organic pollutants (POPs) in the Arctic, entered its second year of implementation. After the initial training workshop in 2001, in addition to the GLOBE protocols, participant countries focused on obtaining fillet, muscle, or liver samples from local fish. At the second summer workshop in Akureyri, Iceland, in August 2002, two new climate change protocols—one looking at migratory birds and the other at the development of the seaweed reproductive system—were introduced to the participant teachers.

GLOBE Germany, in collaboration with its counterparts in the Netherlands, Switzerland, and Austria, is planning a regional investigation project on the Rhine River. Students from the participant countries will study not only the scientific aspects of the river, but also its cultural, historical, and economic aspects. A regional student conference is scheduled for the summer of 2003, where results of the investigations will be presented and discussed.

Bilateral Collaborations

An interesting bilateral collaboration is being developed between GLOBE Alabama, in the United States, and GLOBE Rostov, in southern Russia. Students in both regions will investigate water quality of their home bays using GLOBE protocols, and study seasonal changes in water composition using GIS and STELLA software, a computer-based modeling and simulation application. Students will share data and analyze the data

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[11] "Middle East Hydrology Project Yields Waves of Data and Big Plans," GLOBE Stars. Available at http://www.globe.gov/fsl/STARS/ART/Display.opl?star=bahrain_hydro&lang=en&nav=1.

together through Web-based communication capabilities. What is unique about this school-to-school activity is that the project uses an existing sister-city partnership between the two cities, adding a real-world connection to the student research project. On the basis of the online discussions, students will create development scenarios for their local bays and present the findings to various local environmental protection agencies. The GLOBE partners involved in this project believe that it will not only enhance student academic and workforce skills, but will also add a new dimension to the sister-city partnership, which has been focused mainly on cultural and business areas.

Challenges to Student Research with GLOBE

As we have seen above, Country Coordinators continue to promote the use of GLOBE for student research projects, both within and between countries. However, their experience has not always been easy. From several Country Coordinators' comments obtained through e-mails, the following three themes emerge as major challenges, many of which coincide with our findings from the case studies in the United States, described in Chapter 7.

Planning research projects and collaborations requires time. As was the case with scientific inquiry in case studies in the United States, developing and implementing student research projects requires a great amount of time from the teachers and Country Coordinators involved. This is particularly true for international collaborative research projects because the planning for such projects is generally started in discussions among Country Coordinators at face-to-face meetings, which take place only a few times a year, and is continued mainly through online communications. In addition, Toshihiko Higuchi, one of the Japan's Coordinators, mentioned that translating materials requires additional time. In particular, partners may lack time to translate the learning activities, which may lead to student inquiry projects, published by GLOBE headquarters or other countries.

Limited teacher experience with conducting student research. GLOBE countries vary in their experience with inquiry- or project-based learning that involves the use of scientific data. A few partners that are relatively experienced with such pedagogy, like New Zealand, do not find it necessary to spend much time on training in pedagogical topics. However, many other countries with little or no experience with inquiry- or project-based learning point to the importance of teacher training so that teachers themselves understand and are able to model the scientific research process. In emphasizing the need for training in science knowledge and skills for teachers, Margaret Besong, Country Coordinator for Cameroon, aptly describes what is required for the extended use of GLOBE protocols:

> *GLOBE Program protocols require a [lot of] science background knowledge and keen observations and interpretations of data. The less one knows about what one observes, the less one can see, and the less one can see, the less one can learn and apply.*[12]

Sustainable supporting mechanisms are hard to establish. Far greater supports are needed to facilitate student research projects with GLOBE activities than simply assisting systematic data collections and reporting. Besides improving teacher knowledge and skills through training, learning materials, equipment, and suitable data, mechanisms for shaping successful examples of student research projects may be needed. The number of face-to-face meetings among students and teachers, as well as with scientists and international collaborators, may need to be increased. However, partners face great challenges in coming up with sustainable resources to provide extended support to greater numbers of students and teachers, particularly in the case of international collaborative projects that have high costs for traveling. Although greater involvement of scientists and other experts is ideal, finding funding is difficult.

Summary

GLOBE international partners have been able to start and sustain the Program, to adapt it to local needs, and even to take GLOBE work to a greater depth and significance for their students, as well as for local and global communities. Many countries are helping students and teachers to go beyond the mechanics of data collection and reporting, guiding them to use GLOBE data to answer questions of interest to students or of local importance. However, as several Country Coordinators indicated, the Program faces significant challenges in sustaining and scaling up the current support mechanisms to further facilitate meaningful student research projects.

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[12] "Investigating GLOBE Teacher 'Take-Up" or Reflective and Collaborative Practice After GLOBE Program Training Workshops: Case Study in Cameroon," Education and Implementation Panel Report, by Margaret Besong, The GLOBE Program Seventh Annual Conference. Available at http://www.globe.gov/fsl/html/templ.cgi?teacher_cameroon&lang=en&nav=1.

5. Patterns in GLOBE Implementation

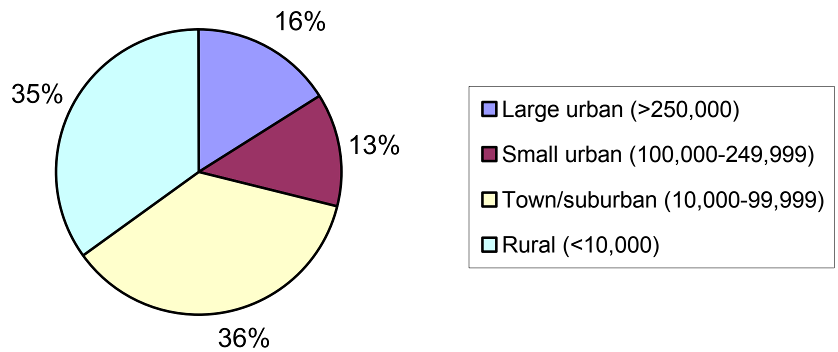
In this chapter, we explore results from the spring 2002 United States teacher survey in greater detail. In addition to capturing data on the reach of GLOBE, this survey gathered data from teachers on the contexts in which they implement GLOBE, the frequency with which they implement various aspects of GLOBE, barriers to GLOBE implementation and data reporting, and the effects of GLOBE training on teachers' practice. In our analysis, we pay close attention to the factors inside and outside teachers' classrooms that shape their GLOBE implementation, since we have found in the past that a range of policies, financial constraints, and classroom realities can influence the extent to which GLOBE implementation is perceived as viable by classroom teachers.

The chapter presents several analyses from the teacher survey. First, the different contexts in which GLOBE is implemented are explored. Second, we examine how well teachers believe their training has supported their implementation of GLOBE and how much access teachers have to posttraining supports. Third, the frequency and breadth of teachers' use of protocols and learning activities in the classroom are discussed. Fourth, we discuss the rationales teachers provided for why they implement GLOBE, or, if they have suspended implementation, why they have stopped using GLOBE with students in their classrooms. Last, we explore significant associations among different implementation variables, with the aim of generating new questions for future research.

Contexts of GLOBE Implementation

In Year 7, we sought to learn more about the location of GLOBE schools. We drew from census categories of community size to construct an item in the 2002 survey in which teachers characterized their schools as rural, suburban, small urban, or large urban. GLOBE teacher survey participants came from schools that were mostly from rural or suburban (71%) areas (see Figure 5.1). A smaller percentage of teachers who responded to the survey came from small or large urban areas, which together comprised fewer than one-third (29%) of GLOBE schools.

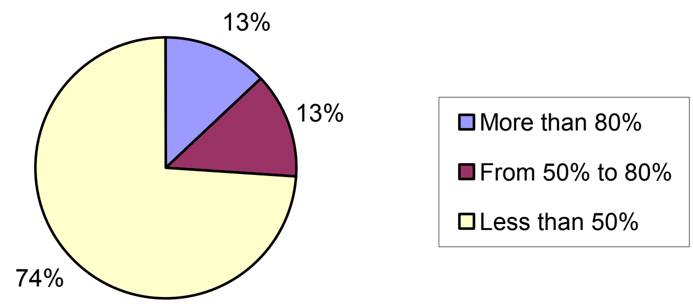
Figure 5.1
Distribution of GLOBE Survey Respondents, by Community Type*



* N = 272

GLOBE, like other science education programs, intends to reach out to all students. Cultural groups who historically have been and remain underrepresented in science—in particular, African Americans and Native Americans—are a focus of outreach for GLOBE, as evidenced by the partnerships the Program has formed with Historically Black Colleges and Universities (HBCUs) and with Tribal Colleges and Universities (TCUs). Many of these underrepresented groups attend schools where there are high concentrations of students of color (Orfield, Eaton, & Jones, 1997). One index of the reach of GLOBE among underrepresented groups, then, is the percentage of schools where there are high concentrations of these students in attendance. About one-quarter (26%) of GLOBE schools in our teacher survey sample were schools with a population consisting of more than 50% of students from these backgrounds (see Figure 5.2).

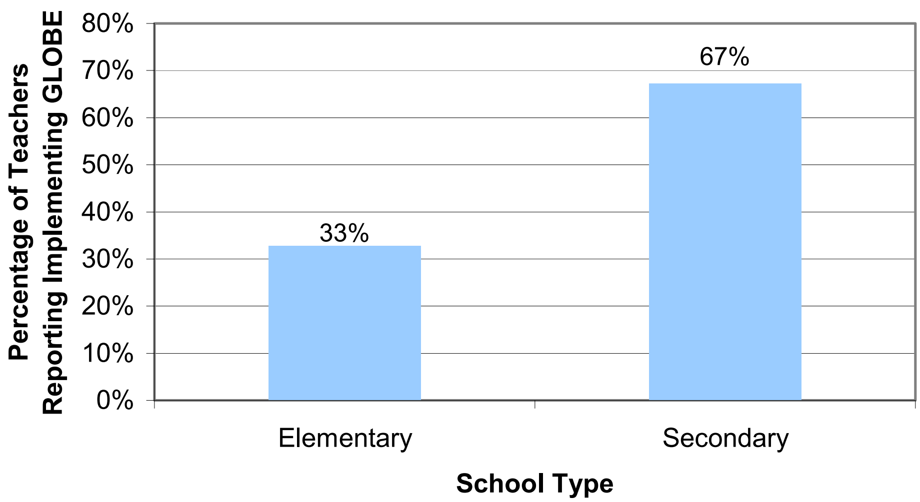
Figure 5.2
Distribution of GLOBE Schools with Different Percentages of Minority Students*



* N = 273

Unlike in previous years, when more elementary teachers who responded to the GLOBE teacher surveys reported implementing GLOBE, a higher proportion of secondary teachers reported implementing GLOBE with their students in Year 7 (see Figure 5.3). One-third (33%) of GLOBE teachers teach in elementary schools (grades K-5), and the two-thirds (67%) of secondary teachers are evenly split between teachers in middle schools and teachers in high schools. Most of the implementing teachers reported being the only GLOBE teacher at their schools (63%) and offering the Program within the course of a regular elementary or middle school class (87%). Roughly 12% offered GLOBE as part of an after-school or pull-out program for students.

Figure 5.3
GLOBE Implementation by Grade Level



Teacher Preparation and Support for GLOBE Implementation

Partners provide nearly all training for new GLOBE teachers today. Training is a prerequisite for a school to become an official GLOBE school, and a key goal is to ensure that teachers are prepared to collect and report data according to the protocols developed by Program scientists. Training is also intended to give teachers practice with other aspects of GLOBE implementation, including conducting learning activities and using the various resources of the GLOBE Web site. Part of every GLOBE training is devoted to classroom implementation issues, though partner trainers typically devote less time to this activity.

GLOBE teacher survey participants generally gave high marks to the quality of partner training. Teachers overwhelmingly reported that the training helped them implement GLOBE protocols and learning activities. To a lesser extent, teachers reported that the training helped them adapt GLOBE to different students' needs and learning styles and to state and local science standards (see Table 5.1).

Table 5.1
Teachers' Ratings of Effectiveness of GLOBE Training
(Percent Reporting)*

	Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
Prepared me to implement GLOBE protocols	9	7	2	38	45
Prepared me to implement GLOBE learning activities	9	5	5	40	41
Prepared me to adapt GLOBE to student levels and learning styles	7	14	17	36	27
Prepared me to adapt GLOBE to state/local science standards	9	16	22	29	25

* Mean number of teacher respondents per question = 267. Response rate: 94%.

The teacher survey also asked teachers to list the three most important things they learned during GLOBE training. This open-ended item gives another view of what teachers took from their training experience. To analyze these data, teacher responses were coded and summarized within each of the three levels of priority (see Table 5.2). Only the codes with the highest frequencies within each of the three levels are presented here. We have analyzed top responses by category of importance, because not all teachers provided the same number of "important things."

Table 5.2
Most Frequently Mentioned Important Elements of GLOBE Training

Level of Importance *N* (Response Rate)	Element	Teachers Mentioning (%)
Most important thing learned	How to use protocols	29
N = 238 (83%)	How to study weather	29
	How to use instruments	20
Second most important thing learned	Data use and importance	19
N = 224 (76%)	How to use protocols	13
	GLOBE Web site use	6
Third most important thing learned	Getting help for GLOBE	4
N = 182 (64%)	Environmental science resource	4
	GPS use	3

We also asked teachers how GLOBE has changed their science teaching. More than half the teachers perceive that GLOBE training contributes in some way to changing how they teach science. These changes focus on involving students more in observation, data collection, data analysis, and hands-on activity. A majority reported that GLOBE training has shifted the kinds of content they use in their classes in various ways, such as using GLOBE examples to a greater extent, using GLOBE materials to teach topics taught before with other materials, or introducing new GLOBE-related topics into their curriculum. Some teachers reported engaging students in more design and implementation of science investigations and having students use the Web-based resources to a greater extent (see Table 5.3).

Table 5.3
Self-Reported Effects of Training on Science Teaching
(Percent Reporting)

	Not at All or Slight Extent	Moderate Extent	Large Extent or Great Extent
I use GLOBE-related explanations and examples in teaching	20	24	56
I use GLOBE materials to teach topics instead of other materials	27	20	53
I have introduced new topics based on GLOBE	31	19	50
I have incorporated more hands-on activity	22	24	54
I emphasize observation and measurement more	19	22	59
I emphasize data analysis more	24	26	50
I have students design and conduct science investigations	35	27	38
I have students use Web resources for science	35	24	41

In open-ended responses, 30 teachers reported that GLOBE changed their teaching practice most strongly in other ways, primarily by helping them to design more curricula and to engage their students in more outdoor science learning activities.

The majority of teachers reported receiving some kind of support from partners after their training had been completed. Such posttraining supports may be particularly important in ensuring GLOBE implementation, particularly data reporting, as reported in

SRI's Year 6 evaluation. For example, providing mentoring, incentives, and supplementary educational materials were all associated with higher levels of data reporting among schools in Year 6.

Yet we found that fewer teachers in Year 7 accessed follow-up supports that were most positively associated with higher levels of data reporting. Teachers reported that they most frequently used communications media (e.g., listservs, newsletters) to obtain continuing expert support for their use of GLOBE. A substantial group (39%) reported frequently using communications such as the newsletter, listserv, e-mail, meetings, and telephone contacts. As their next most commonly used and available source of continuing support, teachers chose supplemental materials, such as tips for GLOBE implementation and participation incentives (26%). Follow-up refresher courses were used by fewer than one-quarter of teachers (17%). A large group (71%) never received any on-site mentoring from GLOBE partners (see Table 5.4).

Table 5.4
Teachers' Use of Continuing Supports after GLOBE Training (Percent Reporting)*

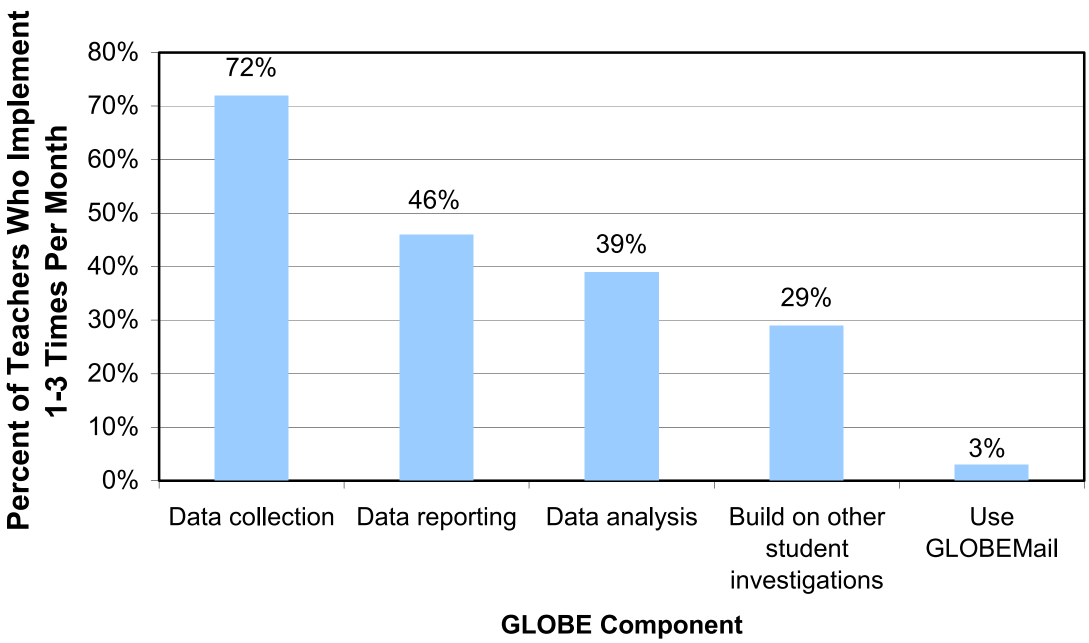
	Not at All	Infrequently	Frequently
Participation incentives (GLOBE equipment, recognition)	42	32	26
Communications (newsletter, listserv, e-mail, meetings, phone)	14	47	39
Supplementary materials (tips for GLOBE implementation)	25	49	26
Follow-up refresher course	57	26	17
On-site mentoring by GLOBE partner	71	20	9

* Mean number of teacher respondents per question = 264. Response rate: 93%.

Frequency of GLOBE Implementation

Schools vary widely in their implementation of GLOBE. Some GLOBE schools are engaged only in data collection using the protocols; others are engaged in data collection, reporting, and analysis. Schools also vary in the frequency with which they implement various activities. Figure 5.4 shows the percentage of teachers who responded to our survey who reported having adapted particular features of GLOBE with students at least once a month in the past year. The vast majority of teachers (72%) had students collect data at least once a month; fewer than half (45%), however, said they *reported* data to the GLOBE Web site this frequently.

Figure 5.4
Frequency of Implementation of GLOBE Components



Also of note in Figure 5.4 is the finding that fewer than half of teachers have students analyze GLOBE data they collect (39%), and even fewer build on other student investigations in GLOBE in designing learning opportunities for their students (29%). This suggests that there are fewer opportunities for us to learn more about students' inquiry and research with GLOBE than opportunities to learn about their collecting and reporting data.

Types of Protocols and Learning Activities Implemented

As has been common for all the years of the GLOBE Program, most GLOBE teachers reported implementing the Atmosphere protocols, somewhat fewer reported implementing the Hydrology and GPS protocols, and sharply fewer reported implementing the protocols for Land Cover/Biology, Soil, and Phenology. Overall, teachers could implement as many as 37 separate protocols across the six GLOBE investigation areas, but most implemented far fewer. Among the learning activities, teacher implementation followed similar patterns, with Atmosphere being the most frequently implemented, followed by GPS and Hydrology (see Table 5.5).

Table 5.5
Mean Number of GLOBE Data Collection Protocols Implemented; by Investigation Area

	Teachers Reporting (*N**)	Total Possible Protocols to Implement**	Mean Number of Protocols Implemented	*SD*
Atmosphere	84	10	3.6	2.1
Hydrology	116	9	2.6	3.3
Land Cover/Biology	128	6	0.6	1.4
Soil	129	6	1.1	1.8
GPS	137	2	0.6	2.7
Phenology	138	4	0.2	0.6

**N* values are smaller than total number of teachers surveyed because teachers who reported "do not know" or left protocol reporting items blank were excluded from analysis.

** The number of possible protocols was determined from the GLOBE Web site at the time the survey was prepared (2/02). These protocols were included in the survey questions.

Teachers' Use of Atmosphere Protocols and Learning Activities

The most frequently implemented Atmosphere protocols involved students in collection of Cloud data, Precipitation data, and Atmospheric Temperature. Fewer teachers implemented protocols focused on Aerosol, Barometric Pressure, Surface Ozone, and Automated Soil and Air Temperature Monitoring. Our teacher survey data on use of the Relative Humidity protocols were incomplete since this item was omitted from the Web version of our survey, but teacher use of this protocol appeared to be relatively low among teachers completing the paper-and-pencil survey (see Table 5.6). When reviewing implementation of learning activities, we also found that substantially more GLOBE teachers implement the learning activities associated with Atmosphere than any other investigation area.

We compared the relative rates of implementing protocols and learning activities within the Atmosphere Investigation Area. Of the 99 teachers who responded to both the protocol and learning activity items on the survey, we found that 85% were engaging students in both data collection and learning activities, 12% were engaging students in collecting data only, 1% were engaging students in learning activities only, and 2% were not engaging students in either.

Table 5.6
Teacher Implementation of Atmosphere Protocols and Learning Activities (Percent Reporting)*

	Don't Know	Not Implementing	Another Teacher Implements	I Implement
Cloud Type	3	5	45	47
Cloud Cover	3	4	45	48
Precipitation	3	7	42	49
Precipitation pH	3	23	32	41
Max/Min/Current Air Temperature	4	9	39	49
Aerosol (formerly Atmospheric Haze)	4	50	6	40
Barometric Pressure	2	37	13	49
Relative Humidity	0	68	6	26
Surface Ozone	3	88	5	4
Automated Soil & Air Temperature Monitoring	3	84	3	10
Atmosphere Learning Activities	1	14	6	79

* Mean protocol *N* = 126. Learning activity *N* = 131.

Teachers' Use of Hydrology Protocols and Learning Activities

Just under half of the teachers who responded to the survey indicated that they conducted protocols or learning activities with students in the Hydrology Investigation

Area. GLOBE teachers collected data on pH, Water Temperature, Water Transparency, and Dissolved Oxygen more frequently than other protocols in the Hydrology Investigation Area (see Table 5.7). After Atmosphere, Hydrology learning activities were the most widely implemented learning activities. We compared the relative rates of implementing data protocols and learning activities within the Hydrology Investigation Area. Of the 99 teachers who responded to both of these items on the survey, 40% were engaging students in both data collection and learning activities (compared with 85% in the Atmosphere Investigation Area), 17% were engaging students in collecting data only (compared with 12%), 5% were engaging students in learning activities only (compared with 1%), and 38% were not engaging students in either (compared with 2%).

Table 5.7
Teacher Implementation of Hydrology Protocols and Learning Activities (Percent Reporting)*

	Don't Know	Not Implementing	Another Teacher Implements	I Implement
Water Temperature	1	50	5	44
Dissolved Oxygen	1	61	5	33
PH	1	51	3	46
Alkalinity	1	66	4	29
Electrical Conductivity	2	68	3	27
Water Transparency	1	60	3	37
Salinity	2	83	2	13
Nitrate	2	69	3	27
Fresh Water or Marine Macroinvertebrates	2	76	2	20
Hydrology Learning Activities	1	50	6	43

* Mean protocol N = 127. Learning activity N = 131.

Teachers' Use of Land Cover/Biology Protocols and Learning Activities

Few GLOBE teachers implemented the Land Cover/Biology protocols. If they implemented Land Cover/Biology at all, the teachers were more likely to have students conduct the Qualitative Land Cover protocols, aimed at familiarizing students with their study site by identifying the major land cover types present at the site. A larger proportion of teachers (27%) reported implementing Land Cover/Biology learning activities with students, however (see Table 5.8).

We compared the relative rates of implementing protocols and learning activities within the Land Cover/Biology Investigation Area. Of the 109 teachers who responded to both of these items on the survey, 20% were engaging students in both data collection and learning activities, 1% were engaging students in collecting data only, 7% were engaging students in learning activities only, and 72% were not engaging students in either.

Table 5.8
Teacher Implementation of Land Cover/Biology Protocols and Learning Activities (Percent Reporting)*

	Don't Know	Not Implementing	Another Teacher Implements	I Implement
Qualitative Land Cover	4	76	2	19
Quantitative Land Cover	4	81	2	13
Biometry	5	87	2	6
MUC System	5	82	2	12
Land Cover Mapping (manual)	4	82	3	12
Accuracy Assessment	7	86	2	5
Land Cover/Biology Learning Activities	1	68	4	27

* Mean protocol *N* = 130. Learning activity *N* = 131.

Teachers' Use of Soil Protocols and Learning Activities

GLOBE teachers implemented the Soil Investigation Area at modest levels. They collected data on Soil Temperature most frequently (see Table 5.9). As with Land Cover/Biology, teachers were more likely to report using learning activities with students than to have students collect data using any of the Soil protocols.

We compared the relative rates of implementing protocols and learning activities within the Soil Investigation Area. Of the 112 teachers who responded to both of these items on the survey, 30% were engaging students in both data collection and learning activities, 6% were engaging students in collecting data only, 10% were engaging students in learning activities only, and 54% were not engaging students in either.

Table 5.9
Teacher Implementation of Soil Protocols and Learning Activities (Percent Reporting)*

	Don't Know	Not Implementing	Another Teacher Implements	I Implement
Soil Characterization & Field Measurements	6	67	5	22
Soil Characterization Lab Analysis	6	69	4	22
Gravimetric Soil Moisture	6	79	3	12
Gypsum Block Soil Moisture	6	84	3	7
Infiltration	6	74	4	16
Soil Temperature	6	63	4	27
Soil Learning Activities	2	57	7	34

*Mean protocol *N* = 130. Learning activity *N* = 131.

Teachers' Use of GPS Protocols and Learning Activities

The majority of teachers responding to our survey engaged students in collecting basic GPS measurements, and 45% engaged students in the GPS learning activity (see Table 5.10). Only a small percentage of teachers (13%) engaged students in the Offset

GPS protocol. It is unclear from the survey whether these data were collected in the context of setting up a study site or as part of an isolated classroom activity.

We compared the relative rates of implementing protocols and learning activities within the GPS Investigation Area. Of the 114 teachers who responded to all of these items on the survey, 49% were engaging students in both data collection and learning activities, 9% were engaging students in collecting data only, 3% were engaging students in learning activities only, and 39% were not engaging students in either.

Table 5.10
Teacher Implementation of GPS Protocols and Learning Activities (Percent Reporting)*

	Don't Know	Not Implementing	Another Teacher Implements	I Implement
Basic GPS Measurement	2	38	7	53
Offset GPS	7	74	5	13
GPS Learning Activities	1	46	8	45

*Mean protocol *N* = 127. Learning activity *N* = 131.

Phenology Protocols

Only a small percentage of teachers implemented the Phenology protocols in Year 7. Of these, Budburst and Green-up/Green-down measurements were most frequently taken. Phenology is a relatively new addition to GLOBE, and teachers trained in the early years of the Program may not have received training in how to implement these protocols. Nearly a quarter of teachers (24%), however, had used the Seasons learning activities with their students (see Table 5.11).

We compared the relative rates of implementing data protocols and learning activities within the Phenology Investigation Area. Of the 117 teachers who responded to all of these items on the survey, 10% were engaging students in both data collection and learning activities, 2% were engaging students in collecting data only, 20% were engaging students in the learning activities only, and 68% were not engaging students in either.

Table 5.11
Teacher Implementation of Phenology Protocols and Seasons Learning Activities (Percent Reporting)*

	Don't Know	Not Implementing	Another Teacher Implements	I Implement
Budburst	5	85	2	7
Lilac Phenology	5	93	1	2
Green-up	6	88	1	6
Green-down	5	91	1	4
Seasons Learning Activities	2	68	7	24

*Mean protocol *N* = 128. Learning activity *N* = 131.

Teachers' Implementation of Student Research and Inquiry with GLOBE

In addition to focusing on breadth of protocol and learning activity implementation, we sought to understand the range of student research and inquiry practices that teachers used when implementing GLOBE. As noted above, fewer than half of all teachers who responded to the 2002 survey involved students in analyzing data, one of the phases of science inquiry specified in the national standards (see NRC, 2000). A similar percentage of teachers involved students in at least one of the other phases of inquiry specified in the standards: developing research questions and hypotheses, planning investigations, carrying out investigations, developing explanations from patterns in data, and communicating results. Nonetheless, about one-third of implementing teachers reported that they *never* engaged students in some phases of inquiry, suggesting that these students may have few opportunities to develop inquiry skills as part of their participation in GLOBE.

Of the inquiry activities we asked teachers about, teachers reported that they most frequently involved students in identifying causes of data variation (see Table 5.12). More than one-quarter (30%) said they had students identify causes of variation in patterns in data at least once a month, and more than one in five teachers (24%) said they had students interpret patterns using multiple representations of data this often. Fewer than one-tenth of teachers engaged students in any of the inquiry activities at least weekly.

Table 5.12
Student Engagement in Inquiry Activities in GLOBE
(Percent Reporting)

	Not at All	Once	Less Than Once a Month	1-3 Times a Month	Weekly or More
Work on projects for 1 week or longer	31	23	28	9	9
Plan investigations	35	19	30	10	6
Interpret multiple representations	28	19	29	20	4
Identify causes of variation in data	21	16	32	26	4
Analyze data from multiple sources	35	20	29	11	5
Generate explanations of data	38	15	31	12	4

Influences on Teachers' Decision-making about GLOBE Implementation

We examined teachers' choices about GLOBE implementation in four different ways. First, we conducted exploratory analyses of significant associations between particular teacher goals and dispositions and GLOBE implementation. Second, we examined teachers' responses to a question about why they chose the protocols they implement with students. Third, we analyzed differences on responses to the survey between teachers who were implementing GLOBE and those who were not. Finally, we examined the responses of teachers who said they had suspended GLOBE implementation to identify the most significant reasons why teachers who are active one year in GLOBE might become inactive the next.

We explored the teacher survey data further to examine relationships between implementation and factors such as grade level, teachers' perceptions of the efficacy of GLOBE training, use of posttraining supports, and teachers' beliefs about GLOBE's effectiveness. Examining these relationships can help us gain a clearer understanding of the contexts in which GLOBE is implemented. These relations are correlational, but they do point to associations that merit further investigation.

As part of this analysis, we used two measures of GLOBE implementation. The first measure pertains to the *frequency* with which GLOBE is implemented. For our purposes, frequency of implementation was calculated from teachers' responses to survey items (Question B2 on the survey, Appendix A). We examined the frequency with which teachers reported that they collected GLOBE data, reported data, analyzed data, and conducted inquiry using GLOBE data. We also measured *implementation breadth.* We calculated two measures of breadth: breadth of protocol implementation and breadth of learning activity implementation. Breadth of protocol implementation refers to the average number of protocols (across investigation areas) teachers reported implementing. Breadth of learning activity implementation refers to the mean number of different investigation areas from which teachers said they used learning activities.

Association of Context Factors with Frequency of Implementation

Access to posttraining supports appeared on the whole to be more significantly associated with more frequent GLOBE implementation than training effectiveness. Although training is an important part of GLOBE, teachers' ratings of its effectiveness in preparing them to implement protocols, adapt activities to meet the needs of their students, and align their implementation to local standards were not significantly related to implementation frequency. This finding held true for all aspects of GLOBE implementation examined: data collection, data reporting, data analysis, and inquiry with GLOBE (see Table 5.13). By contrast, a number of posttraining supports were significantly associated with more frequent data analysis and inquiry with GLOBE. Participation incentives and access to supplementary educational materials were positively associated with more frequent GLOBE data analysis. Supplementary materials, refresher training, and on-site coaching and mentoring were positively associated with more frequent inquiry with GLOBE.

Table 5.13
Means, Standard Deviations, and Correlations (*r*) of Training Effectiveness and Posttraining Supports with Frequency of Implementation

	M	*SD*	Data Collection	Data Reporting	Data Analysis	Inquiry with GLOBE
			Training Effectiveness			
Protocol Implementation	4.03	1.23	.17	.20*	.13	.13
Adaptation to student needs	3.61	1.21	.06	.13	.10	.03
Adaptation to local standards	3.46	1.26	.10	.03	.13	.15
			Posttraining Supports			
Participation incentives, including equipment	1.84	.81	.05	.05	.19*	.14
Ongoing communications	2.24	.69	.05	.00	.12	.12
Supplementary materials	2.01	.72	.04	-.08	.21**	.32**
Refresher training	1.60	.77	-.14	-.13	.08	.20*
Mentoring and on-site support	1.39	.65	-.03	-.03	.01	.18*

*$p \leq .05$. **$p \leq .01$.
$130 \leq N \leq 136$

Teachers' beliefs about GLOBE in some cases were associated with frequency of implementation. In particular, teachers' belief that GLOBE was effective in increasing students' conceptual knowledge of atmospheric science was positively associated with more frequent data collection ($r = .31$, $p = .00$), more frequent data reporting ($r = .18$, $p = .04$), and more frequent data analysis ($r = .19$, $p = .03$). Frequency of data collection was inversely related to teachers' belief in GLOBE's efficacy in building map skills ($r = -.19$, $p = .03$) and other language skills ($r = -.22$, $p = .01$). These associations are logical, given that data collection is most likely to build skills such as measurement. There was a small but significant positive association between frequency of data reporting and teachers' belief that GLOBE builds technology skills ($r = .22$, $p = .01$). This result is not surprising since GLOBE students must use a computer to enter their data. Also expected was the positive significant association between frequency of GLOBE data analysis and teachers' belief that GLOBE was a positive influence on students' data interpretation and analysis skills ($r = .27$, $p = .00$). GLOBE teachers who engaged their students more in data interpretation also reported higher gains in students' collaboration skills ($r = .24$, $p = .01$).

Associations were found between the frequencies with which teachers reported engaging students in inquiry with GLOBE and teachers' beliefs about the Program's efficacy in developing students' skills (Table 5.14). On nearly every dimension surveyed, small but significant correlations were found; it appears that when teachers engage students more in inquiry, they also believe the Program to be more effective.

Table 5.14
Means, Standard Deviations, and Correlations (*r*) of Frequency of GLOBE Inquiry Activities with Teachers' Reports of Student Skills Developed

Skill	*M*	*SD*	Inquiry with GLOBE
Measurement	3.63	.62	.18*
Observation	3.71	.53	.19*
Map	2.90	1.18	.15
Technology	3.17	1.04	.22**
Collaboration	3.30	.79	.23**
Data interpretation and analysis	3.36	.83	.32**
Critical-thinking	3.32	.83	.18*
English-language	2.60	1.35	.19*
Other language	2.38	1.52	.13
Comprehension-monitoring	2.92	1.12	.16
Science inquiry	3.46	.72	.32**
Mathematics	3.12	.94	.21*

*$p \leq .05$. **$p \leq .01$.
$132 \leq N \leq 137$

Association of Context Factors with Breadth of Implementation

Among the teachers who implemented GLOBE, we also found that grade-level differences were associated with implementation breadth. With respect to protocol implementation, we conducted ANOVAs to compare the mean number of protocols implemented by grade level, and we found the difference to be significant between high school teachers and elementary teachers [$F = 5.87$ (2, 74), $p < .005$]. High school teachers were more likely to implement a wider range of protocols than were elementary teachers. Grade level (elementary, middle, high school) also significantly predicted differences in the implementation of learning activities [$F = 3.27$ (12, 200), $p < .0001$]. Elementary teachers tended to emphasize Atmosphere protocols more than middle and high school teachers. Middle and high school teachers more commonly implemented Hydrology, and high school teachers implemented Land Cover/Biology and Soil more than other grade levels.

Teachers' ratings of training effectiveness were significantly associated with breadth of both protocol implementation and learning activity implementation (Table 5.15). To the extent that teachers reported that training prepared them to implement protocols, they were more likely to also report implementing a wider range of protocols and learning activities. To the extent that training prepared them to adapt GLOBE to their particular students' needs, they were more likely to implement a wider range of learning activities. The posttraining supports that were significantly associated with broader implementation overall were access to supplementary materials and refresher training.

Table 5.15
Means, Standard Deviations, and Correlations (*r*) of Training Effectiveness and Availability of Posttraining Supports with Implementation Breadth

	M	*SD*	Breadth of Protocol Implementation	Breadth of Learning Activity Implementation
	Training Effectiveness			
Protocol implementation	4.03	1.23	.28*	.19*
Adaptation to student needs	3.61	1.21	-.23	.18*
Adaptation to local standards	3.46	1.26	-.11	.14
	Posttraining Supports			
Participation incentives, including equipment	1.84	.81	.06	.27**
Ongoing communications	2.24	.69	.01	.08
Supplementary materials	2.01	.72	.33**	.32**
Refresher training	1.60	.77	.18	.24**
Mentoring and on-site support	1.39	.65	-.01	.14

*$p \leq .05$. **$p \leq .01$.
$71 \leq N \leq 114$

Not surprisingly, we found a strong relationship between implementation breadth and beliefs in GLOBE's efficacy in teaching students the content involved in the less widely implemented protocols. Table 5.16 indicates that the more broad teachers' implementation of GLOBE, the more likely they are to believe GLOBE is effective in building students' understanding of the domains of Hydrology, Soil, and Land Cover/Biology.

Table 5.16
Relationship of Teachers' Beliefs about GLOBE's Effectiveness in Increasing Conceptual Knowledge with GLOBE Implementation Breadth

	M	*SD*	Breadth of Protocol Implementation	Breadth of Learning Activity Implementation
Atmosphere	3.56	.75	-.02	.02
Hydrology	2.70	1.31	.40**	.35**
Soil	2.43	1.36	.32**	.28**
Land Cover/Biology	2.18	1.36	.26*	.27**

*$p \leq .05$. **$p \leq .01$.
$68 \leq N \leq 115$

The relationship between teachers' beliefs about GLOBE's efficacy in building students' skills and implementation is somewhat more complex (see Table 5.17). Implementation breadth was positively associated with teachers' belief that GLOBE builds map skills, technology skills, critical-thinking skills, English language skills, comprehension-monitoring skills (regulating one's own learning), and science inquiry skills. To the extent that teachers reported broad learning activity implementation, they reported greater "other language" skill gains as well.

Table 5.17
Relationship of Teachers' Beliefs about GLOBE's Effectiveness in Building Skills with GLOBE Implementation Breadth

	M	*SD*	Breadth of Protocol Implementation	Breadth of Learning Activity Implementation
Measurement	3.63	.62	-.17	.04
Observation	3.71	.53	.04	.11
Map	2.90	1.18	.25*	.21*
Technology	3.17	1.04	.26*	.23**
Collaboration	3.30	.79	.17	.12
Data interpretation and analysis	3.36	.83	.06	.11
Critical thinking	3.32	.83	.35**	.26**
English language	2.60	1.35	.29**	.25**
Other language	2.38	1.52	.23	.19*
Comprehension monitoring	2.92	1.12	.37**	.23**
Science inquiry	3.46	.72	.29**	.21*
Mathematics	3.12	.94	.15	.15

*$p \leq .05$. **$p \leq .01$.
$71 \leq N \leq 115$

Teachers also provided reasons for implementing GLOBE protocols and learning activities. The most common reasons for choosing particular activities have shifted since Year 5, the last time teacher survey results were reported. At that time, active teachers reported that the capacity to implement GLOBE activities in minimal time was the most important determining factor, while in Year 7, teachers reported that the convenience of the GLOBE field site associated with the activity was most important. Availability of equipment and materials increased somewhat as a factor positively influencing the decision to implement particular protocols, while curriculum fit remained highly important (see Table 5.18).

Table 5.18
Teacher Reports of Major Reasons Determining Their Choice of Protocols and Learning Activities for Implementation
(Percent Reporting)

	Protocols*	Learning Activities**
Minimal time requirement	51	53
Availability of equipment/materials	58	43
Convenience of location/lack of transportation requirement	62	50
Ease of protocol procedures	46	44
Low cost	40	45
Curriculum fit	55	48
Match to students' level/interests	47	53
Familiarity/clarity of procedures	47	44
Conceptual support for protocols	36	44

* Mean *N* = 136.
**Mean *N* = 114.

Barriers to Implementation: Differences between Implementers and Non-implementers

We found that "non-implementers" and "implementers" generally agreed in their perceptions of barriers to GLOBE implementation (see Table 5.19), but there were a few key differences. The largest difference concerned a change in teaching assignment, with more non-implementers reporting this as a barrier than implementers. Another key difference was that non-implementers found it more difficult than implementers to complete GLOBE activities within the school schedule. This difference was statistically significant ($p = .04$). Both groups of teachers expressed concern about time taken away from mandated tests and standards, good ways to collect data during weekends and vacations, difficulty finding time to prepare a GLOBE lesson, and difficulty integrating GLOBE into the curriculum.

Table 5.19
Differences between Implementers and Non-Implementers of GLOBE, by Barriers to Implementation (Percent Reporting)

	Non-implementers	Implementers
Change in teaching assignment	28	11
Lack of good way to collect data on weekends, vacations	57	52
Difficulty completing GLOBE during school	53	38
Concern about GLOBE's value to students	3	2
Difficulty identifying GLOBE field site	22	19
Concern about reducing time for tests/standards	34	42
Difficulty integrating GLOBE into curriculum	31	24
Lack of technical support	11	14
Lack of computer hardware or software	11	17
Lack of Internet access	15	18
Difficulty finding time to prepare	36	40

Reasons for Suspending GLOBE

Of the 89 teachers who had collected GLOBE data with their students in past years but were not doing so in the 2001-02, 66 provided answers regarding the top reasons for suspending GLOBE. The most frequently reported reasons were: a change in teaching assignment (30%); difficulties working GLOBE activities into the school schedule (20%); and other reasons (16%), such as difficulties obtaining support from a GLOBE partner, having a weather station stolen, lacking space because of a school building renovation, or a sudden death in the family. Another 11% (7 teachers) reported lacking time to prepare activities or adapt GLOBE to grade level.

Discussion

Our analysis of how teachers use GLOBE confirms past years' findings that Atmosphere protocols and learning activities are the most widely implemented aspects of GLOBE, followed by Hydrology protocols and activities. Relatively few teachers were implementing protocols and learning activities in other investigation areas. There were some teachers who engaged students broadly across all these investigation areas, and these teachers tended to share certain characteristics. They shared strong beliefs in the instructional impact of GLOBE on students' science skills and knowledge of specific environmental science areas, and they tended to be high school teachers. We also found that only about a third of teachers engaged students in data analysis and inquiry with GLOBE, and that data collection and data entry to the Web site predominated as typical GLOBE activities. The most common form of data analysis focused on identifying reasons for variation in data. Other aspects of the inquiry process, such as engaging students in planning investigations, developing explanations from their data analyses, and communicating results, were not widely implemented in the context of GLOBE.

For many teachers, finding time to implement GLOBE is a major challenge. Teachers reported it is hard to find time to prepare activities and implement them within the school day. Competing pressures on the science curriculum, including standards and testing, are primary barriers to GLOBE implementation for many teachers. Our analysis also suggested that ongoing support after initial training, particularly the frequency of obtaining personal support and follow-up courses, plays a key role for teachers who implement GLOBE most broadly across investigation areas.

Our analysis of factors associated with more frequent and broader implementation underscores the possible significance of posttraining supports and teachers' beliefs about GLOBE's efficacy. Provision of posttraining supports, more than training itself, appears to be associated with more frequent GLOBE implementation. Although teachers' beliefs that training prepares them well to implement protocols is related to implementation breadth, it does not appear to be related to frequency of implementation. By contrast, participation incentives, supplementary educational materials, refresher training sessions, and mentoring are all significantly associated in some way with GLOBE implementation.

Teachers' beliefs about the efficacy of GLOBE in developing student skills are strongly associated with both the frequency with which students engage in inquiry with GLOBE and the breadth of GLOBE implementation. These findings are consistent with those of Garet et al. (2001) on the importance of coherence in reforms for teachers. We might interpret from these findings that when teachers perceive GLOBE to be particularly effective in improving student educational outcomes, GLOBE implementation is *deep,* that is, both broad and focused on the most complex aspects of the Program (e.g., data analysis, inquiry). It may be, as we discuss in Chapter 7, that deep implementation is rare within the Program in part because of the challenges we note above. If, however, teachers' beliefs about GLOBE's effectiveness can be influenced through training or posttraining support activities, deep implementation could become more widespread.

6. Student Learning in GLOBE

The primary education goal of GLOBE is to improve students' science and mathematics achievement. Each year, SRI's evaluation activities have examined an aspect of GLOBE's effect on student learning in science. SRI has found that students from classrooms that report data frequently are more likely than students from less actively reporting schools to describe their environment in scientific terms and to perform better on tasks that require them to solve problems using GLOBE-like data (Means et al., 1999, 2000, 2002; Coleman & Penuel, 2000). In addition, previous evaluation studies have found that GLOBE students are more likely than non-GLOBE students to believe that science is a process of active inquiry into the natural world (Means et al., 1997).

One focus of SRI's evaluation efforts in Year 7 was the impact of the wide variation in teachers' implementation of GLOBE. Because many teachers implement protocols and learning activities but do not report or analyze data, it is important to know what the likely impact of that pattern of implementation is on student learning in science. Teachers also hold different instructional goals for students and have different instructional styles. These factors, too, could influence student learning. To date, we have not examined the impact of implementation variation on student learning, except to examine the unique influence of data reporting. As findings presented in this chapter suggest, however, data reporting is only one possible source of influence on student learning, and it may not be the strongest.

Hypotheses about Influences on Student Learning

To select which aspects of GLOBE implementation to investigate for their possible influence on students' science learning, SRI researchers reviewed previous years' findings from teacher surveys and case study reports. In addition, we consulted with GLOBE Program staff about their views on the relative importance of particular GLOBE activities to student learning. On the basis of these reviews, we decided to focus on seven possible influences on student learning, four of which correspond to aspects of GLOBE implementation:

- The frequency and breadth of GLOBE data collection activities (implementation-related influence).
- The frequency with which students reported data to the GLOBE Data Archive (implementation).
- The frequency with which students analyzed GLOBE data (implementation).
- The relative importance of GLOBE to teachers, in terms of meeting their most important instructional goals (implementation).
- Teachers' coverage of investigation area constructs in their classes, regardless of whether they taught these by using GLOBE (curriculum-related influence).
- Teachers' use of an inquiry approach to science teaching across the curriculum (curriculum-related influence).
- Student characteristics, including gender, age, and attitudes toward science (individual-level influence).

We developed and administered assessments of student learning in two investigation areas, Atmosphere and Hydrology. There were too few classrooms in the Hydrology sample for us to draw reasonable inferences about the influence of particular aspects of implementation on student learning. Therefore, we are limiting our discussion in this chapter to analyses from the study of learning in the Atmosphere Investigation Area.

We used three different outcome measures. We first sought to measure two different, but related, aspects of student learning. First, we tested students' conceptual or background knowledge of GLOBE-relevant constructs. These include concepts related to weather and climate, accuracy in data collection, and knowledge of conventions in reading and interpreting graphs. We also tested students' skills in conducting inquiry. This assessment involved an extended problem using weather and climate data, using the SRI-developed assessment template. Finally, we used a measure of student attitudes toward science as an outcome variable developed by other researchers (Kanai & Norman, 1997). The attitude measure focused on students' perceptions of the importance of science, their skill in school science, and the likelihood that they would pursue a career in science.

In this chapter, we present results of our analyses that tested the following hypotheses about the relationship between GLOBE implementation and student outcomes:

1. The more teachers involve their students in GLOBE data collection, the better the students will perform on the GLOBE Atmosphere inquiry and science knowledge content assessments.
2. The more teachers involve their students in GLOBE data analysis, the better the students will perform on the GLOBE Atmosphere inquiry and science knowledge content assessments.
3. The more teachers involve their students in GLOBE data reporting, the better the students will perform on the GLOBE Atmosphere inquiry and science knowledge content assessments.
4. The higher the goals a teacher sets for student opportunities to contribute to scientists' knowledge about the environment, the more positive will be the attitudes of these students toward science.

Approach to Testing the Hypotheses

Evaluation studies designed to measure *whether* a program is effective must rely on experimental or quasi-experimental designs to reduce the likelihood that researchers will make invalid inferences about program success (Cook & Stanley, 1979). However, when researchers aim to investigate the circumstances in which a program is effective, they often rely on natural variation in levels of program implementation and statistical techniques to investigate the relationship between an outcome variable and implementation factors. In our study, we are relying on this variation and statistical techniques to investigate our hypotheses about GLOBE.

Our approach to data analysis has important limitations. Our analysis does not permit us to determine whether particular influences are *causal* in nature. We can identify, however, aspects of GLOBE implementation that are correlated with one another. For example, individual teacher characteristics may influence content coverage and implementation choices, each of which in turn may affect student outcomes. Data from other sources, including our larger teacher survey and case studies, are needed to triangulate findings discussed in this chapter to support our hypotheses about which influences on learning are likely to be causal in nature.

We collected data from 308 students from 20 randomly selected GLOBE classrooms, which varied in the degree to which they implemented the different aspects of GLOBE we investigated. Of these, 294 students from 15 classrooms with complete data (for both students and teachers) were included in the analysis. The variation in implementation levels, as calculated from indices described in Chapter 5, appears in Table 6.1. These levels are indices derived from teacher survey data; the important numbers to note are the standard deviations, which show the wide range of data collection, reporting, and analysis levels represented. They also show a range, though somewhat more limited, of teacher attitudes about the importance of GLOBE to their instructional goals for science.

Table 6.1
Variation in Implementation Levels

	Mean Level of Implementation	Scale Maximum	Standard Deviation
GLOBE Data Collection	3.1	16	1.4
GLOBE Data Reporting	9.5	16	5.6
GLOBE Data Analysis	5.5	16	3.4
Centrality of GLOBE to Instructional Goals	13.4	16	3.2

*Teachers may have stated higher levels of data reporting than data collection because students most likely complete data collection in one session, but may require more than one session to enter data online.

The sample also varied by the other important characteristics. Teachers varied in the level of content coverage of Atmosphere concepts in their science curriculum and in their use of the inquiry approach. Roughly half of the students were male, and students from the sample represented the full range of likely ages of middle- and high-school students (10 to 19), with the vast majority spread evenly across the ages of 11 to 14.

To measure the influence of these different factors on students' outcome scores, we used a statistical technique called *hierarchical linear modeling*, or HLM. HLM is a technique that is particularly well suited for education, because it is designed to handle situations when some variables of interest vary at the individual level (such as age) and others vary at the classroom level (such as frequency of GLOBE data collection activities). SRI employed experts trained in conducting these analyses for educational program evaluation from UCLA's Center for Research on Evaluation, Standards, and

Student Testing to assist with these analyses. A more detailed description of our methodology appears in Chapter 2.

Although the study includes a large sample of students, it should be noted that the number of classrooms is relatively small. Larger sample sizes are preferred because they generally provide greater power, or sensitivity, to detect effects of programs. We have been cautious in our own interpretations of the results, drawing inferences about nonsignificant findings only when the likelihood that a larger sample size would influence our results is small.

Overall Assessment Results

Across the classrooms, the inquiry skill measure proved more difficult to students than the test of conceptual knowledge. On average, students scored 26.5 out of a possible 40 points, or 66%, on the conceptual knowledge test. By contrast, they scored an average of 18.7 out of 52 points, or 36%, on the test of inquiry skills. In general, their attitudes toward science were positive (24/52). Table 6.2 shows the overall results for the three outcome measures.

Table 6.2
Overall Assessment Results

	Description	Mean	Standard Deviation
Knowledge	Student Background Knowledge Score (Sum of Scores on Assessment Section A)	26.5	7.1
Inquiry	Student Inquiry in the Atmosphere Investigation (Sum of Scores on Assessment Section B)	18.7	10.7
Attitudes	Student Attitudes Toward Science (Sum of Scores on Assessment Student Survey Question 10)	24.4	4.9

Influences on Students' Conceptual Knowledge

We found that just two aspects of GLOBE implementation influenced students' scores on the test of students' conceptual knowledge. The two aspects that were significantly associated with scores on the test of conceptual knowledge were the frequency of GLOBE data analysis and teachers' goals for GLOBE. The more frequently students analyzed data using GLOBE, the more likely they were to score higher on SRI's test of students' knowledge of Atmosphere concepts. In addition, the more central the teacher considered GLOBE in contributing to students' science learning, the higher students scored on the test of conceptual knowledge.

There were other influences on students' scores as well. Students' attitudes toward science, treated here as a possible covariate on student outcomes, were associated with student scores, as was coverage of Atmosphere topics in the curriculum. Content coverage is an index of how much particular topics that appear in GLOBE are examined by students across activities, regardless of whether they are studied as part of GLOBE. Table 6.3 shows the factors that were and were not significantly associated with student performance on the test of conceptual knowledge.

Table 6.3
Predictors of Student Scores on the Conceptual Knowledge Measure

Significant Predictors of Scores	Significance Level (*p*)
Frequency of GLOBE data analysis	.05
Centrality of GLOBE to Instructional Goals	.05
Students' Attitudes Toward Science	<.05
Coverage of Atmosphere Topics	<.005

Nonsignificant Predictors of Scores	Significance Level (*p*)
Breadth of Protocol Implementation	.80
Frequency of GLOBE Data Collection	.99
Frequency of GLOBE Data Reporting	.29
Student Participation in Inquiry Activities across Curriculum	.21

From these data, we might infer that two aspects of GLOBE implementation—the breadth of protocols implemented and the frequency of data collection activities—would be unlikely to influence student outcomes, even with a larger sample size. Further investigation of other factors, however, is needed to determine if the frequency of data reporting could influence outcomes. Because previous SRI results found an effect for data reporting, these results should be interpreted with much caution.

Influences on Students' Inquiry Skill

SRI measured students' skill in planning and carrying out inquiry with data because the emphasis GLOBE places on student inquiry merits a closer look at how these skills could be developed. In particular, it is important to investigate which aspects of GLOBE as currently implemented might support the development of inquiry skills. Assessment of student inquiry skills is not a straightforward matter: there are no widely accepted models for testing students' skills in planning and conducting scientific investigations, and performance assessments involving laboratory equipment are expensive to implement in a large-scale evaluation. To measure student skill in inquiry, SRI has relied on templates developed at SRI in collaboration with the GLOBE office over the past few years of the Program, which are closely aligned with the NSES Standards for Science Inquiry (NRC, 2000).

The assessment we provided students engaged them in solving an extended, real-world problem in which they were required to construct and carry out an investigation designed to solve the problem posed. They were scaffolded through the inquiry process, question by question, with each subquestion designed to test their skill in conducting a particular phase of inquiry: deciding on a relevant question to ask, planning an investigation, collecting data, interpreting data, and communicating results. We worked to ensure that student difficulties early in the task did not adversely affect their overall score. In other words, if students had trouble formulating a question, their failure to correctly formulate a question would not affect their score on how well they analyzed data.

Still, as noted above, students did not perform well on the inquiry measure. They found many aspects of inquiry difficult, at all levels of GLOBE implementation. Moreover, GLOBE data collection efforts in particular appeared to have very little influence on those scores. Of GLOBE implementation factors, only the frequency with which students analyzed GLOBE data was a significant predictor of their scores on the inquiry measure (see Table 6.4).

Table 6.4
Predictors of Student Scores on the Inquiry Measure

Significant Predictors of Scores	Significance Level (*p*)
Analysis of GLOBE data	.03
Coverage of Atmosphere Topics	.02
Student Participation in Inquiry Activities across Curriculum	.03

Nonsignificant Predictors of Scores	Significance Level (*p*)
Breadth of Protocol Implementation	.29
Frequency of GLOBE Data Collection	.53
Frequency of GLOBE Data Reporting	.20
Centrality of GLOBE to Instructional Goals	.11

As with the analyses of student conceptual knowledge, it is important to treat some of these results with caution. With a larger sample size, it is possible that data reporting, breadth of protocol implementation, and teacher goals might prove to be significant predictors of student inquiry skills. At this point, however, there is limited evidence to support such claims.

Discussion

These findings underscore the central importance of analyzing GLOBE data for student learning. It may not be enough, these results suggest, to involve students in data collection and reporting efforts to achieve positive student outcomes. To boost student learning in science, students must have many opportunities to examine and analyze the data they or other students collect.

These data analysis activities, moreover, influence both conceptual learning and students' skill in conducting inquiry. The link between data analysis and inquiry skills is relatively straightforward, since analyzing data is a central aspect of inquiry, according to the standards (NRC, 2000). The link to conceptual learning may be less obvious, but it may be that by analyzing data, students are able to encounter concepts at a deeper level than simply by carrying out a protocol, the scientific significance of which they might not fully understand.

We have found in our implementation studies in previous years that teachers' goals really do shape how they implement GLOBE, but they appear to also have a direct influence on student learning. How important teachers believe GLOBE is to student learning—in particular, how much they believe GLOBE contributes to student achievement in science—appears to be a strong predictor of actual student learning outcomes. This finding is consistent with research on the relationship between teacher expectations of student learning and actual learning outcomes. Future studies will need to examine the possibility that teacher characteristics, such as teachers' goals for instruction, may influence the choice to conduct data analysis with students. It may be that data analysis in itself does not cause greater learning gains but that there is a strong "teacher effect" within GLOBE. We have have found in our case study research that GLOBE attracts teachers who actively seek out curricular supplements like GLOBE for their students. These teachers may be particularly skilled in putting together elements of their curriculum to provide a better learning experience for students. It may be that GLOBE's effects are strongest, moreover, in the hands of these teachers, who are able to adapt the Program to their students' needs more successfully.

The finding that Atmosphere content coverage was a significant predictor of student outcomes is consistent with previous studies of students' opportunities to learn. Previous research (Wang, 1998) has found that when students are given ample opportunity to learn a concept through classroom activities, they are more likely to perform well on tests of measures of those concepts. For GLOBE, these findings suggest that even active GLOBE teachers are using the Program as one of many different resources for helping students explore the concepts that GLOBE protocols and learning activities cover. This interpretation is consistent with our case study findings, discussed in Chapter 7, and with previous findings from our case study site visits.

In Year 9 (2003-04), SRI will conduct a new large-scale study of student learning. In this study, we will address unanswered questions from this study and increase the number of classrooms from which we collect data. We know that more evaluation research is needed to investigate the significance of data reporting for student learning outcomes, since the current study seems to contradict earlier findings from SRI studies. In those studies, we used different outcome measures, which could account for the differences. In the current study, our sample size also may have been too small to detect a significant difference.

7. Student Research and Inquiry in U.S. GLOBE Classrooms

> *It's hard, it's not easy, it's a little bit scary…but I've really seen amazing results with my students. They're willing to take risk, they understand the concepts better…I definitely have seen big improvement…in their thinking, in their ability to take ownership of their learning.*
>
> – A teacher's description of student inquiry with GLOBE

Introduction

Many national and state standards specify an understanding of the process of scientific inquiry as an essential component of science learning and literacy (AAAS, 1989, 1993; NRC, 1996; Olson & Loucks-Horsley, 2000). Inquiry-based science instruction—in which students conduct research related to a driving question of interest—helps students to understand what it means to "do science" and conduct scientific sense-making, as well as promoting deeper understanding of scientific concepts and engaging students in grappling with the "big ideas" in science (NRC, 1999).

The GLOBE Program offers outstanding opportunities for students to collect authentic data and to interact with scientists who are using those data for important research. In some classrooms, teachers are building on this foundation, giving students the opportunity to conduct their *own* research based on the GLOBE data they collect and/or data they find on the GLOBE Web site. As this chapter will describe, these projects often engage students in investigating local environmental issues, and teachers report that the approach helps students understand GLOBE science more deeply and motivates their science learning.

Nevertheless, student inquiry with GLOBE is not yet widespread; many teachers are just beginning to explore how they can make student research and inquiry a part of their GLOBE implementation. As noted in Chapter 5, only a fraction of active teachers who responded to a survey in spring 2002 said they analyzed GLOBE data once a month or more, and fewer than half of these teachers analyzed GLOBE data in the past year with their students. When they incorporated aspects of student inquiry into GLOBE, teachers were most likely to engage students in developing explanations for variations in data they collected. They were less likely to engage students in planning investigations and developing complex explanations of patterns found in the data.

This chapter describes examples of student inquiry in selected classrooms in the United States and presents an analysis of what, from these examples, are common keys and barriers to successful student research and inquiry. The GLOBE case studies discussed here are intended to illuminate classroom-level perspectives on the process of inquiry, deepening our understanding of why, in our survey and in previous case study research, we have found that inquiry with GLOBE is relatively infrequent. In the last chapter of this report, we discuss implications of our findings from the case study examples and recommendations for program improvement.

Rather than draw a random sample from all GLOBE classrooms, including those where student research and inquiry activities with GLOBE are not occurring, we looked for classrooms where teachers are integrating these types of activities with GLOBE. As part of our research, we selected three classrooms to visit and nine more teachers to interview over the phone, asking them to describe how they use GLOBE with their students, the challenges they face, and the benefits they see when they engage students in research or inquiry. Our sample was drawn from a search of the GLOBE Stars on the Program Web site, and from recommendations made by GLOBE partners or by science and education PIs of successful examples of student inquiry or other personalized student activities using GLOBE data. In addition to teachers who were actively engaged in broad research and inquiry activities with their students, the sample also included teachers who had tried these approaches but experienced challenges as they tried to use GLOBE for student research in their classrooms. We also sought to include teachers from a number of different community and educational contexts to understand the range of approaches they used to make GLOBE relevant to their diverse populations of students.

Table 7.1 shows the sites that were part of the study, their locations, and the aspects of the research in which teachers participated. The three sites we visited were an inner-city elementary school (Forest Heights Elementary School in Baton Rouge, Louisiana); a rural high school (Marana High School in Tucson, Arizona); and a program that teams preservice teachers and students at two high schools in a Native American community (Yakama Tribal School and Toppenish High School in Toppenish, Washington). Some of these teachers used strategies other than student inquiry to engage students in thinking about the science behind the data and linking that science to their lives in personally or culturally relevant ways. For example, they took students on extended field trips to experience the environment near where they lived or connected western science to native ways of knowing. Rather than limiting our search to "student inquiry using GLOBE data," we have included examples across this broader range of uses so that we can better illustrate the ways that GLOBE is being implemented.

Table 7.1
GLOBE Schools Included in Study on Student Inquiry

	Location	Site Visit or Phone Interview
Forest Heights Elementary School	Baton Rouge, LA	Site visit
Marana High School	Tucson, AZ	Site visit
Yakama Tribal School and Toppenish High School	Toppenish, WA	Site visit
Charleston Elementary School	Charleston, AR	Phone interview
Gilbert High School	Gilbert, AZ	Phone interview
Huntingdon Area Middle School	Huntingdon, PA	Phone interview
St. Andrew School	Grand Rapids, MI	Phone interview
St. Mary's School	Spring Lake, MI	Phone interview
Snow Elementary School	Dearborn, MI	Phone interview
Field Elementary School	Canton, MI	Phone interview
Charles B. Murray Elementary School	Sheridan, MT	Phone interview
Pikeview High School	Princeton, WV	Phone interview

Student Research and Inquiry in Three Communities

Projects designed to enhance the personal relevance of GLOBE data will necessarily take different shapes for students in different contexts: environmental awareness in the inner city has different goals and challenges than in farming communities, for example, and GLOBE activities can be designed to build on the various forms of connection that students from different cultural backgrounds may feel to the land.

In this section, we describe how teachers at the three sites we visited weave student research and inquiry, as well as other means of promoting the personal relevance of environmental science to students, into their GLOBE classrooms. We aim to paint portraits of these classroom contexts, articulate teachers' and other school community members' goals for GLOBE instruction, and share teachers' reflections on their experiences of promoting science inquiry. In our research, we sought to examine each of these sites on its own terms, seeking first to understand the contexts that shape GLOBE implementation and then to uncover the ways it unfolds in classrooms. The portraits, therefore, reflect a diversity of regional and cultural contexts, goals for learning, and topics for student research projects.

Making Connections with GLOBE Data in an Inner-City School

Forest Heights Elementary School is in a residential neighborhood in an industrial section of Baton Rouge. The dominant industry here is chemical processing: oil refineries and plastics plants are the largest local employers. The school serves a population of nearly all African-American students, with roughly 96% of students eligible for free or reduced-price lunch programs. According to the principal and the teacher with whom we spoke, many of the children come from single-parent homes or live with an aunt or grandparent, with little support at home for academic work. Furthermore, although a bay and wetlands are very close, children in this neighborhood tend to have little exposure to the natural environment beyond the city streets.

One distinguishing feature of the school is its math/science magnet program, which offers advanced math and science instruction to a subgroup of students in the school for 2 hours of each day. A group of 60 students, chosen by lottery from those that meet academic qualifications, participate in this magnet program. The Program aims to build sufficient scientific and mathematical literacy for students to be ready for Algebra 1 and physical science by 8th grade.

GLOBE teacher Jill Calloway, science teacher and science magnet program director, says that inquiry has been a very strong focus of curriculum development for the magnet program, partly in response to pressures from the statewide high-stakes accountability test that controls advancement from 4th grade. The test focuses on higher-order thinking skills; state science standards dictate many topics that students need to know, but the test also focuses on science inquiry skills and conceptual understanding. In 2001-02, science was included in the 4th-grade pass/fail testing requirement for the first time.

Student test performance is a highly scrutinized public measure of success for the school. In the past, Forest Heights did not perform well on accountability tests and was at risk of reconstitution. When we visited, however, they were flying a flag to acknowledge exemplary improvement: 27% improvement in test scores over 2 years, which is 17% above their target.

In addition to accountability pressures, both Jill and principal Carolyn Garnett emphasized the importance of inquiry skills to the overall life skills of students of poverty, who need to learn to think for themselves and take responsibility in order to be empowered to succeed later in life. According to the principal, the importance of these skills for students is one reason why inquiry has been a focus of schoolwide professional development in the past year.

GLOBE is an important part of the magnet program's efforts to teach students inquiry and other higher-order thinking skills. All three magnet teachers and the principal have completed GLOBE training. Fourth- and 5th-grade students in the magnet program collect Atmosphere data daily and Hydrology data weekly. The Atmosphere station is in the "outdoor classroom" in the schoolyard: a covered patio with a GLOBE weather station, several gardens, and other outdoor learning environments. The Hydrology site is about 10 minutes away at a wildlife refuge on the Comite River. After visits to each of these sites, data are entered immediately after the students return to the classroom. The classes report data consistently throughout the school year. Jill was hoping to start using Soil protocols as part of a unit on gardening in spring 2002.

Inquiry as a teaching strategy, however, is new to Jill. She said that during the 2000-01 school year, student GLOBE activities were limited to collecting and reporting data. Some interesting discussions and links emerged in class discussion—for example, in one uncharacteristically cold week, temperatures dropped below 0° C and students had an engaging reason to learn about negative numbers, which hadn't yet come up in the math curriculum. But posing questions and pursuing data analysis was not built into students'

GLOBE activities; as a result, the GLOBE data they collected were not particularly meaningful to the students.

Meanwhile, Jill was learning more about inquiry in her master's program, and from her observations of the students' work with GLOBE, she decided there was potential for deeper learning. During the 2001-02 school year, her students did a lot of questioning and researching using GLOBE data. In 5th grade, the students asked their own questions based on things they observed in the classroom. For example, students noted while looking at temperature graphs of the previous month's GLOBE data that readings on the last day of the month were higher than those on the first day. Students hypothesized that the reason was that the seasons were changing, and compared their readings with readings obtained by another GLOBE school elsewhere in the country. (Jill supported this activity by searching the GLOBE Data Archive to identify schools that were consistent reporters for comparison.) Jill was thrilled with this project because the students took ownership of the inquiry process, asked their own questions, designed the investigation, and were proud of the results.

The 5th-graders at Forest Heights were doing an extended (i.e., over several months) project when we visited, conducting research on a local ecosystem of their choosing. Groups of students were exploring saltwater marshes of Louisiana, the Gulf, and the nearby Comite River. This project started with an Activities Integrating Math and Science (AIMS[13]) investigation of environments. Jill said that the project expanded beyond what she had originally planned when students went to the river on Fridays to collect GLOBE Hydrology data and began making observations about the life of animals around them. As students collected data, they were also learning about local plants and animals and how they interrelate, so GLOBE is contributing to a broader understanding of ecosystems.

In addition, class discussion about fluctuations in students' pH readings raised questions about local pollution. At the time of our visit, these questions were triggering a possible investigation into pollutants in the local watershed, a topic of great relevance to the students. According to Jill, for many of these city students, data collection at their

[13] AIMS, from the AIMS Education Foundation at Fresno Pacific University, and FOSS, the Full Option Science System from the Lawrence Hall of Science, are environmental science curricula used by the magnet science program in addition to GLOBE.

Hydrology site was their first experience in a wooded environment, so investigations like these—as well as simple experiences like seeing animal tracks and smelling the earth—have had a great impact on students' awareness of the natural environment.

Jill reported that, in comparison with data collection and reporting activities in 2000-01, the students gained a much deeper understanding of the concepts behind the GLOBE measurements with their research in 2001-02: they don't just know how to measure pH, they now understand its relationship to the ecosystem, with plants and animals able to live only in a certain range, and are aware of the environmental results of pH fluctuations. In addition, she said that making the students responsible for scientific investigations increased their engagement in their science studies. She attributed the improved behavior of her students to their newfound experience of "feeling respected as humans and learners" and empowered to think and solve problems. Said the school principal, "For children of poverty, thinking is *the* most important skill."

Rural Community Planning with GLOBE

The area served by Marana High School, 31 miles outside of Tucson in the Arizona desert, has a mix of traditional rural-agricultural land uses and newer land development projects intended to position the town of Marana as a bedroom community of Tucson. Marana's students are described as having "one foot in rural, one in suburban" regions, and 40% of Marana's 1,500 students are eligible for free or reduced-price lunch programs. Half of the students pursue higher education, with roughly 30% going to technical/vocational/community colleges and 20% going to 4-year colleges or universities. The other half go directly into employment (40%) or the military (10%), making preparation for the working world a pressing educational goal for these students. Said the principal, "These kids will need to get a job and make a living, and high schools are disconnected from the real world."

GLOBE teacher Gary Campbell has a background in agricultural education, vocational agriculture, and guidance counseling. His vocational education background colors his hands-on approach to teaching and inspires a focus on practical projects for his students. A strong believer in exploratory learning, Gary likes to give students a problem context and let them figure out where they need to go. His approach, he says, is to "tell the kids what you want them to learn, give them the tools, and then get out of the way."

Gary teaches a Biosphere Research class for honors 11th- and 12th-grade students, as well as Integrated Science and Marine Sciences. The Research class is focused on student projects. He introduces GLOBE protocols to his Research students at the beginning of the year, and then lets them teach Integrated Science students how to carry out ongoing data collection and reporting while they move on to more research-focused activities.

Gary has found that his students are more motivated by research projects that investigate the local environment than, for example, by comparisons of rainfall data between distant GLOBE schools. In 2000-01, students in his research classes conducted a GLOBE Land Cover mapping project in their region, manually interpreting satellite images and comparing current with historical land cover data. Students' scientific approach to their research won them credibility with local town planners, leading to projects during 2001-02 in which the town was a client of their work. Students helped to plan a system of bike paths and hiking trails in Marana, and they conducted environmental planning related to a park and recreational area the town is developing. For the latter project, the town hired professionals for the official environmental impact study, and the students had an opportunity to see how their own data compare with environmental consultants' "real" data.

Although these projects were structured according to the needs of the town rather than solely according to GLOBE protocols, they drew on GLOBE skills that students had developed earlier in the year (e.g., using GIS software, interpreting satellite images, classifying land cover) and put these skills to practical use in the local economy. In Gary's class, students' scientific skills are also embedded in other professional preparation. For example, they learn about teamwork, effective communication, and dressing for success as they present their work. At the time of our visit, student teams were looking forward to presenting their results and recommendations to the town council at the end of the year, expecting to influence choices for the park and bike paths that students and their peers would eventually use. Said Gary, "One of the things I'm most proud of—I'm turning out kids who know how to do it…Kids walk out of here more capable of doing science."

Using GLOBE to Promote Culturally Relevant Science Learning

Toppenish, Washington, is a rural town 170 miles southeast of Seattle. This traditionally agricultural community is a motherland for the Yakama Tribe. GLOBE instructor Pat Falco described the local community as "poverty-stricken" and said that school children are "struggling to survive from day to day." Permanent residents are faced with a myriad of social problems, complicated by limited access to very few resources. In the past 5 to 10 years, there has been a growing interest among the young adult population to seek out higher education opportunities in order to better understand and address some of their community's social and economic concerns. One major trend has been an increased interest in teacher preparation by local young adults who intend to return to their local communities and schools to improve student achievement, opportunity, and overall academic experience. The hope is that through better education, the community residents will be better able to address their own needs and be able to turn around the deteriorating local economy.

Heritage College, a GLOBE partner since 1999, is a private tribal college in Toppenish. In addition to providing summer GLOBE training for teachers, Heritage offers a GLOBE-based practicum for preservice teachers led by Pat Falco, a Heritage faculty member with a background in chemistry and scientific research. Pat noted that statewide standardized testing emphasizes basic English and math skills; to succeed, reading and writing skills are of particular importance to the region's many English as a Second Language (ESL) students, and teachers spend a limited amount of classroom time on science. As a result, science knowledge is lacking at all levels of the educational system, from elementary and secondary students to preservice teachers at Heritage and teachers in area schools. A primary goal for Pat, then, is to provide an engaging and accessible program for preservice teachers who have little background or confidence in science.

The preservice program is part of a University of Washington science outreach program called Sciences and Tribes Educational Partnership (STEP). STEP director Nan Little said that the Program uses science as a vehicle to promote a "whole system of understanding the world," integrating important local issues that include identity, self-esteem, history, culture, language, and even arts and crafts through partnerships between high school students, teaching assistants (many of whom are Native American), and local elders. In Toppenish, students participating in the STEP program include a regular science class at Yakama Tribal School (a private school of approximately 100 Native American students in grades 7 to 12) and participants in a voluntary after school science program at Toppenish High, a nearby public school. The Program's focus is to transform an abandoned gravel pit near the schools into a native-plants arboretum, with preservice teachers acting as teaching assistants, taking turns teaching lessons and learning the science along with the students. Ultimately, program directors hope this partnership will build capacity and science depth into the local educational system.

The Program uses GLOBE protocols to provide a hands-on context for science concepts that are core to garden design and maintenance, including soil fertility and hydrology. For example, Soil protocols are used to determine the optimal nitrogen content for fertilizers used in the garden. Pat Falco described the approach to using GLOBE: "We teach the Program in terms of following the protocols. Then we spend roughly 2 to 4 times the amount of time the students spend with the protocols teaching them why it is important to understand and know the science content and concepts involved." She also stresses with students links to Native American culture and values. For example, our site visitors watched one of the preservice teachers use a model of a traditional sweathouse as a demonstration of evaporation and condensation, and a Yakama tribal elder, Lewis Malatare, incorporate traditional oral storytelling into an introduction to the Hydrology protocols:

> *Have you heard Native Americans say, "There isn't a place where you can walk where you are not standing on my ancestors"? A lot of our elders from across the country in this world of ours constantly say that in the beginnings of their stories just to remind one another just how long we've been here on this world. We've been in this portion of the country so long that every place that we step onto the ground is our relatives. That is why our culture means so much to us. Water is the most sacred, in other words, we look to the mountains that gather water for us.*

The teachers we talked to believe that GLOBE is an effective agent for introducing science concepts that will then be deepened and put to use through practical application in building the garden. Heritage master's student Irma Lange said,

> *It's the teachers who benefit the most…Because of its hands-on nature, teachers find GLOBE easy to use and make science enjoyable for their students. It reduces teachers' fear towards science and makes it fun to do in the classroom.*

In this program, teachers have no plans to report the GLOBE data they collect. They are challenged by lack of nearby natural resources that would qualify as data collection sites and by insufficient Internet connectivity, and ongoing data reporting does not meet their instructional goals. Nevertheless, GLOBE is an instrumental part of this program that strives to make science relevant and accessible for the students and preservice teachers in Toppenish.

Commonalties of Inquiry Practice across Sites

As we visited classrooms and talked to teachers, it became evident that for many teachers who seek activities beyond those in the GLOBE Teacher's Guide, GLOBE is one of many resources they draw on to engage students in exploring their environment. Some teachers told us, for example, that they schedule field trips to a stream in which students collect water quality data using GLOBE protocols, conduct water quality activities from other environmental science curricula, and study the nearby ecosystems, ultimately submitting research projects that use some or all of those data sources. GLOBE is also seen by some teachers as a valuable part of larger environmental awareness programs or programs designed to promote personal or cultural relevance of science content, depending on the goals of the teacher and the other science resources that are available. It is therefore important to view GLOBE as one resource within teachers' broader environmental science education toolkits, a perspective that has implications for teachers' implementation choices and the challenges they may face in integrating GLOBE into their curriculum.

Students at the sites we visited are engaged in investigations of local environmental issues, whether the issue is pollution in local watersheds, establishing the locations of bikeways, or developing wider awareness of the cultural and scientific importance of water in a particular area. Investigations of local issues, moreover, appear to go hand in hand with keeping students motivated: GLOBE teachers who promote inquiry-based approaches in their classrooms report that these projects give students ownership over the data they collect, promote a deeper understanding of the science behind the data, and support new custodial relationships of students with their environment—all important goals of the GLOBE Program and critical elements of science education.

Another commonalty across sites was that teachers who are engaged in inquiry with GLOBE share a driving goal of getting students to think, believing that problem-solving skills will serve students best in the long run. Most of these teachers are equally passionate about the goal of connecting students to their environment, helping them to build a healthy awareness of and love for the natural world in which they live. Interviews consistently suggested that teachers believe strongly enough in these goals to spend personal time in developing successful activities, forging partnerships with local scientists, and doing the other activities that are required to make classroom inquiry work. These teachers also share a willingness to let the curriculum flow in emergent directions, following topics of particular interest to students that they believe might result in exciting new discoveries.

In communities where technology access is easy and data reporting is valued as a goal of GLOBE learning, teachers report that the frequency and accuracy of student reporting of GLOBE data *increased* with the use the data for student inquiry. When students engage directly with the data, teachers say, they build a much stronger awareness of the scientific process, the importance of accuracy, and the utility of the data they report for answering important scientific questions. As a result, they develop a much stronger sense of ownership and pride in the data they report and are more likely to strive for consistent and accurate data collection. Said Jill Calloway,

> *I think they realize the importance of being accurate, taking their time, and knowing that, hey, nobody can study this if the data wasn't good.*

Jill also said that GLOBE-related inquiry is improving her understanding of the importance of consistent data entry, and motivating her to find more creative ways to make GLOBE work. She planned to establish a partnership with staff at the local wildlife preserve that serves as their Hydrology site to continue data collection over the summer and make data reporting into a year-round activity.

In other cases, the work students are doing with GLOBE is not integrally tied to data reporting: students at Toppenish High School use GLOBE protocols without reporting data at all. But in cases where data are not reported, the reason tends to be either logistical challenges that prevent reporting (a consistent challenge documented in survey data, as well) or the lack of fit with the teacher's academic goals. Inquiry, then, does not necessarily make students and teachers less likely to focus on data reporting; rather, it may provide opportunities for students and teachers who otherwise would not participate in GLOBE to engage productively with the Program.

Overall, the examples above and those from other teachers we have visited and interviewed demonstrate that student inquiry and other locally relevant classroom activities help students find personal connections to GLOBE data they collect. These data become more meaningful when both students and teachers understand the scientific significance of measurements, their relevance to the local environment, and the importance of data collection, reporting, and analysis to the scientific process. Teachers agree that these approaches deepen students' understanding of the science behind GLOBE and promote their abilities to conduct and discuss scientific research. Inquiry-based approaches on personally meaningful topics can also prompt students to feel more strongly connected to the environment and to be curious about the world around them.

Although GLOBE can be a catalyst for these sorts of outcomes, the teachers we talked to also agreed that there are a number of practical challenges to using these types of instructional approaches in the classroom. The following section explores these challenges.

Challenges to Student Inquiry with GLOBE

Our experience in soliciting teachers for our case studies indicated that classroom implementation of GLOBE student inquiry is still in an early stage: very positive examples exist, but the practice is not yet widespread. We talked to many teachers who had hoped to conduct inquiry with GLOBE but had not succeeded in fitting it into their curriculum. Other teachers we interviewed were enthusiastic about inquiry approaches but used these primarily with non-GLOBE resources. The challenges they described follow.

Time Required to Plan Student Research and Inquiry

The teachers we interviewed who were facilitating classroom inquiry had invested a great deal of personal time in developing and guiding extended student projects. When teachers use GLOBE for data collection and reporting, they have access to detailed, step-by-step instructions for conducting protocols; this is also a major focus of GLOBE training. By contrast, although some of the projects teachers conducted were based on or inspired by GLOBE learning activities and resources, most of their projects were adapted significantly to the local students and environment or developed entirely by the teacher. Currently, the use of GLOBE in inquiry-based activities tends to be highly dependent on individuals—the initiative of highly motivated and skilled teachers—and supportive situations, such as standards that map well to GLOBE topics or the curricular freedom to try out new approaches in the classroom.

Teachers also reported the challenge of finding consistent data from other schools to offer useful comparisons. One teacher said he stopped giving students GLOBE inquiry assignments for that reason: his students would spend a great deal of class time simply in searching the database for a school with enough data to answer their research question. Another teacher said she spent evening time finding appropriate comparison schools in the database so that students could focus on their analysis. Teachers also cited lack of resources as a challenge, either the money to buy and maintain GLOBE equipment or enough computers in the classroom to allow student online research.

Students' Experience in "Doing Science"

In traditional educational environments, students gain minimal experience formulating questions and designing research to answer them. School science rarely prepares students to either understand or be able to engage in real scientific activities, even at a level that would be developmentally appropriate. It often takes a lot of encouragement to get students to ask questions and phrase them in ways that are appropriate to scientific investigation, or to learn to work productively in teams as they conduct their research. Some teachers find it necessary to design simple activities in scientific questioning before diving into more complex GLOBE data. For example, students in an elementary school class observed the class's guinea pig and chose to design an experiment to answer the question "Do guinea pigs prefer oranges or lettuce?" Again, teachers suggested that the provision of models for these sorts of activities in the GLOBE Program would be useful.

Teachers' Experience in Facilitating Student Investigations

A common theme for all the teachers we interviewed was their own learning curve, a trajectory that typically began in GLOBE with standard use of protocols and evolved to exploration of more inquiry-based strategies as they saw the potential for students to take their GLOBE work to a greater depth. Some teachers spoke of the personal risks they faced as they took their instructional strategies from teacher-centered to learner-centered, giving up some control to students and in some cases conducting projects in which the teacher didn't know "the answer." A teacher trainer we spoke with conducts classes that put teachers in the "inquirer's seat," inviting them to conduct their own inquiry, thereby building great enthusiasm for using inquiry approaches in their classrooms.

Poor Match with Standards, Curricular Goals, and Other Activities

Student inquiry implies extended exploration of a topic, which in turn places a stronger demand for integration with the broader curriculum and with other science curriculum packages that may be in use in classrooms (for example, FOSS or AIMS). Examples discussed above demonstrate that GLOBE is frequently one of many curricular resources that teachers draw on to explore a particular subject area, and it may contribute to a student project that encompasses many activities outside of GLOBE. Some teachers reported that GLOBE is generally complementary with other curricula and with required science topics. For example, other commonly used science curricula include water quality testing and weather investigations that can be augmented with GLOBE protocols. However, curriculum integration can be very time-consuming. One teacher described her curriculum mapping process as "an ever-changing thing: as I teach the things…I need to teach, I pull GLOBE in and I see what works and what doesn't." Some teachers said that they find it easier to use the related activities that are already in their more complete science curriculum packages than to try to incorporate GLOBE. Several teachers suggested that it would be helpful for GLOBE to provide a workshop or coaching on integrating GLOBE with local curriculum and standards, and opportunities to share ideas among teachers. Those teachers whose GLOBE partners have offered services like these were extremely positive about their value.

Discussion

The research described here implies that student inquiry and other locally relevant strategies for use of GLOBE have the potential to contribute to gains in student science understanding and environmental awareness, as well as to increase the consistency of GLOBE data collection and reporting. But all of the teachers in this study who were successful in facilitating student inquiry described a passion for active student learning that motivated them to devote personal time to planning locally relevant, student-centered classroom activities. One teacher, for example, described his overall teaching style as "hands-on, exploratory, multisensory, inquiry-based," which guided him to promote active application of GLOBE concepts in his classroom. Therefore, the use of GLOBE in student inquiry in the current context appears to be highly dependent on individuals—the initiative of highly motivated and skilled teachers—and supportive situations, such as standards that map well to GLOBE topics or the curricular freedom to try new approaches in the classroom. The final chapter of this report suggests some supports that can help make these approaches feasible for a broader range of GLOBE teachers.

8. Putting It All Together: What We Know about GLOBE

At the end of GLOBE's seventh school year of operation, we have learned a great deal about its implementation in schools and its effectiveness. SRI's evaluation research activities have gathered data over these 7 years to document how widely GLOBE is implemented in the United States and internationally. We have documented how GLOBE is being implemented and the challenges that teachers report they face in conducting learning activities, using GLOBE protocols to collect data, and reporting data. We have also examined the effectiveness of GLOBE through several assessments of student learning. These evaluation research activities have resulted in an accumulation of knowledge and questions that can inform and have informed both GLOBE staff and evaluation researchers at SRI.

As the Program has evolved, SRI's evaluation research activities have changed in response to GLOBE's emphases and concerns. In spring 2002, GLOBE Program staff formulated a set of key research questions that they hoped would guide future evaluation efforts. We have organized the concluding chapter of this report around these questions, indicating the current breadth and depth of knowledge that informs our answers to them. We also present here answers to a question SRI researchers posed regarding a relatively new emphasis within the Program: encouraging student research and inquiry using GLOBE data.

We address the following questions in this chapter:

- What is the reach of GLOBE?
- Which aspects of GLOBE are teachers implementing?
- What is the impact of GLOBE on student achievement?
- What are the effects of different types of GLOBE implementation on achievement?
- What are the major barriers to data reporting?
- What influence do GLOBE partner training and support activities have on data reporting?
- How are teachers incorporating inquiry and student research into GLOBE?

In each section in this chapter, we present what is known currently, what we have discovered through 2001-02 evaluation activities, and the questions that remain to be investigated in future evaluation activities.

The Reach of GLOBE

There are different ways to measure how many classrooms GLOBE may have reached over the years, because GLOBE implementation can take so many different forms in classrooms. Teachers must attend training before officially becoming part of GLOBE, so we use the number of teachers trained as an indicator of the potential reach of GLOBE. The reach of GLOBE (i.e., the percentage of teachers trained who ever implement any part of GLOBE) is not known, but just over one-third of the more than 14,000 teachers trained in the Program have ever reported data. Data reporting provides a “lagging indicator” of the reach of GLOBE, because increases in GLOBE training and data collection activities will necessarily precede increases in the numbers of students in schools reporting GLOBE data. To estimate the reach of GLOBE, therefore, SRI conducted a teacher survey in 2002, designed to provide some indication of how many students may have been reached in the past year by GLOBE.

The Number of Students Reached by GLOBE

In the spring 2002 teacher survey, SRI asked teachers to identify how many students had been reached by GLOBE in the 2001-02 school year. By “reach,” we mean participation in any GLOBE activity, whether students have engaged in learning about protocols; collected, reported, or analyzed GLOBE data; or completed a learning activity. Although our survey was targeted to all GLOBE schools, regardless of whether students had reported any data, only the schools that had reported data since 1999 had a response rate that was sufficient (60%) to draw inferences about the reach of GLOBE.

Among the 3,130 schools that have reported data since 1999, we estimate that the reach of GLOBE is between 153,000 and 244,000 students in 2001-02, on the basis of our survey results. Each GLOBE school reaches, on average, from 49 to 78 students. The actual reach of GLOBE among all schools is likely to be as much as twice that figure; however, our low response rates from the other samples of schools prevent us from calculating a reliable estimate. Moreover, this figure gives us a 1-year total of numbers of students reached, rather than cumulative total.

Student Backgrounds and Classroom Settings

We also obtained demographic data for the first time on schools in the sample to learn more about the location of GLOBE schools and backgrounds of students. More than one-third (35%) of teachers who responded to the survey came from schools in rural areas, and another third came from schools in towns or suburban areas whose populations were under 50,000 people. About 16% of GLOBE teachers teach in schools located in large urban areas. Most GLOBE teachers who responded to the survey teach in schools that are predominantly white. Three-quarters teach in schools where fewer than 50% of students are from cultural groups that are underrepresented in science (e.g., African-Americans, Hispanics, Native Americans). One in eight teach GLOBE in a school that has more than 80% students of color.

We obtained good estimates of the wide variety of classroom settings in which GLOBE is implemented through surveys in previous years. Comparisons across surveys suggest that there has been a shift in recent years toward using GLOBE at the elementary level with students. In Year 5 (1999-2000), 44% of recently trained teachers implemented the Program at the elementary level, 30% implemented at the middle school or junior high level, and only 26% implemented it at the high school level. This figure contrasts with figures obtained from teacher survey data in Year 3, when approximately one-third of GLOBE teachers implemented the Program at each level: elementary (35%), middle school (36%), and high school (29%). International GLOBE teachers from the beginning have been much more likely to be working at higher grade levels: roughly half of these GLOBE classrooms are high school classrooms, and nearly all of the rest are middle school classrooms. Both at the elementary and the secondary levels, GLOBE activities were most often implemented in regular classes, but there is an increasing trend toward GLOBE implementation in pull-out programs, clubs, and lunch activities.

Growth in Data Reporting

Data reporting, the “lagging indicator” of the reach of GLOBE, grew steadily for the first 5 years of the Program and is now fairly stable. In the first year of the Program, the number of schools reporting per month ranged from a low of 170 in September 1995 to a high of 792 in May 1996. Over the past 3 years, the average number of schools reporting per month has ranged from 1,000 to 1,100. A reduction in the numbers of teachers trained each year and an increase in the data reporting attrition rate are possible explanations for the stabilization of data reporting rates at this level.

The decline in numbers of schools reporting in late spring and in the summer evident from the beginning of the Program has gotten steeper in recent years, however. In 2001-02, for example, 1,012 schools reported data in April but only 523 in June. This contrasts with data from the first year of the Program, which show a decline from 703 schools reporting data in April 1996 to 468 schools in June 1996. Explaining the change remains a puzzle, though we have some evidence from case study research to suggest that the increased emphasis on accountability tests in reading and mathematics in the lower grades may mean that fewer schools have time to focus on science activities during the months when testing is taking place.

Future Investigations of Program Growth

Despite our dissatisfaction with this year's low survey response rate among schools that have never reported data or have not reported since 1998, SRI researchers believe it would be unwise to devote resources to an accurate count among those schools. Such schools may indeed have valuable data, but the cost of collecting those data far outweighs the likely benefits. The low response rates we obtained were after two telephone follow-up calls to teachers, and already reflect a large investment of evaluation resources. We also oversampled these groups because we expected the response rate to be low. We recommend devoting our efforts to increasing the response rate among randomly selected schools that have reported some data in the past 3 years, to reduce the broad confidence interval we obtained through our sampling procedure.

We do recommend that evaluation activities focus on how successful teachers in schools with large proportions of students from groups that are underrepresented in science implement GLOBE. We plan in Year 8 to conduct a telephone survey of a random sample of teachers from such schools to learn more about successful strategies for improving learning outcomes for students of color. We expect that there may be particular challenges to data collection and reporting in some of these schools, and we hope to analyze these challenges in order to help GLOBE partners provide more effective follow-up to these schools.

SRI also plans to continue to monitor data reporting patterns, which remain the best year-to-year indicator of Program implementation available, despite their limitations. They provide a window into changes in the rate of Program growth and breadth of protocol implementation. In addition, they provide us with one way to measure the rate of persistence or retention in GLOBE, an important concern. Third, data reporting patterns can be linked to other data collected through surveys and student learning assessments, providing us with valuable information about the barriers to Program implementation and effectiveness.

Aspects of GLOBE That Teachers Are Implementing

Atmosphere has from the beginning of GLOBE been the most widely implemented investigation area, if data reporting is used as an indicator of how much teachers use the Atmosphere protocols and learning activities. The number of schools reporting Atmosphere data in any given month is more than four times the number of schools reporting Hydrology data and more than 10 times the number of schools reporting Soils data. Soils and Land Cover data, to be sure, are not expected to be collected on as regular a basis as Atmosphere data, but the total numbers of schools reporting any data in these investigation areas remains much lower than the numbers of schools reporting Atmosphere and Hydrology data.

As many GLOBE partners and Program staff are well aware, there is evidence that more teachers implement GLOBE than report data. Nearly all the teachers we have surveyed each year say that they are implementing GLOBE in their classrooms, regardless of whether they report data. A high percentage of teachers surveyed—estimated at just under a third (29%) in 2001-02—say that they have collected data that they did not report. These teachers report that they are collecting data and implementing learning activities with their students. On average, teachers report using two learning activities with students per year; previous years' data suggest that teachers from actively reporting schools do not differ from recently trained teachers (regardless of level of data reporting) in the likelihood that they are implementing GLOBE learning activities. It appears, moreover, that for the Soils and Land Cover Investigation Areas, teachers may be implementing learning activities and teaching protocols at a much higher rate than they report data.

Protocol implementation at individual schools varies widely. We discovered a trend in the 2002 teacher survey data that suggests protocol implementation may be broader at the high school level than at the elementary level and may be focused on different investigation areas. The average number of protocols implemented at the elementary level is five, and the most commonly implemented protocols are those in the Atmosphere Investigation Area. At the middle school level, teachers report implementing an average of eight different protocols; Hydrology replaces Atmosphere as the most frequently implemented investigation area. And at the high school level, protocol implementation is broadest, with teachers reporting implementing an average of 12 protocols across a range of investigation areas. The high school data should be treated with caution, since so few teachers who taught at this level answered this question on the survey.

Teachers' Goals for GLOBE and Beliefs about Its Effectiveness

An important question that arises from observed variation in implementation is, What influences teachers' choices regarding GLOBE implementation? We examined teachers' goals for GLOBE and beliefs about its effectiveness as one possible explanation. External factors that contribute to implementation are examined in subsequent sections of this chapter.

Early data collection efforts by SRI focused on understanding motivations behind teachers' choice to implement particular protocols. Although these data do not tell us why teachers implement GLOBE in the first place, or about the beliefs about GLOBE's effectiveness (if any) that distinguish implementers from non-implementers, they do help explain why some protocols are more widely implemented. Teachers have consistently picked ease of implementation as the top reason for choosing to implement one protocol over another. Protocols that are easy to implement, teachers reported, were those that required little time to prepare and did not require travel. Availability of equipment and materials was also a factor in ease of implementation. Teachers also reported that the fit within their curriculum and match to students' interests and capabilities were factors in deciding what protocols to implement.

Our case study data over the years has provided greater insight into why teachers implement GLOBE. Many teachers are drawn to GLOBE because they view the Program as complementary to their curricular goals or to special programs they have developed. We have observed GLOBE to thrive in environmental science magnet programs, for example, in Georgia and New York, where teachers see GLOBE as a particularly compelling way to engage students in doing real science. We have seen GLOBE implemented consistently among teachers who are interested more generally in finding hands-on ways to involve students in their science classrooms and who are using a wide range of programs like GLOBE with their students. The Program lives up to its ideal of being a curricular supplement in these settings, adding value to an already rich environmental science curriculum.

Our case study data have also pointed to some key distinctions among active GLOBE schools with respect to the views teachers hold about the importance of GLOBE. We have found that for many teachers, their primary emphasis with GLOBE is on having students practice doing science. These teachers want students to experience the inquiry process, either by observation or by participating in it directly. GLOBE data collection is an activity of scientists; collecting and, especially, reporting data are avenues for practicing the doing of science. But GLOBE is more than the practicing the doing of science for these students and their teachers, it is a way to *contribute* to science. When schools place importance on providing students the opportunity to contribute to science, the GLOBE Program realizes not only its science education goals but also its scientific goals.

The 2002 teacher survey included questions about reasons why trained GLOBE teachers do not implement or suspend implementation of GLOBE. With these questions, we aimed to understand which motivations or goals are particularly relevant to why teachers do or do not implement GLOBE. Changes in teaching assignments were a big barrier for teachers who had suspended implementation of GLOBE. Another key difference between teachers who were still implementing GLOBE and those who had suspended implementation was that non-implementers found it more difficult than implementers to complete GLOBE activities within the school schedule.

We examined teachers' beliefs about the effectiveness of GLOBE in meeting the different goals set by the GLOBE Program. We asked teachers in the Year 7 teacher survey to rate GLOBE's effectiveness in reaching each of its five Programwide goals. GLOBE teachers, on average, believe that the greatest impact is on students' awareness of their environment. They also believe strongly that the Program improves the likelihood that students will pursue a career in science and helps students to achieve at higher levels in science. Interestingly, however, they gave the lowest ranking to GLOBE's effectiveness in meeting its goal of contributing data for scientists' use.

We found that teachers' beliefs about GLOBE's effectiveness have shaped their implementation of GLOBE. Teachers who believe that the GLOBE Program improves students' science skills and knowledge of specific environmental science content tended to implement GLOBE protocols more frequently. We also found that teachers who believe GLOBE improves students' knowledge of specific environmental science areas tended to implement GLOBE learning activities more frequently.

Future Investigations of Program Implementation

GLOBE Program staff, United States partners, and teachers have been concerned for some time with developing an index of program implementation other than data reporting. And although SRI has sought alternative indicators as well, the GLOBE Data Archive remains a reliable—and consequential—index available for our analyses. In the coming year, SRI will develop a framework for examining GLOBE implementation in the context of studying effective partnerships (discussed in greater detail below). That framework will outline dimensions (such as use of learning activities and data collection activities) that previous research has found to be ones along which GLOBE schools differ. As part of that framework, SRI researchers will develop a rubric for characterizing implementation along the dimensions of the framework. We will share the framework with GLOBE and United States partners, make revisions based on the feedback we receive, and use the framework to guide the development of surveys and assessment instruments.

A key focus of case study research in the next 3 years will be to articulate the influence of teachers' goals for GLOBE on their implementation of the Program. We will use interview techniques we have developed elsewhere (Shear & Penuel, 2002) to elicit

GLOBE educators' goals for their students and ideas about the key implementation components that will help realize those goals. We plan to use findings from these interviews to guide teacher and partner survey development for Year 9.

The Effects of GLOBE on Student Achievement in Science

The primary aim of GLOBE for education is to improve students' science and mathematics achievement. Each year, SRI's evaluation activities have examined some aspect of GLOBE's effects on students' learning in science. In our investigations, we have relied on assessments of our own design, rather than on standardized measures of science achievement. Many of our assessment items look like standardized test items, but they are focused on concepts that are actually taught as part of GLOBE. Our aim in using our own measures has been to provide evidence from research studies using *instructionally sensitive* assessments, that is, tests that would be able to pick up changes in student learning brought about by participation in GLOBE.

Our studies have relied on comparison groups, but they have not involved randomly assigned groups. We have typically used comparison groups of students and teachers similar to active GLOBE schools: comparison groups have been drawn in each of our studies from teachers who have signed up for, but not yet received, GLOBE training. Using such a comparison group helps ensure that there is not a selection bias—that is, that teachers who are part of the GLOBE sample are similar to those in the comparison group, and differences in student learning outcomes can be attributed to GLOBE rather than teacher differences.

Some methodologists promote the random-assignment experiment as the only sure way to evaluate program impacts. We do not believe this design is feasible in the case of GLOBE because it is a program to which teachers "opt in." Moreover, teachers' implementation of GLOBE varies widely from year to year, so it is difficult to identify teachers at the beginning of the school year who will implement GLOBE at a significant enough level to detect program effects. Cook and Payne (2002) has argued that such variation in implementation is accounted for in random-assignment studies; outcome studies are necessarily judgments of how "implementable" a program is. The GLOBE office and partners readily admit that the Program could be made better by becoming more easily implemented by teachers and are working toward that goal. We have therefore focused our efforts on understanding GLOBE's impact on classrooms where teachers have been successful, rather than spending valuable evaluation resources on a study whose outcome would yield little benefit to the Program.

GLOBE's Effects on Conceptual Development in Environmental Science

In Years 2, 6, and 7, SRI's student assessments gathered information on students' conceptual development in science. These items were multiple-choice and short-answer items that are similar to many standardized tests in science in their emphasis on recall of important concepts and testing students' basic knowledge of a domain. They are valuable for examining the conceptual understanding students may develop through their participation in GLOBE.

GLOBE's impact on students' conceptual development has been primarily in the area of fostering students' knowledge of data collection procedures in science and understanding of possible sources of error and variation in measurement of environmental phenomena. In the Year 2 study, for example, items that discriminated between GLOBE and non-GLOBE students were ones related closely to GLOBE data collection protocols. GLOBE students were more likely to recognize when variation among a group of students recording temperature was too great to trust an average reading and to be able to use GLOBE-like tools to measure canopy cover.

In Year 6, we compared the scores of actively reporting GLOBE students' conceptual knowledge across investigation areas with scores from students in non-GLOBE classrooms. Overall, GLOBE students' conceptual understanding scores were higher than comparison students'. The items on the scale where there were significant differences related to the concept of pH and identifying an appropriate sampling method for water chemistry to test a hypothesis about the influence of farming activities on water quality. This finding is not surprising, since we chose as our GLOBE sample for this study actively reporting Hydrology schools, and pH and water chemistry concepts are covered as part of this investigation area.

The Year 7 student learning assessment focused on students' conceptual understanding of core concepts in the Atmosphere Investigation Area. This test included items related both to basic concepts, such as the difference between weather and climate, and to procedural knowledge, such as knowledge of what kinds of factors can influence temperature readings at a weather station. In this study, GLOBE students who were actively engaged in data analysis with GLOBE tended to score higher. These results are discussed in greater detail in the next section, "The Effects of Different Kinds of Implementation on Student Achievement."

GLOBE's Effects on Environmental Awareness

GLOBE has always sought to improve students' environmental awareness. For purposes of our evaluation of students' environmental awareness, we defined the construct as a scientifically informed perception and recognition of the environment as a coherent set of interdependent and interconnected adaptive elements. SRI investigated as part of its evaluation activities in Years 4 and 5 the hypothesis that collecting data with GLOBE protocols, especially within the investigation areas we assessed, and reporting results to the GLOBE database can be expected to contribute to a greater awareness of the Earth as a system of interconnected elements and cycles. Students in GLOBE, we reasoned, observe firsthand variations in temperature and rainfall, for example, as the seasons progress, and they may begin to see patterns of relationships between these two atmospheric phenomena (e.g., it often cools off after a heavy rainfall).

We found that over the 2 years we measured students' environmental awareness, GLOBE students outperformed their counterparts in comparison classrooms. We analyzed student interviews for instances of "environmental" inferences, that is, statements that included any interpretive reference about the environmental scene (e.g., "those trees must be evergreen"). All of the students' utterances were divided into idea statements. Each idea statement was coded as a simple description, low-level inference, or higher-level environmental inference. In the student assessments administered in Years 5 and 6, we found students from high-reporting schools in GLOBE were more likely to make higher-level inferences than students from schools with low levels of data reporting.

We also found in these studies that GLOBE students were more likely to make reference to "big ideas" in science—such as cycles and interdependencies of systems—than were comparison students. We discovered in Year 5 that they made these without prompting, moreover, to a greater extent than did comparison students. A simple prompt to describe how the water cycle shaped the environmental scene students were shown, moreover, nearly doubled the specific aspects of the water cycle that were cited by GLOBE students.

Problem Solving with GLOBE-like Data

Most of today's assessments of student learning that intend to measure higher-order thinking skills use what have been called ill-structured problems (Wiggins, 1998). That is, they engage students in tasks they might be expected to perform in the broader world, tasks that have both scientific and social constraints. Often, these new assessments involve an external audience for student work, whether in the form of a public presentation or an imagined audience for the text, artistic creation, or performance they are asked to complete.

We have developed two different sets of tests of student problem-solving skills. The first test, called the Olympic Task, is described in Coleman and Penuel (2000). Students were required to use sets of GLOBE-like data and specified parameters to decide (and justify their decision about) where to host the next Winter Olympic Games. This task was administered to students in Years 4 and 5. A second set of tasks was designed to test students' inquiry skills with GLOBE-like data. These tasks were based on national standards (NRC, 2000) and SRI's assessment framework for GLOBE. They were administered in Years 6 and 7.

In the Olympic Task, students from higher-reporting GLOBE schools outperformed students from low-reporting and non-GLOBE schools. In this task, the ability to develop coherent arguments to justify their choice of host city was more evident among GLOBE students. GLOBE students in both years were able to marshal more and better evidence to support their decisions.

On the inquiry tests, we found that students did not generally score as well as they did on tests of conceptual understanding. Students had difficulty planning investigations and using data to solve an extended problem in the Atmosphere Investigation Area. Moreover, the effects of data reporting per se were mixed, a topic that is discussed in greater detail in the next section, "The Effects of Different Kinds of Implementation on Student Achievement."

Attitudes toward Science and Careers in Science

SRI's evaluation findings have been mixed with respect to the Program's influence on student attitudes and career choices. Results from Year 2 suggested that GLOBE students had a more accurate conception of scientists' activities than did non-GLOBE students. However, when these same items were administered in Year 6, SRI found no significant differences between GLOBE and non-GLOBE students with respect to their conceptions or understandings of science. In the Year 7 study of student learning, no aspects of GLOBE implementation predicted students' attitudes toward science or their intention to pursue a career in science. Attitudes such as these may be quite persistent; moreover, there may be a lag between GLOBE participation and an influence on students' attitudes, making it difficult to accurately measure GLOBE's effects.

Future Investigations of Student Achievement

SRI will continue to investigate the Program's effect on student achievement. In the next large administration (in Year 9) of a student learning assessment, SRI will investigate students' mathematics skill to a greater extent than has been done in the past. We will focus on students' skill in using, interpreting, and creating graphs, tables, and other visualizations of data to solve problems with GLOBE or GLOBE-like data. We hope that this study will help us better understand the effect of GLOBE on student achievement.

We will also use items we have developed in the past to test the hypothesis that GLOBE has an impact on student achievement in science. To do so effectively, we will need to collect data on student achievement prior to GLOBE participation. Using the GLOBE Data Archive, we can identify schools that vary widely in the level at which they implement GLOBE.

We will use what is called a "proxy-pretest design" to measure program impact. This design is a quasi-experimental design that is appropriate when evaluators can only test outcomes once a program has already begun. A "proxy" measure is used—such as students' science and mathematics grades the year before GLOBE implementation—as a pretest measure. Although it is ideal to have equivalent measures, such information can be used to improve the validity of inferences about program impact when gathering pretest data is not feasible.

The Effects of Different Kinds of Implementation on Student Achievement

Until Year 7, SRI had limited data on the effects of different implementation patterns on student learning. We could speculate, on the basis of survey data collected, that actively reporting schools were more successful in reaching students, because teachers from these schools cited higher levels of student achievement as a result of GLOBE than did recently trained teachers. We also knew that data reporting levels were associated with higher scores on our environmental awareness task, the Olympic Task, and our test of student inquiry skills in science. But we knew little, for example, about the differential effects of data collection, data reporting, and data analysis on student achievement in science.

Results of the Year 7 assessment activities, however, have added significantly to our understanding of which aspects of GLOBE implementation contribute to student learning. We now have evidence that data analysis activities are among the most significant contributors to student learning. These data analysis activities, moreover, appear to influence both conceptual learning and students' skill in conducting inquiry. We also have evidence that teachers' goals not only shape implementation, as discussed above, they influence student outcomes. This finding is consistent with research on the relationship between teacher expectations of student learning and actual learning outcomes, but it also suggests that teachers' goals for GLOBE are an important target of intervention for GLOBE partners.

The small number of unique classrooms from which we collected data, however, limits the inferences we can draw from our Year 7 study. Although we tested hundreds of students, these came from a limited sample of 15 randomly selected classrooms. We hope in Year 9 to draw from many more classrooms, to ensure wider variation in type of implementation, and to investigate the influence of other aspects of GLOBE implementation, such as the use of learning activities, in that study. We know that more data are needed to elaborate on the significance of data reporting for student learning outcomes, particularly because the findings in the 2001-02 study seem to contradict findings in earlier SRI studies.

Major Barriers to Data Reporting

GLOBE's philosophy has always been one of providing resources and leaving decisions concerning curriculum and pedagogy to teachers. At the same time, because the premise of GLOBE is that students and teachers can collect scientifically useful data, GLOBE scientists are concerned with schools' persistent and reliable reporting of the collected data. The GLOBE Data Archive provides a record of every data submission going back to the Program's beginning in 1995, and in our evaluation research we have used the archive in concert with teacher surveys to identify the major barriers to data reporting for teachers.

Two patterns from the GLOBE Data Archive are of particular importance. First, fewer than half of the teachers trained in GLOBE have reported data to the GLOBE Data Archive. Many teachers attend the full training session and may even receive posttraining supports from a GLOBE partner, but their students never report GLOBE data. Second, a number of schools stop reporting data after having been active data-reporting schools. Some stop reporting after 1 active year, others after 2 to 3 years. Explaining both these patterns is important to ensuring that GLOBE makes the most out of the training dollars partners spend and to facilitating higher levels of data reporting among GLOBE schools.

Teachers point to a variety of reasons for not reporting data. The two reasons most often cited on a teacher survey administered in Year 5 were difficulty finding time to submit the data (65% of trained teachers) and lack of confidence in students' measurements (64% of trained teachers). Technical problems were also cited as barriers to data reporting by a majority of teachers: 57% said that problems with their Internet connections prevented their school from reporting data. Computer problems were also cited in Year 7 by teachers: two factors that distinguished GLOBE implementers and non-implementers were availability of technical support and access to adequate technology to implement the Program.

Many of these same barriers proved significant when we examined their impact on the data-reporting levels of schools. Finding time to implement GLOBE, integrating it with the curriculum, and having a good Internet connection were all significantly associated with the number of months schools reported data. And although few teachers cited it as a reason they did not report data in Year 6, teachers' belief that the value of

GLOBE lay in taking, but not reporting data, was associated with lower levels of data reporting.

Teacher mobility helps explain much of the pattern of attrition from the GLOBE Program. In our teacher surveys, we discovered that almost one-third of teachers in our sample had left the school where they had been first trained in GLOBE. In schools with just one GLOBE teacher, when that teacher leaves, data reporting is likely to cease. Teachers also are reassigned within their school, sometimes causing them to suspend GLOBE implementation. A large minority of teachers told us that they could no longer teach GLOBE in their new assignment, either because it was no longer aligned with their curriculum or because they no longer had time to implement it.

SRI will continue to use surveys and interviews with teachers to investigate barriers to data reporting. We will ask teachers about barriers to data reporting in the large-scale teacher survey in Year 9 and ask GLOBE partners to share their knowledge about barriers to data reporting. We will interview teachers through our case study research to elicit descriptions of precisely how lack of time and technical support may work against data reporting in GLOBE schools.

The Influence of Partner Training and Support Activities on Data Reporting

SRI's evaluation research related to training and support activities has been focused on partners in the United States. We have relied on teachers' self-report for data focused on the quality of training, and we have supplemented self-report data with analysis of student data-reporting patterns to examine more carefully the effectiveness of posttraining supports provided by partners.

Training Effectiveness

Teachers are generally positive about their experience of training, according to teacher surveys conducted by SRI researchers. Nearly all GLOBE teachers report that training has influenced their teaching in some way, for example. Teachers say they have given more emphasis to observation and measurement in science classes and led more hands-on activities with students as a result of their GLOBE training experience. Active GLOBE teachers say that as a result of their training, they use GLOBE-related explanations and examples in their teaching and have introduced new curriculum topics based on GLOBE.

Our teacher survey in Year 7, discussed in Chapter 5, asked teachers to rate their satisfaction with different elements of GLOBE training. Of particular importance was the finding that teachers who gave higher satisfaction ratings to the preparation they got in implementing protocols were more likely to say they regularly reported GLOBE data. These teachers were also more frequent users of GLOBEMail. Teachers who reported higher levels of satisfaction with training in learning activities were more likely to say that they took protocol measurements with their students. It may be, in this case, that learning the *why* of data collection through learning activities is a significant support to encourage actual data collection.

Posttraining Supports

Many GLOBE partners offer additional resources to teachers following 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.

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. The results of this analysis were presented in the Year 6 Evaluation Report. Partners are most likely to provide ways to communicate with teachers after training, such as listservs or newsletters. Teachers are less likely to access more time-intensive, site-based mentoring or supplementary materials, and only 15% of teachers access , being available to 70% of respondents. Least often used by teachers are incentives, which were available to 15% of respondents.

Of the posttraining supports available, mentoring, materials, and incentives appear to have a significant impact on data reporting. Of the respondents for whom mentoring support was available, fewer than a quarter (22%) were nonreporters, and almost half (46%) were schools that reported data at least 7 months out of the year ("steady reporters"). Similarly, of those for whom supplementary materials were available, 30% were nonreporters, compared with 43% who were steady reporters. When incentives were available, 10% of respondents still were nonreporters, whereas 23% were steady reporters.[14] Communication activities did not appear to have a significant relationship with steady reporting.

Future Investigations of the Effect of Training Supports on Implementation

In the next 3 years, SRI will focus its attention on understanding better the strategies that a small number of effective partners use to organize training and provide support to teachers after their introduction to GLOBE. We will seek to understand the goals that partners hold for teachers' implementation and how these goals shape the design of their training and organization of their support activities. We will also describe the range of services—including teacher recruitment, training, and posttraining supports—the partnerships offer to promote effective implementation of GLOBE. And in response to concerns raised by partners themselves about the sustainability of their issues, we will examine the human, social, and technical capacity issues that partners are attempting to address in the course of their work.

SRI researchers will also continue to relate these descriptive characteristics of training and posttraining supports to teacher implementation and outcomes. We will rely on case study, teacher survey, and student assessment data to develop an understanding of the significant associations among training topics covered, training quality, and availability of particular posttraining supports. As part of this research, we will share

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

results regularly with the partners we are visiting, so that they can make adjustments to their own work, as they choose, on the basis of evaluation data.

How Teachers Are Incorporating Inquiry and Student Research into GLOBE

GLOBE's emphasis on student research and inquiry is both a new thrust and a natural extension of its scientific mission. The Program has always supported students' collecting and analyzing data about the environment; moreover, it has always had at its core a design that emphasizes collaboration between students and scientists. But in recent years, as local and state standards have come to emphasize inquiry skills and as GLOBE has sought to broaden its impact on student learning in science, GLOBE educators and staff have paid increasing attention to student research and inquiry.

In the past year, SRI has focused its evaluation efforts on developing a clearer picture of what student research and inquiry looks like in GLOBE classrooms, when it occurs. The task proved difficult, since few GLOBE schools engage young people in the full range of inquiry experiences outlined in the National Science Education Standards (see NRC, 2000). A small number do report that they engage their students in some analysis of GLOBE data, but few teachers have students generate research questions, formulate hypotheses, plan investigations, or communicate results to others as part of their GLOBE implementation.

Teachers told us many reasons why they have difficulty incorporating student research and inquiry into GLOBE. Planning for a student investigation requires much more time than implementing a protocol, teachers told us. There are too few ready-to-hand curricular materials to help them work with students to plan their own investigations, so they must spend time preparing their own materials and sequences of activities. Also, students and teachers alike hold views of science—and science education—that are often at odds with an inquiry approach. They may believe, for example, that at the heart of science learning is helping students develop an understanding of a core set of unchanging concepts, rather than helping them develop skills to carry out a scientific investigation of a phenomenon. Such ideas are not in and of themselves contradictory, but with limited time for science instruction, many teachers may opt to approach the teaching of science's fundamental concepts through direct instruction rather than inquiry.

Key to making student research and inquiry work are teachers with a particular set of approaches to getting students started on projects that can sustain students' interest. Teachers at schools we visited in Year 7 all engaged students in scientific investigations of local environmental issues, whether the issue was pollution in local watersheds, establishing the locations of bikeways, or developing wider awareness of the cultural and scientific importance of water in a particular area. Another commonalty across sites was that teachers who engaged in inquiry with GLOBE shared a driving goal of getting students to think, believing that problem-solving skills will serve students best in the long run. In communities where technology access was easy and data reporting was valued as a goal of GLOBE learning, teachers generally reported that the frequency and accuracy of student reporting of GLOBE data *increased* as they began to use the data for student inquiry. When their students engaged directly with the data, teachers said, they built a much stronger awareness of the scientific process, the importance of accuracy, and the utility of the data they reported for answering important scientific questions. As a result, they developed a much stronger sense of ownership and pride in the data they reported, and were more likely to make sure it was consistent and correct.

As the Program continues to evolve, and as successful examples of student research and inquiry raise the bar of what GLOBE teachers believe is possible, there will be a greater need for materials, training, and support for science inquiry. Fortunately, many resources and models for inquiry have been developed in the past 10 years. Many, moreover, have been studied by researchers and have evaluation data to back up claims of their effectiveness. GLOBE could look to such examples in its own journey to expand further its commitment to helping students do real science in a way that they find meaningful and relevant to their own lives and communities.

Recommendations to the Program

SRI's evaluation researchers each year have made data-based recommendations to the GLOBE Program on how the Program might be further refined and improved. In some cases, these recommendations have come directly from GLOBE teachers and were discovered through our case study or survey research. In other cases, we have derived recommendations from significant findings with respect to implementation patterns and student outcomes. This section does not attempt to provide a summary of all the recommendations SRI has made in the past; rather, here we outline recommendations from the Year 7 findings.

Present evaluation research findings about the effectiveness of GLOBE at trainings. Teachers' perceptions of GLOBE, in particular their beliefs about how effective it is, strongly shape the likelihood that teachers will implement GLOBE in their classrooms. This implementation, in turn, shapes students' outcomes. When teachers believe GLOBE is particularly effective in improving science achievement, they are more likely to implement GLOBE. Presenting teachers with a summary of key evaluation findings at each GLOBE training session, as part of their introduction to GLOBE, might shape their beliefs about the Program's efficacy and improve the chances they will implement GLOBE.

Increase time to practice data entry and analysis skills in all training, including Train-the-Trainer sessions. Teachers say that GLOBE training prepares them well to implement protocols and engage young people in data collection. Time to practice data entry and time to practice analyzing GLOBE data, however, are not cited by teachers as among the most helpful aspects of training. Teachers need opportunities to learn how to conduct both of these activities to prepare them adequately to have students report data to the GLOBE Data Archive and to engage more deeply with the data students collect.

Design ways to capture additional data on use of materials on the GLOBE Web site. The most reliable source of data that is available today on GLOBE implementation is the GLOBE Data Archive. Yet Program staff, partners, and teachers do not believe that data reporting is an adequate measure of GLOBE implementation. Other reliable sources of data are needed, and the GLOBE Web site could provide some additional information. A key source of data is page views; specifically, the number of unique addresses that "hit" a particular protocol or learning activity could be one source of additional information on program implementation. The number of unique "repeat" visitors to these pages is yet another source of data on implementation; it is even more likely that these repeat visitors are actually using what they are viewing in their classrooms. Although these are not perfect indicators of implementation themselves, these data would provide additional information to help approximate the reach of GLOBE.

Provide recognition and incentives for partnerships to develop mentoring and intensive follow-up programs to teachers. GLOBE partners today are responsible for supporting training and follow-up in their local areas. The GLOBE office, for its part, has continued to offer Train-the-Trainer workshops and to provide the Teacher's Guide to partners. One additional way the office could support and encourage "best practice" among partners would be to use some of its funding to provide incentives and recognition to partners who provide more intensive mentoring and follow-up to teachers. This support might come in the form of competitive mini-grants to partners to set up such programs, with the expectation that partners will show measurable improvements in the percentage of trained schools that report data in any given year. GLOBE could provide recognition to these partners on its Web site and provide new responsibilities (as it has through the Year 7 conference organizing committee) to successful partners who adopt effective support strategies for schools.

Develop additional curricular materials focused on different aspects of inquiry with GLOBE. Teachers who access supplementary materials provided by partners are more likely to report data at higher levels than those who don't access such materials. These materials now often consist of implementation tips that go beyond those provided in the Teacher's Guide. Teachers might benefit from additional materials focused on how to conduct inquiry with GLOBE. The CD developed already contains some activities teachers could use; the Web site includes a rubric for judging the quality of student research projects. Both resources could be highlighted in partner training and reviewed with GLOBE teachers. More resources are needed, as well, particularly ones focused on helping students generate good research questions, plan investigations, and develop presentations of results.

Encourage formalized partnerships between each active United States partner and at least one GLOBE scientist. An additional way to support more student research with GLOBE is to encourage partners to broker connections between schools and scientists. Scientists need schools in particular areas to assist with their research; schools benefit from contact with scientists, because it makes the scientific aspect of GLOBE visible for students. Partners are the logical entity within GLOBE to broker relationships between GLOBE scientists and schools. These relationships might be made formal, with partners working with scientists to help them identify issues that students could research in their local environment and to identify data sets that could support student research. Schools could agree to provide scientists with data using GLOBE or GLOBE-related protocols, to aid in scientists' investigations. Such partnerships could be a "win-win" situation for students and scientists, helping GLOBE to realize both its educational and scientific objectives more effectively.

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Appendices