THE ROLES OF REGIONAL PARTNERS IN SUPPORTING AN INTERNATIONAL INQUIRY SCIENCE PROGRAM

William R. Penuel

Linda Shear

Christine Korbak

SRI International

Elena Sparrow

University of Alaska-Fairbanks

The work has been supported by National Science Foundation grant #0223068. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

THE ROLES OF REGIONAL PARTNERS IN SUPPORTING AN INTERNATIONAL INQUIRY SCIENCE PROGRAM

This paper explores the roles that regional partners play in helping to support implementation within the GLOBE program, an international earth science and education program. Researchers at SRI International conducted case studies of these partners' practice, in order to learn more about what contributes to effective program implementation that is embedded within an inquiry teaching approach.

The Need for Change in Earth Science Education

Earth Science is becoming increasingly recognized as a core domain within science education. More and more students take Earth Science as part of their education, both at the elementary and secondary levels. Earth Science content is a separate strand within many states' standards today, and a small number of states require all high school students to take Earth Science. This growing recognition means that more students have opportunities to develop an understanding of how science contributes to our response to such critical issues as global climate change, threats to biodiversity, and risk and hazard management. Developing such understandings depends, however, on good Earth Science teaching and on curriculum, assessment, and pedagogical support for teaching.

Much of Earth Science education is open to the charge that it offers too little insight to students about how scientists go about their work of investigating Earth's systems. Reformers have therefore called for a "revolution" in Earth and space science education, to align teaching and learning practices more closely with NSES standards for teaching science through inquiry. A recent report from a national NSF-funded conference underscores the need for new instructional and assessment materials, policies, technology experiences, and professional development supports to bring this revolution about (Barstow & Geary, 2002). It calls on teachers to gain a deeper understanding of the Earth as a system, to learn how to apply earth science concepts to issues of local concern, to develop effective pedagogical strategies, and to use technologies appropriate to the field. The report also underscores the need for teacher professional development opportunities and policies that could support teachers being able to enact changes in their practice, to encourage more inquiry-oriented approaches to teaching Earth science.

Research suggests that teachers need much social and curriculum support, if they are to be able to enact inquiry-based practices in their science classrooms. Teachers need opportunities to practice inquiry in the context of their pre-service and in-service preparation (Carpenter et al., 2004; National Research Council, 2000). They need access to people who are familiar with inquiry and experienced in providing support to teachers (Carpenter et al., 2004). Teachers also need professional development with a strong subject matter focus (D. K. Cohen & Hill, 2001). This professional development should be experienced as part of a coherent strategy of science education reform (Garet, Porter, Desimone, Birman, & Yoon, 2001). Furthermore, teachers need sustained involvement over time in professional development related to inquiry-based teaching practice and the support of an “investigative classroom culture” (Supovitz & Turner, 2000).

To date, however, not much research has illuminated the particular problems faced by Earth Science educators in reforming their practice or the supports they need to accomplish reforms (cf., Feldman, Konold, & Coulter, 1999; Songer, Lee, & Kam, 2002). This omission is significant, because Earth Science content and methods are distinct from the other sciences: Earth Science is very much a modeling science, and too few textbooks treat the "inquiry process" in a way that accounts for the ways Earth Science knowledge actually develops. Furthermore, the need for teachers to be able to identify Earth Science problems of local significance around which students can conduct their own investigations places special demands on teachers and reform initiatives.

The kind of research that is needed is not just evaluative research into "what works" but also *implementation* research that focuses on aspects of how different reforms are implemented, the social and curricular supports provided teachers for implementation, and the challenges teachers face in implementing them than just on student outcomes (Confrey, Castro-Filho, & Wilhelm, 2000). Data on within-program variability in program implementation are of scientific importance to researchers, because the scale, depth, and fidelity of implementation can never be assumed ahead of time when designing an evaluation (Patton, 1979; Rossi & Freeman, 1989; Scheirer, 1994). In addition, such data can help identify competing hypotheses for observed impacts (Schiller, 2001) and possible flaws in the assumptions that underlie the program design (see Goodson, Layzer, St. Pierre, Bernstein, & Lopez, 2000). Implementation research can also critical insight as to what supports make a difference as to whether a program or reform gets implemented or not, and at what level (Penuel & Means, 2004).

Reform Intermediaries as Catalysts of Change and Implementation

Beginning in the late 1990s, implementation research has focused increasing attention on the role the intermediary organizations in the enactment of large-scale school reforms. Intermediary organizations are typically nonprofit companies, universities, or other entities that at not part of the K-12 school system, but have as part of their mission the improvement of that system. Such organizations may be critical to the reform process, many researchers have argued, because they can provide knowledge, skill, and resources necessary to scale up reform efforts (G. Cohen, 2000; Fullan, 2000; McDonald, McLaughlin, & Corcoran, 2000). As outsiders, they may be in a better position to pose challenging questions to entrenched interests within school systems that block significant reforms. Many reforms employ intermediaries to provide professional development, materials, and teacher support, including some in Earth Science education. A deeper understanding of how they work, and with what success, would therefore benefit the field as it seeks to create improvements in the quality of inquiry teaching.

Why Reform Intermediaries May Be Necessary

Reliance on intermediary individuals and organizations may not only be desired, it may be necessary if the goal of a reform is to reach many classrooms. Very few reform leaders have the resources to bring a program to scale on their own; scaling quickly becomes too expensive to undertake and stretches the resources of reform groups too thin. Furthermore, to the extent that the program seeks to reach diverse classroom contexts, it will be difficult for a program that is national or international in scope to know and meet the challenges teachers will face in those contexts.

Getting an educational reform to scale is itself a difficult undertaking; many successful educational reforms come to rely on a network of affiliates or intermediaries to help support scaling (Elmore, 1996). Organizations that design and test new reforms may not have the skills necessary within their organization to shift from sheltered implementation in a few classrooms to support broad-scale adoption. Even if these organizations do have the skills, they are rarely large enough to support implementation beyond a limited local geographical area. The costs to support a national or international program would quickly exceed the typical resources allocated to educational programs. As with the adoption of new technologies in business, scale up inevitably comes to depend on people and organizations outside the direct purview of the reform designers (Moore, 2002).

For their part, teachers may need people from intermediary organizations to help them adapt new curricular materials to their own classroom situations. Despite scores of studies that point to evidence to the contrary, the idea that new programs and scripted teacher curricula can be made “teacher-proof” has been a persistent belief of some policymakers in science education (Atkin & Black, 2003). In fact, teachers will always need to analyze how a new curriculum reform fits into their setting, and they will need to adapt the reform to meet the particular demands of their classrooms, school, district, and state. The kind of support needed for “localization” must come from people who have a good understanding of the particular settings where teachers are expected to implement a reform; those people need to have relationships with both the designers of a reform and with teachers enacting it (Carpenter et al., 2004).

Neither these claims about the need for intermediaries nor claims about their functions have been systematically investigated in science education. Even in studies of whole-school reform, where the work of intermediaries has been closely studied, there remains little research on the capacity needed for such organizations to succeed or on which strategies they employ that are successful (Nuefeld & Guiney, 2000). The current study investigates some preliminary hypotheses about the roles that reform intermediaries can play in an international Earth Science education program, in the hope that it might form the basis for a line of implementation research to help us better understand how to support reform in the field.

Studying the GLOBE Program and Its Reform Intermediaries

GLOBE is an international environmental science and science education program focused on improving student understanding of science by involving young people in the collection of data for real scientific investigations. The program is organized into several “Investigation Areas,” each focused on a particular topic in environmental science and headed up by a GLOBE scientist who has been selected through a competitive, peer-reviewed proposal process. Each scientist has developed a set of data collection protocols for his or her investigation area that K-12 students are expected to follow in measuring characteristics of their local atmosphere, bodies of water, soil, and land cover. In addition, GLOBE scientists have collaborated to produce scientific and educational materials designed to promote understanding of the Earth as a system through the program.

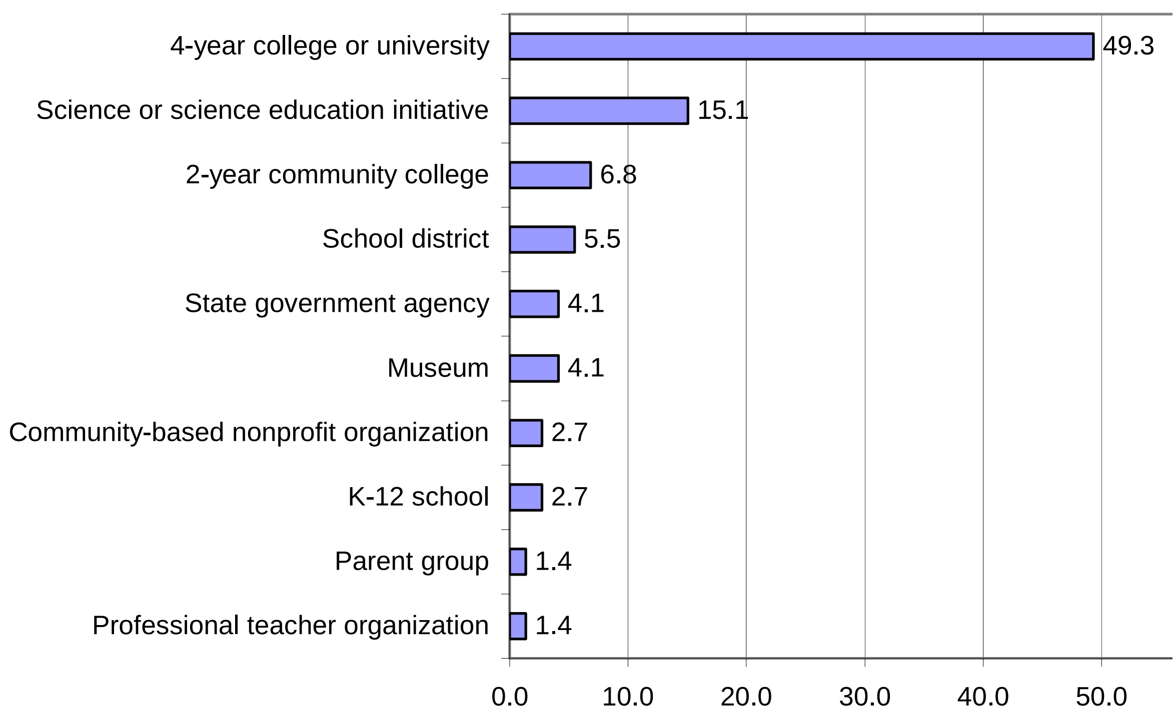
GLOBE has always had as a sub-goal broad-scale adoption by teachers. Since its inception in 1995, GLOBE has scaled significantly. There are now 104 countries that are part of GLOBE, and more than 20,000 teachers from 14,000 schools have been trained in the scientific protocols that are the heart of the program. According to a recent teacher survey, it is estimated that the reach of GLOBE is between 153,000 and 244,000 students among schools that have reported data to the GLOBE Web site in the past three years (Penuel, Korbak, Lewis, Shear, Toyama, & Yarnall, 2002).

The program has faced significant challenges as it has scaled up. For example, by 1999, the program could no longer manage the training and support of teachers directly from its Washington, D.C. Headquarters. Staff felt that teachers needed more readily available support for implementation, so they instituted a program to engage regional GLOBE *partners*. These partners would be charged with the task of recruiting, training, and supporting new GLOBE teachers in the program.

Since that time, both partners' and the GLOBE Headquarters' attention has been focused on another challenge, program implementation at the school level. Despite the large numbers of trained GLOBE teachers, only about 1,000 schools report data to the GLOBE Web site each month, suggesting that only a small fraction of teachers trained are actively implementing the program (Penuel et al., 2004). In addition, despite the program's emphasis on students' conducting their own investigations and research using their school's GLOBE data, very few students have this opportunity (Penuel, Korbak, Lewis, Shear, Toyama, & Yarnall, 2002).

The partners and staff at Headquarters acknowledge that the partners have the primary responsibility for implementing strategies to improve these results, because the partners function as intermediaries between GLOBE and teachers. It is partner staff who communicate with GLOBE Headquarters about their challenges, needs, and successes and who also prepare teachers to implement GLOBE. The partners also function as do reform intermediaries in other contexts in that they tend to be organizations that are outside the K-12 system that have as their aim or mission the improvement of science education in schools. In fact, partners cite their involvement in helping improve science teaching and learning more frequently as a benefit to their own participation in GLOBE than they cite their role in helping the program to scale (Penuel et al., 2004). As Figure 1 shows, just under half are housed within universities; most of the partners in these settings, moreover, are within colleges of education charged with teacher preparation.

Figure 1
Partner Organization Type, Percent Reporting from Partner Survey



GLOBE's partners face a significant challenge that other intermediaries face—they must find their own funding for their activities. The GLOBE Headquarters has funded a small staff who function as "partner support" but has never provided funding directly to partners for their activities. Partners fund their activities through a variety of sources, including federal grants, foundation grants, state and local education agencies, and from sources within their own institutions (Means et al., 1999; Penuel et al., 2004).

Despite being from different regions, GLOBE's partners in the United States at least share similar views of the chief obstacles facing them in their work of supporting GLOBE implementation. More than 72% of partners surveyed in 2003 said that a major challenge to their work was teachers' beliefs that implementing the program conflicted with pressures to teach to state standards and perform well on accountability tests. In addition, more than two-thirds suggested that more resources were needed to follow-up with after an initial training session in the GLOBE protocols, to help teachers overcome obstacles to implementation (Penuel et al., 2004)

As part of its evaluation of GLOBE, researchers at SRI International's Center for Technology in Learning decided to undertake a set of case studies to help explain differences in the accomplishments of different kinds of GLOBE partners. Our case studies are informed by research we have conducted on a large sample of teachers to identify the post-training support strategies that are associated with higher levels of data reporting (Penuel & Means, 2004). In addition, they are informed by alternative explanations that have been articulated by different parts of the GLOBE organization (including partners) as to what partners should do to try and address the problems of implementation. This paper describes the design, findings, and implications of our case study research.

Design of the Case Studies

Key Research Questions

In our case study research, we sough to address the following research questions that the GLOBE Headquarters had about the work that partners do:

> *What partner strategies are effective in supporting teachers' implementation of GLOBE?*
> *What partner strategies are effective in supporting student research and inquiry?*
> *What are partners' challenges in supporting GLOBE schools, and how do they seek to overcome those challenges?*

A key goal in conducting these case studies was to replicate and extend through multiple-case studies selected findings from an earlier study about the importance of particular implementation support strategies carried out by partners. In this study, we found that some strategies—particularly mentoring, equipment support, and supplementary materials—were all associated with higher levels of data reporting in GLOBE (Penuel & Means, 2004). Through our case studies, we hoped to learn more about the nature and quality of the support provided to teachers and how they perceived them as helping them to implement GLOBE.

It is important to note that our purpose in selecting a case study approach was not to assess the prevalence of either particular strategies among GLOBE partners or the availability of supports to individual schools within the partnership. Rather, our goal was to test several hypotheses about partnerships' obstacles and successes. Through testing these hypotheses, we sought to advance understanding about the potential roles of reform intermediaries in an Earth Science education program. These studies would need to be further replicated for other programs, to test how robust they are when applied to different program designs in different school contexts.

Overall Study Design

We chose an explanatory multiple-case embedded design for this study (seeYin, 2003). The purpose was to test rival hypotheses or explanations about the success of particular strategies of teacher support employed by partners and about the capacity needed within partnerships. The primary unit of analysis is the partnership, with its own particular mission, structure, staffing pattern, and organizational context; selected teachers were examined as embedded units of analysis as “belonging to” the partner.

There are two partner cases that form the basis for the analyses conducted as part of this paper. Those two cases were selected, as indicated below, because both were active and were visible both to teachers and to GLOBE as significant intermediary organizations. However, they are in quite different geographical areas, serve different kinds of schools, and have different structures. As we describe below, it is the similarities of the two cases but differences in individual teachers’ involvement with partner activities that were critical in selecting case study sites.

Each of the case studies is treated here as if it is a “whole” study, in which evidence is analyzed with respect to the hypotheses of the study. In this respect, our view of case study research is consistent with Yin’s (2003), in that we view each case’s conclusions as needing to be replicated by evidence from other individual cases. These particular findings call not only for further replication within GLOBE, but they also call for replication within other kinds of Earth Science programs with different designs and built-in teacher supports.

Hypotheses Guiding the Study

In multiple-case study designs, it is important to explore in particular *rival hypotheses* that explain the phenomenon being studied (Yin, 2003). Researchers need to gather and analyze evidence that support particular propositions and that support alternate propositions or explanations for patterns in the data. By gathering data on alternate or rival hypotheses, researchers can reduce the risk that their initial theories will be the only ones that get serious consideration as part of the case studies.

Our own hypotheses and their rivals are drawn from the literature cited above and from our earlier studies of partners in GLOBE. We list and elaborate on each below, and use each to guide the case study descriptions that are included in the paper:

Hypothesis 1: *The awareness that students are contributing to the work of scientists helps motivate teacher and student participation in GLOBE as much as locally-defined answers to "why GLOBE".*

Rival: *A locally-defined answer to the question "why GLOBE" drives teachers' decisions to implement GLOBE.*

The GLOBE program has always believed that the appeal of GLOBE to students and teachers is in the opportunity to contribute to real science. The fact that students contribute data that scientists use in their own investigations is believed to be what makes the program unique. Yet research suggests teachers may adopt reforms for reasons that are different from the ones designers intended; reform intermediaries may play a strong role in "translating" goals to teachers and helping them see connections between their own goals for students and the reform goals. These two hypotheses are posed as rivals for the study to test the program's own assumptions about teachers' answers to the question, "Why do GLOBE?"

Hypothesis 2: *Face-to-face mentoring from a GLOBE partner helps teachers to overcome common obstacles to implementation.*

Rival: *Lower-cost alternatives to face-to-face mentoring can be equally effective in overcoming obstacles to implementation.*

Our research on GLOBE suggests that face-to-face mentoring is important to predicting different levels of data reporting. One GLOBE partner has suggested that face-to-face visits are the critical component of the mentoring process, because they provide an opportunity for teachers to solve problems of implementation jointly with an expert in the program. Such mentoring is costly, and just over a third are able to provide it. It would be more advantageous if lower-cost alternatives could be identified to support mentoring.

Hypothesis 3: *Providing models of teaching with GLOBE helps students make connections between GLOBE's education activities and real science.*

Rival: *Providing incentives for student research and aligning goals with other inquiry programs are also necessary conditions to help students make connections between GLOBE's education activities and real science.*

Part of inquiry teaching is helping students make connections among what they are learning in class, real science, and their own observations and experience in the world. Where resources permit, partners may be able to provide model lessons—either as part of professional development workshops or in the classrooms—that show teachers how to help make a connection between classroom GLOBE activities and the work of real scientists. Many partners, however, must work at a distance from teachers; they must rely on strategies that can be implemented from afar to support teachers' using GLOBE in a way that students perceive as meaningful. Two strategies that may be important are providing incentives and structures to enable inquiry and forming alliances with other programs that support student investigation in science.

Hypothesis 4: *The work partners do with teachers to align to standards and assessments helps teachers identify multiple opportunities for integrating GLOBE into their curriculum.*

Rival: *Teachers' perceived conflicts between teaching to standards and implementing GLOBE prevents them from implementing the program, despite the alignment efforts of partners.*

Standards, state achievement tests, and accountability systems are drivers of educational reform throughout the United States (and increasingly other countries as well). GLOBE teachers have reported to SRI as part of our evaluation work that standards and accountability pressures often prevent them from implementing GLOBE (Means et al., 2000). To address these concerns, many partners work actively to help teachers align GLOBE with their state's standards, a task that the GLOBE Headquarters does not have the resources to undertake on its own. It is not known whether these strategies are effective, or if the perceived conflicts are major obstacles to GLOBE implementation even in regions where partners have spent time aligning GLOBE with local standards and assessments.

Hypothesis 5: *A few strategic relationships with other programs and with policymakers allow partners to build a sustainable funding base over time.*

Rival: *A broad portfolio of strategic relationships helps transcend the unpredictability of single relationships in establishing a sustainable funding base over time.*

GLOBE's partners get their funding from multiple sources, but different partners have developed different strategies for accomplishing the goal of a sustainable, stable funding base. Two strategies that are common but not widely understood are to seek a few strategic relationships of central importance and to seek a broad portfolio of strategic relationships to reduce risk associated with any individual relationship. We investigate these here, in an attempt to learn more about which strategy might be more effective.

Selection of Cases

When multiple case studies are used, it is important to select cases that are either similar or that predict contrasting results in ways that are expected, given the hypotheses that are driving the analysis (Yin, 2003). For this study, we selected two partnerships, GLOBE in Alabama and the partnership run by the University of Alaska-Fairbanks. The two cases we have selected are *similar* in that they both provide supports to teachers after training, and also have as one of their goals supporting inquiry teaching with GLOBE. They are also similar in how successful they are in training teachers who go on to implement GLOBE (see Table 1). If the percentage of those actually reporting data seems low, it must be also be pointed out that these two partners have the highest percentage of teachers trained who report data among U.S. partners.

Table 1. Teachers Trained and Reporting Data in Alabama and Alaska

Partnership	**Number Trained (through 2003)**	**Number Reporting Data (through 2003)**
GLOBE in Alabama	1033	213
University of Alaska-Fairbanks	585	61

We did attempt to select teachers to interview for our study that were different with respect to the types of support they had from partners, in order to be able to test our hypotheses about the importance of post-training support. We also sought out teachers with different implementation patterns, to test our hypotheses about support and curriculum integration.

Case Study Protocols and Procedures

SRI researchers prepared interview protocols for each of several categories of people associated with partnerships. We prepared a *partner leader* interview, which focused on eliciting the partnership structure, funding, and central challenges. A *partner staff member* interview was used with mentors, affiliates, and other people who did work with the partnership to assist with professional development or performed support functions. We also prepared a *school administrator* interview, which focused on principals' perceptions of the program and its fit within their school. We prepared a *teacher* interview aimed at finding out about how teachers were implementing the program, their obstacles to implementation, and how (if at all) they overcame those obstacles.

Where possible, we also conducted *structured observations* of GLOBE activities in classrooms. These observations were designed to capture instructional goals, materials used, and sequences of activity. We attempted also to capture dialogue and discourse throughout the observations in selected classrooms. Each of the observations tended to last roughly 45 minutes to an hour.

The site visits took place in spring or summer 2003, and researchers spent a week in each state. Case study researchers visited each partnership in pairs, and set up site visits to schools ahead of time. Where possible, site visitors were asked to set up site visits in different regions of the states and to include both a rural and urban school in their sample. Before their visits, case study researchers were given instructions in how to use each of the protocols and capture forms. In addition, they had time to conduct practice interviews as part of a training session designed for new case study researchers.

Analytic Strategy

Upon their return from their sites, each case study research team was tasked with completing two capture forms. First, they completed a rubric for each individual school they visited, based on a model of GLOBE implementation developed for the evaluation of the program (Penuel, 2003), which site visitors were asked to “fill in” with evidence from interviews, observations, and artifacts they collected as part of their case studies. The rubric elements included not only implementation depth and quality but also the quality of external supports (some provided by the partner) available to teachers. Second, they created a summary of five key themes from their case studies, with evidence backing each theme. These themes were then presented back to the partner leaders, as a check on their validity and for comment.

Both these documents were used to help organize the study findings with respect to the key hypotheses. We systematically reviewed evidence from interviews, the rubrics, and the thematic summaries to produce the case study reports that appear in the sections below.

The case study analyses were conducted as if the case studies were not recurrent but were intended as replications of one another. An advantage of treating the cases as replications is that we can review evidence in light of a revised (and potentially more refined) set of hypotheses about the role partners play in supporting implementation. However, had we conducted these analyses as true replications, we would have attempted to revise our interview protocols and observation instruments to gather data systematically on these new hypotheses. Because of the schedule of the evaluation, it was not possible to sequence the case studies in this way. Further, we had hoped to be able to conduct these case studies as longitudinal studies to enable us to refine our instruments and hypotheses appropriately, but the priorities of the GLOBE program itself have shifted somewhat, directing our evaluation resources to other activities.

In the reports that follow, we use the actual names of partnerships and their leaders. We do so because they have been collaborators with us in the study; the third author of this paper is the partner leader in Alaska. We view their participation as critical in helping to establish the validity of our findings. Although having them so closely involved is a potential threat to our own impartiality, we have found that the partners are open about discussing their challenges, and our focus on looking at effectiveness from the viewpoint of teachers provides an independent point of reference for the study. All teachers' names and their schools are pseudonyms.

GLOBE in Alabama

GLOBE in Alabama has long been a major, visible partner within the program. It was director Greg Cox who first suggested that GLOBE refer to its new network of training organizations as "partners," and the Alabama partnership helped to chart the course for effective partnership activity. A lynchpin of the strategy in the recent past has been a system of mentors, spread throughout the state, who provide close support to teachers who are implementing the program. Until recently, these mentors were led by another leader in the organization, Jennifer Lockett. Based out of Mobile, she served as the original mentor and helped to organize mentoring activities throughout the state.

The partnership has trained a large number of teachers, and many of them actually implement GLOBE. The partnership was able to obtain grants for equipment and funding for the kinds of follow-up support that have been associated with higher data reporting, and Alabama has reaped the benefits of that approach. This success is a key reason why the partnership was selected for the study.

Another significant achievement of this partnership has been its integration with other statewide initiatives. The program participated in the governor's blue ribbon panel to reform mathematics, science, and technology education, and Greg has served as a leader with the Alabama Math, Science, and Technology Initiative (AMSTI) that grew out of that panel's efforts. The mentoring model employed by the program is the model for preparing teachers in this new initiative. Furthermore, the partnership's visibility within the GLOBE program as a whole also makes it an important, credible intermediary organization both within the state and beyond.

In this section of the paper, we explore how this partnership has been experienced by teachers, reviewing under each sub-section evidence related to our central hypotheses. At the end of this section, we consider how we needed to adjust our hypotheses to reflect what we found in Alabama.

Teachers' Reasons for Implementing GLOBE

The perceived benefits of GLOBE resonated strongly with individual teachers and their school leaders. At the same time, it was GLOBE's perceived educational benefits that teachers' most often cited as their reasons for implementing GLOBE, rather than the possibility that they could contribute to scientists' findings. The philosophies and pedagogical approaches of schools implementing the program diverged, yet there was a common thread across each, namely that GLOBE was a way to help students connect to the world outside their local communities.

GLOBE middle-school teacher Fran Kastings discovered GLOBE because of a personal interest in the environment. She is a member of a local hiking club and regularly takes her students each spring to Oak Mountain State Park, a 10,000-acre park whose northern edge touches the school property. A ranger there, "Keener", who usually leads student activities, was working with GLOBE mentor Taylor Steel, when she found out about the program and signed up for training.

Upon completion of her GLOBE training, Fran still needed the approval of her school's principal to use GLOBE. She teaches at Rock Hill Christian School, a parochial school with a strong religious emphasis. The school is involved in a project to develop their own science textbooks, in an effort to ensure that content is consistent with the religious beliefs of the school; all content, including GLOBE content, had to be filtered through the principal for acceptability. Fran mentioned needing to exclude certain scientists' letters from the Teacher's Guide because of their inconsistency with her own and her school's beliefs.

There were several influences on the choices Fran made in implementing GLOBE. When she got started implementing GLOBE, one influence was a conversation she had with a high school teacher, who told her that developing students' skill in measurement particularly important. Another influence was her belief that GLOBE could help students "get out of their bubble" by performing community service. Third, Fran sees international collaboration with other students as facilitating students' desires to learn about other countries, especially where they may go on mission trips.

Fifth-grade teacher Mary Castella, who teaches in a public school some 50 miles to the southeast of Fran's school, views GLOBE as a way to expand children's worlds by taking them outside. When she first encountered GLOBE activities at her local arboretum, she said she really liked GLOBE, "because the world is global." "Students can't just stay in their shells," she added. She could see a place for GLOBE in her classroom, she told us, because it would give students a chance to get outside and be in nature. She hopes students will gain comfort in using technology, learn science, and get better connected to other parts of the world through GLOBE. She hopes her students develop a greater sense of care for the environment around them, as well. She wants her students to ask, "How can we preserve the Earth, and make things better?"

Of the teachers we interviewed, only Cindy Kinnard cited as a major reason for implementing GLOBE the possibility of contributing to the work of scientists. She emphasized, however, that it was what students would learn from the experience that was important. She hoped that her students could learn observation, measurement, and inquiry skills from GLOBE and that they could gain practice in reading charts and graphs by looking at their data on the Internet. She also said that she expected her students would gain valuable mathematics skills by learning how to look at weather data over time.

The primary overlap between GLOBE's goals and teachers' goals could best be described as a passion for environmental science. All three teachers we interviewed in the first year of our case studies shared a passion for the environment. GLOBE was not their first encounter with environmental science or with environmental education; in fact, all of them encountered GLOBE through networks of people concerned with the environment that they already knew. These networks may be important additional supports to GLOBE's scaling in Alabama, because they help to spark (or re-energize) interest among teachers in GLOBE from a trusted source of information.

Mentoring in Alabama

These networks are not the only groups that help GLOBE to scale in Alabama. GLOBE in Alabama's mentors work to ensure that a high percentage of teachers trained will actually implement the program. The program includes 4 paid, part-time mentors who are (to varying degrees) available to help trained GLOBE teachers by visiting their schools, responding to emails, and talking over the phone with them. The state is divided into geographic regions, and each mentor is assigned one or more regions whose schools they are to assist. Although these mentors are not able to assist all schools in the region, they are responsive to individual requests and make periodic visits to schools whose teachers they have helped train. Their location closer to teachers than the GLOBE in Alabama bases in Mobile (in the south) and Huntsville (in the north) makes them more accessible than they would otherwise be.

The mentors that work with GLOBE in Alabama all have multiple affiliations, of which GLOBE is just one. Two work as education staff in local science museums, and another works for the state. A fourth is currently a full-time teacher. Their home-base organizations support their participation to varying degrees and for varying amounts of time. Not surprisingly, the teacher who serves as a mentor in the southern part of the state has the least amount of time available to visit schools.

These mentors engage in several different kinds of activities with teachers that they view as critical supports for teachers implementing GLOBE. First, they provide models of GLOBE teaching in teachers' classrooms with their students. Mentors teach learning activities, protocols, and model effective questioning strategies. Mentors also engage in joint curriculum planning with teachers, to help them see connections between GLOBE and their own local curriculum or state standards. Third, mentors help teachers set up equipment and solve problems related to taking measurements in their schools. In some cases, this may involve equipment re-set up, because a school has renovated and made a site less appropriate for taking GLOBE measurements.

In each of the schools we visited, teachers had received face-to-face visits from mentors. Fran Kastings has received a variety of supports from GLOBE in Alabama: mentoring (she can ask Taylor to come on a weekly basis); refresher training; support for any equipment; and links to other GLOBE teachers (she's connected to an area high school teacher). These supports have been indispensable to Fran: on-site mentoring has allowed her to see GLOBE teaching modeled, helped her solve equipment problems, and given her a second “team teacher” to work with, something Kathy misses from her public school teaching days.

These mentoring activities appeared to have a significant influence on teachers' ability to overcome obstacles to implementing GLOBE. It is doubtful that if Fran had just received her basic training in GLOBE and been left alone that she would have ever implemented GLOBE. Despite the fact that Fran's training was spread over five months, from January to May 2002, she described her initial response to training as “overwhelming.” Mary Castella characterized her initial training in the same way; she was initially discouraged because other teachers in her school who had been trained were not implementing the program. When she got back to her school, she had no idea how to obtain an instrument shelter and realized she'd need to wait an entire school year if she wanted to purchase them with school funds. Through partnership funding, however, she learned from mentor Kathryn Royall that she could get equipment free. Kathryn came to her school and helped her set up the shelter; *she also* brought by a GPS module, so that she could enter the data about the study site onto the GLOBE Web site.

Although mentors didn't help Cindy Kinnard get started with GLOBE, a mentor did help with implementing GLOBE again after a four-year hiatus. She had suspended GLOBE implementation after moving to Blue Hill School four years ago, but when a colleague of hers who was also doing the JASON Project mentioned something about GLOBE, she connected Cindy to Taylor, who was offering refresher training courses. She's been participating in refresher training with Taylor this year, and is beginning to implement GLOBE again with her students. She saw Taylor as someone “who could help with follow-up,” so she sought out his help in getting GLOBE started again in her new school. “He helps you remember how to do things,” she added.

According to GLOBE in Alabama’s current director Greg Cox, there are some important qualities that make a good mentor, qualities that are consistent with what we observed mentors exhibiting. First, the mentors should have some teaching experience and understanding of inquiry teaching in particular, whether in school or as part of an informal organization like a museum. Such experience helps to build trust with teachers and establish a pedagogical model that is consistent with using GLOBE to support student investigations and research. The mentors also need to be able to listen well to teachers and have the patience to deal with a wide variety of situations. There are serious obstacles to implementation in schools, and careful listening is required to understand those obstacles and help teachers find solutions that are workable in their schools. Finally, a strong science content background helps because GLOBE is content-rich but provides little scaffolding in its materials for teachers (or mentors) to be able to master concepts that may be completely foreign to them.

It would be a mistake, however, to attribute the success of teachers in overcoming obstacles to implementation to themselves alone. Mentors have not been able to overcome obstacles to technology access, for example, and teachers have had to come up with their own strategies for addressing limits to their access. Until spring 2003, Fran Kastings did not have Internet access in her room, or a place where she could send students to enter data. She did not start collecting and reporting data until then for this reason. Now, there’s a full computer lab available, and she’s had no trouble getting access when she wants it, but she imagines the lab will become more popular over time and therefore somewhat more difficult to access.

In addition, Fran had to work largely on her own to secure permission from her principal to implement GLOBE. She alone could build a bridge between her school's Christian philosophy and GLOBE's goals, presenting the information about GLOBE in such a way that it would be viewed as consistent with her own and her school's faith, rather than in contradiction with it. Her principal's trust in Fran was also a key factor in his decision; he noted in our interview with him that the in the school's effort to write its own science materials, Fran was "critical" and added that she would be a key participant in an upcoming school science summit.

Mary Castella had a different set of obstacles, which she too figured out how to address largely on her own. Mary did not find that all of her 5th-grade students' data could be trusted, so she entered the data herself. Over time, and especially this year with her GLOBE group, she's had students take more responsibility for these activities. The transformation has come about not just because she's gotten more comfortable with implementing GLOBE, but also because she's moved toward having a selected group of students implement GLOBE, rather than having all students participate. She trusts the data collected by these students to a much greater degree than before, so she's comfortable giving them more autonomy.

The Meaning of GLOBE to Alabama Students

Neither local issues nor student research are central in motivating students to participate actively in GLOBE in the classes we observed. Although Fran Kastings would like to conduct a student research project with her students, she has yet to do so. And although Taylor has introduced students to local information about Alabama's soils, students don't seem to understand why soils are important to study. One girl, for example, on finding a Web site on a "soil survey," wondered aloud why anyone would do such a boring thing, but did not at all pursue her own question even though it would certainly be relevant to GLOBE. Mary Castella has given little attention to data analysis in her classes; her students are not familiar with patterns in their own data or with what the GLOBE scientists do with the data they report. Third-grade teacher Cindy Kinnard has been involved in a number of inquiry-science initiatives and has her students begin all their units with listing a set of "testable" scientific questions about the topic, but her students don't necessarily understand the depth of the programs with which they are involved. Students appeared engaged and motivated in each these classes, but not in the ways we had initially expected.

Students in Fran Kastings's class did appear to be motivated to compare their own data with the data from other classes in the school. When she began, Fran did not review the data from her five classes and recorded only the data collected by the class that was in session at solar noon (the time specified in the GLOBE protocols for collecting temperature data). But students grew eager to learn what other classes had obtained for their readings. When she agreed to share, she discovered that many students' recordings were wildly off. These discrepancies were visible both to her and her students, and the students became more motivated to make accurate measurements as a result.

Students in Mary Castella's fifth-grade class seem motivated not by comparisons of data but by the technologies used to take measurements. In the lesson we observed, students hung on the GLOBE mentor’s every word as she explained the max-min thermometer. They would add words like “cool” to each of her explanations. She had structured opportunities for the GLOBE students to share with others in their class how to use the GLOBE equipment, which they took very seriously. They were particularly fascinated by the data logger for measuring maximum and minimum temperature, noting what an advantage it had over the thermometer they had been using in their instrument shelter.

Mentors’ Support for Curriculum Planning and Integration

One of the roles identified as critical that mentors play in Alabama is in supporting teachers’ planning for integrating GLOBE into their curriculum. Key to Fran Kastings’s getting started was having her mentor sit down with her and walk through her curriculum to find opportunities to integrate GLOBE into the curriculum. Although she was enthusiastic about GLOBE initially, she was not yet confident in her ability to implement the program. It took a mentor’s visits to her class—to plan where to insert GLOBE into the curriculum and troubleshoot issues related to the placement of her weather station—before she could really get started. Her mentor also modeled GLOBE teaching at the beginning with Fran, letting her observe from the back of the class, so she could see GLOBE in action. After a while, the mentor realized that she needed to develop confidence herself, so he asked her to take over.

Mary Castella noted that assistance from a mentor was particularly important in addressing the sense she had that there would not be enough time in her curriculum to integrate GLOBE. Mentor Kathryn Royall helped Mary to look at where the Alabama

Course of Study and GLOBE were aligned. "We sat down and looked at it," she said, "especially after I said to her that we needed to make sure it's covered in the Course of Study."

This help was not enough, though, to prevent Mary from having to limit students' exposure to GLOBE content, despite her interest in the program. Mary noted that she has to teach more than science—as an elementary teacher in an intact classroom, she must teach reading, mathematics, and social studies. The breadth of what she must cover does limit the time she can spend on GLOBE. Accordingly, she's made GLOBE into a "centers" activity, so that not all students are heavily involved in GLOBE activities.

For at least one teacher, the perception that GLOBE would not fit into the curriculum was not an issue at all. At Blue Hill School, where Cindy Kinnard teaches, the school district was in the midst of a five-year emphasis on reforming science education through emphasizing student inquiry. In addition, despite the fact that state accountability tests at the elementary level do not focus at all on science, because of parent advocacy the school decided to dedicate an extra room in the new school building (built 3-4 years ago) to science for every grade, plus a large lab for students to use across grades. Parents demanded an emphasis on science, and Cindy perceived GLOBE to be a perfect fit that met her district's and her parents' needs for science education. There was little that the mentor needed to do to convince her of the fit; she saw the connection right away.

How GLOBE in Alabama Funds Its Activities

A key to the success of the Alabama partnership has been its ability to fund mentors, equipment, and other activities. Greg Cox and Jennifer Lockett's leadership have both contributed to helping to put together the funding and infrastructure for GLOBE's mentoring and for establishing a place for GLOBE within the state's mathematics and science initiatives. Their strategy has been to seek funding from a combination of private and government sectors.

Funding for mentors has come from two different sources of state funding. The Department of Community Affairs gave the program approximately $125,000, and another $145,000 came from the state Department of Education. These sources, however, do not ensure the program's sustainability, and a change in administration in the state makes it less likely that funding can go directly to GLOBE for its mentoring activities.

However, the program's successful alignment with the state's initiatives in math and science initiatives has put the program on track to continue to be able to provide mentoring services and to train teachers in GLOBE. GLOBE training is now integrated with several other science initiatives, and mentors who serve as mathematics and science specialists on the GLOBE in Alabama model are soon to be placed throughout the state.

Funding is still a big issue for the partnership, however. Greg Cox is looking to raise additional funding from the private sector to fully fund the initiative, including all of the regional hubs. There has been little continuity of funding over the years, except for support for equipment.

Revisiting the Hypotheses about Partnerships

Before turning to analyze the University of Alaska-Fairbanks partnership, we consider how our hypotheses about the role of partnerships in supporting implementation and their capacity might be revised or refined to better reflect findings from our case study of Alabama. These revised set of hypotheses will serve as a guide to our analysis of the Alaska partnership.

The data from Alabama do support the hypothesis that locally-defined goals for participating in GLOBE are strong drivers for implementation, rather than teachers' (or students') sense that they are contributing to real science. We did encounter one teacher who cited the ability to contribute to real science as a reason she was drawn to GLOBE, but this was just one of several reasons she was interested in the program. Another characteristic of teachers seemed to be a more important driver of their interest in GLOBE—an interest in the study and protection of the environment. Teachers' prior interest in environmental science education, conservation, and earth science was all evident from interviews and cited by teachers as a reason why they were drawn to GLOBE. We would thus suggest that both locally-defined rationales for GLOBE and teachers' interest in the environment drive teachers' decisions to implement GLOBE (revised Hypothesis 1).

Because all of the teachers we interviewed had received face-to-face mentoring and all cited this assistance as essential to implementation, we cannot find any evidence to contradict our hypothesis that this form of mentoring is necessary to overcome obstacles to implementation. For each of these teachers, the evidence supports the claim that face-to-face helped, although we don't know what would have happened without it. But we do need to acknowledge that mentors are not the only key, given the central role that teachers themselves continue to play in overcoming obstacles to implementation in their school, especially when they are in schools that are not particularly supportive of science instruction. Further, mentors play an additional role that we uncovered in Alabama for the first time, namely that mentors, through their own participation in social networks of science educators, are critical agents in the scaling process. Two of the three teachers we encountered had found GLOBE through their mentors. Like partner leaders, these mentors are important in bringing new teachers to GLOBE. GLOBE in Alabama may be unusual in being able to rely on intermediaries of its own, but it merits further investigation whether such structures might work successfully in other partnerships.

Partners do not appear to be able to completely overcome the difficulties teachers face in curriculum integration. It is important that teachers see connections for themselves between GLOBE and their state's curriculum frameworks and standards. In addition, where teachers perceive particular protocols to be both difficult to implement and only partially aligned to standards, these protocols are not implemented. As one teachers said about the soils protocol—a favorite of her mentor--"it's a great idea, but I wasn't going to do it" because it didn't fit with her school's curriculum.

GLOBE in Alabama has proven continuously resourceful with respect to funding, pursuing both smaller and larger funders. Yet neither has proven reliable over a long period of time, with funding going up or down from year to year. More data—over a longer period of time—may be needed to understand what kinds of strategies are successful in producing a sustainable partnership.

University of Alaska-Fairbanks

The partnership at the University of Alaska-Fairbanks is headed up by soil microbiologist Elena Sparrow, who is also a GLOBE scientist in charge of the phenology protocols. The partnership started small—with funding from just a handful of small grants—but has grown over the past several years to be among the most successful and visible of the GLOBE partnerships. A distinguishing feature of the partnership is its successful blend of educational, scientific, and cultural concerns in its preparation activities for teachers and subsequent support of GLOBE in local communities. The program has successfully engaged scientists, teachers, and Native elders to explore how GLOBE can become one lens—along with other cultural ways of knowing—for observing changes in the local environment.

Like GLOBE in Alabama, the University of Alaska has developed partnerships with other programs and organizations that have helped the program to scale. These include other science and education programs, as well as statewide initiatives. One of these initiatives, a statewide attempt to integrate Native cultural knowledge with science education, has been particularly useful to the program because GLOBE has sought to align itself with standards for reaching Native communities more effectively. This strategy is particularly important to examine, because it represents other organizations that have been critical to GLOBE implementation beyond teachers and partner staff.

Another important program component is its summer teacher institute, a 3-week workshop that weaves together the three strands of science, best teaching practices, and culturally-relevant curricula. We timed our site visit to experience some of this institute; we also visited one village’s summer elementary program that utilized GLOBE, and interviewed several other teachers (either in person or by telephone).

In this section of the paper, we explore how this partnership has been experienced by teachers and students, reviewing under each sub-section the evidence related to our revised set of hypotheses. At the end of this section, we consider how we needed to adjust our hypotheses to reflect what we found in Alaska.

Teachers' Reasons for Implementing GLOBE

In Alaska as in Alabama, we found that teachers' reasons for implementing GLOBE tied closely with their own deep personal interest in the environment. The two teachers we interviewed at Green Valley, Polly Cross and Manny Star, share a long history of interest and involvement in projects for the study or management of the environment where they were living at the time. For example, Manny had been involved in a major river restoration and study project when he lived in Pennsylvania. These teachers hope that their students will come to understand their own impact on the environment and that GLOBE serves as "another way for them to see that everything's connected."

Connections to local issues and communities are also important to GLOBE teachers in Alaska. Weather extremes are ever-present in Alaska and make for good fodder in science instruction. Teachers can and do provide students connections between weather they observe and phenomena related to global warming, such as changing patterns of ice breakup, tundra plants that grow taller than a generation ago, and reduction in the permafrost. GLOBE teacher Dylan Simkins commented that weather has often spurred discussions that relate to GLOBE. Students make observations about what they see as unusual weather, ask questions about it, and probe with GLOBE data about the patterns they see. Many activities we observed used in class, moreover, explicitly link local perspectives to GLOBE topics. For example, the water cycle was introduced in one classroom with a book called *Go Home River*, about a trip taken by a Native Alaskan boy and his father to experience the river from origin to the sea. In another Native village, a health specialist recently trained by GLOBE said that she saw GLOBE as an opportunity to foster collaboration between local Native elders and youth in the community.

For some teachers we interviewed, the connection to real science and scientists was important. One teacher we interviewed on the telephone indicated that she chose to implement GLOBE because she was “looking for better connections for kids with real science.” According to another, GLOBE provides role models “at-a-distance” for students in isolated villages that are lacking in professional opportunities and role models: “One big thing for me is to make my students understand that when they grow up they can be scientists.” This teacher mentioned that the fact that students’ data is used in the service of real scientific research was a motivating factor, particularly when this relationship was reinforced through a visit from scientists that had actually used cloud cover data from this village: they actually took a copy of a student data collection notebook, giving the students a personal connection to the more distant notion that data entered into the GLOBE database may eventually be used by scientists.

Student Inquiry with GLOBE in Alaska

Most of the teacher preparation for GLOBE that takes place today is conducted within the Observing Locally, Connecting Globally (OLCG) program, an NSF grant that the University of Alaska has had since 2000. The goal of this program has been to provide Alaskan teachers and students opportunities to engage in original global change research and to promote global change education in Alaska, with a special emphasis on presenting students with opportunities to learn that are culturally relevant. The project's three-week summer training institute includes the participation of Native elders and other local environmental experts to examine issues of culturally relevant teaching and curricula as applied to the protocols and learning activities of GLOBE. Integrated throughout the science and cultural content, leading education professionals provide instruction for participating teachers on "best practices" in science and math education and strategies for supporting teachers and students in developing and carrying out scientific investigations. For example, when teacher participants in the institute conduct GLOBE investigations in teams and then present their results, the facilitated debrief of each presentation may focus on related pedagogical strategies, embedding both educational research findings and practical tips on such issues as facilitating teamwork among diverse groups of students.

The integration of GLOBE training with OLCG means that new teachers in the program have different kinds of opportunities to learn about inquiry science teaching than do most GLOBE teachers. The majority of standard GLOBE training focuses on the mastery of the protocols. Much less time is devoted to planning for classroom implementation, much less for inquiry. Partners report that their teachers are not generally familiar with inquiry science teaching (Penuel et al., 2004); therefore, the added attention within the OLCG summer institutes provides teachers with tools for teaching they might otherwise not have.

Another important method the Alaska GLOBE team has used to expand the focus on inquiry has been to establish collaborative partnerships with other inquiry-based science education programs. GLOBE protocols are often positioned as the data collection arm of existing inquiry science programs like the Longterm Ecological Research Project, a program in which teachers and students conduct research near their school. These programs often provide models of professional development for teachers, frequently in the context of ready-to-use curricula or project ideas that help make the connection between GLOBE and local issues more visible and meaningful to students. As a result, students in GLOBE as a group in Alaska seem to have many more opportunities to encounter inquiry with GLOBE than do students in other areas.

If Alaska's representation at the recent GLOBE Learning Expedition (GLE) in Croatia is any indication, the focus on inquiry has paid off. The GLE is an international student conference, with participants from the US selected competitively based on the reports of GLOBE inquiry projects that they submit. Two groups of student researchers from different schools in the Fairbanks area were selected to attend on the basis of their research in GLOBE.

Fairbanks High School student April Kyle's research project focused on the effects of hot water discharge on the dissolved oxygen level of the Chena River in Fairbanks. She chose to investigate the effects of a nearby power plant and used GLOBE data to investigate the hypothesis that dissolved oxygen levels might be so low near the plant that they could not support life. Although she found that dissolved oxygen levels were lower near the plant than elsewhere along the river, the levels were high and not a danger to the aquatic wildlife. Her report of her research reflects a mastery of the conventions of scientific communication: citation of prior work that frames the study, a clear explanation of the problem and its significance, a clear description of procedures she followed, and effective data displays and analysis. She compared the two sites' dissolved oxygen levels using a statistical significance test, no small achievement for a high school science student! Finally, as good researchers do, she noted the limitations of her study and their implications for the conclusions she was able to draw.

Not all GLOBE students have the experience of inquiry with GLOBE that April did. Younger students would not have been able to perform her analyses, and the elementary school we visited tended to focus on more modest goals for its 1st-4th grade students. Although the students in this school were excited about following the data collection protocols, many of the students we talked to were not able to articulate much understanding of the significance or purpose for some of the activities they were doing. Very little formal data analysis is conducted in this classroom either, but teachers do regularly engage the whole class in discussions of what their data might mean and what things (concepts) might help them better understand the science and other reasons behind the measurements they are making. Proper science terminology as related to the protocols, and the science concepts behind them, are introduced with age-appropriate approaches and degrees of sophistication.

In Alaska, there are numerous opportunities to communicate with other schools in the program. Many other GLOBE schools are interested in Alaskan schools because of their remote and somewhat unique geographical location. Alaskan teachers report that these emails have motivational value, and help these very remote students feel they have something in common with students in other places. However, the email inquiries they receive tend to contain more questions than data to share; at Iditarod time, one school even instituted a form letter response to handle the volume of communication.

Support for GLOBE Teachers after Training

Our observations and interviews with teachers in Alaska lend support to our revised hypothesis, that mentors and teachers each make a significant contribution to overcoming obstacles to implementation. The Alaska partnership places a premium on follow-up support. They attribute their high state-wide implementation rate to the strategy of close follow-up support for teachers. Furthermore, according to partner staff, they judge the success of their partnership not on how many teachers are trained but on the level and quality of implementation at the schools.

A key vehicle for maintaining face-to-face contact with teachers is through annual GLOBE conferences held for teachers in Alaska. At these conferences, teachers receive follow-up training in both GLOBE protocols and in teaching with GLOBE. They also have opportunities to share practices with other GLOBE teachers. According to one teacher, these conferences yield "wonderful insights" into how to organize instruction with GLOBE. Another teacher noted that the return trips to GLOBE help keep them up to date on the program.

Despite the vast distances that separate many schools from the partner headquarters in Fairbanks, Elena and her staff do what they can to make site visits and provide hands-on support for teachers. According to teacher Sally Belfour of Barrow Elementary, these kinds of visits are "invaluable…the crucial thing that makes this program work." Where possible, face-to-face support is offered for each of the programs three strands: science (for example, troubleshooting GLOBE data collection challenges), best practices and pedagogy (for example, co-PI Leslie Gordon helped make protocols age-relevant by teaching an elementary school class a lesson on percentages in preparation for a cloud protocol that expected students to estimate the percentage of the sky covered by clouds), and culturally-relevant curriculum (for example, co-PI Sidney Stephens often helps to identify local Native elders and facilitates their participation in the classroom).

In addition, email and telephone support on each of the three strands are extensive, particularly where distance or time preclude face-to-face contact. Clearly, however,distances prevent the level of face-to-face support during the school year that can be provided in a state like Alabama with its regional network of mentors, and teachers sometimes must work on their own to solve problems related to implementation.

An additional way that the Alaska partnership promotes implementation after training is to provide incentives and accountability for implementing the program. Once trained, teachers are asked to submit journals of their teaching and student work samples to Elena and Leslie during the year. These help provide partner staff with insight into the level and quality of implementation and also encourage teachers to follow-through on plans developed at the annual conference. Teachers are motivated to complete the work because they receive course credit at the university, which is contingent on them reporting data. In many cases, teachers' tuition is subsidized through grants.

Standards for Culturally Relevant Curriculum

The Alaska partnership has sought to make clear its alignment not only with the state's standards in science but also a set of standards that address specifically the needs of Native Alaskan students. The state has developed a separate set of standards, the *Alaska Standards for Culturally Responsive Schools,* which focus on how best to provide instruction to the state's many Native students. These standards call on educators to find ways to involve Native communities as active participants in education and to become aware of how Native ways of knowing intersect with the forms of knowledge valued in schools and in the disciplines. The University of Alaska-Fairbanks partnership has integrated these standards into its training, and some schools whose teachers we interviewed had involved local elders in their implementation of GLOBE.

Teachers first encounter this sensitivity to Native ways of knowing in their introductory GLOBE training, where it is one of the three core strands of instruction. Throughout the training session, there were many explicit discussions of native ways of knowing as they relate to environmental change, including a talk by Howard Luke, an elder who discussed respect for the land and how that affects environmental change. Sandra Motherwood, a Native GLOBE teacher, discussed environmental change in Barrow and native/scientist partnerships that informed international policy on whaling restrictions. Partner staff member Sidney Stephens provided participants with a book on integrating native ways and presented a chart that depicted a “middle ground” between native and western scientific thinking as a guide for curriculum development

GLOBE teacher Tom Daugherty teaches in a school where more than 80% of the students are Native Alaskan. For Tom, the involvement of local elders has made a big difference in his ability to implement GLOBE. He notes that the state’s emphasis on reading has taken away a focus on science, but he reports that the partnership has been a source of support for him. In addition, he notes that elders are integral to the program in his community. They have come in to talk with students about the environment and about how GLOBE has a good relationship to the Native community. Tom highlights the role that the elders play in reaching his Native students, indicating that they help make a bridge between GLOBE science and a Native appreciation for the environment.

In similar schools elsewhere, GLOBE teachers say elder involvement helps to overcome barriers to implementation. Sandy Hamilton, who also teaches in a school that is comprised primarily of Native students, says she gets little support from her principal and colleagues from GLOBE. She notes that the leaders in her school are all “scared of science,” and that there is extreme pressure to increase scores on the state standardized tests. But she is inspired to implement GLOBE because of the involvement of elders that the program has facilitated. Elders visit her class and talk about topics like climate change that include reference both to the ways that Native elders observe change and the way changes can be observed by GLOBE students. Hamilton observes, “GLOBE is culturally relevant for students: the elders talk about the old sweat lodges and their predictions for great changes in the climate. Now this makes sense to the kids. It is easy to make GLOBE culturally relevant for them: there’s a lot of flexibility and ability to expound on what they already value in their culture.” GLOBE teacher Randall Henderson indicates that Native elders in her community help her tremendously in working with students in her classroom. They help students gain a deeper understanding of the local environment and about the traditional relationship of Native communities to the land. Elders who visited emphasized themes similar to those emphasized in Sandy Hamilton’s class: how observation in GLOBE relates to the forms of observation valued in Native culture.

As in Alabama, the teachers often play an important role in helping to make the connections to standards—both state and cultural—that allow them to implement

GLOBE. Dylan Simkins, for example, cites his own science team as an important source of support, since they work together to decide on curriculum. Polly Cross is on a state-level committee to rewrite the state science standards, and uses her resulting understanding of the alignment process to help her make connections between GLOBE and standards. Harriet Smith notes that she has to implement GLOBE almost in defiance of her leadership; she must herself defend her decision to implement GLOBE regularly within her school.

The experiences of teachers in Alaska suggest that there are actors other than teachers and partner staff who can play an important role in supporting implementation. Community members—especially when they help to demonstrate the relevance of GLOBE to local issues and to ways of living that are valued within the cultural traditions of students—can inspire teachers and students, and rebuild trust of the educational institution in Native areas that have long felt a disconnection with White-run schools. The elders with whom they work made a strong impression on each of the teachers we interviewed, especially among those who teach primarily Native Alaskan students. Their contribution, moreover, was similar across schools, in that they provided a conceptual bridge between how Native Alaskans observe and care for the environment and the GLOBE protocols.

Nevertheless, we heard consistently about the challenges that teachers often face in bringing elders into their classrooms. Elders are far less visible and accessible in cities than in villages, for example, and their conceptions of time and topic often depart from the common workings of the classroom. Teachers say that the mentoring they receive from the program on these topics is invaluable, and some are finding that younger Native "bridgers," with one foot in Western society and the other in Native traditions, offer effective links. Still, the co-PIs agree that too few successful examples exist so far of the desired integration of Native communities into the life of the science classroom.

Alaska's Strategy for Sustainability

Elena Sparrow has a successful track record of pursuing grants to fund work with GLOBE and build capacity for the partnership. Her grant strategy was to start small, and then gradually to apply for larger grants. Elena began her partnership with no GLOBE funding, and her first grants were as small as $5,000 or $10,000. Now she has a large grant portfolio with much larger grants. The OLGC program is one of these larger grants: it comes from the National Science Foundation, and has funded training sessions for several summers.

Elena's strategy for building capacity has been to partner with a network of trainers, scientists, and other science programs. These partnerships both contribute to Elena's salary and payment for trainers, as well as in-kind benefits like access to large groups of already-recruited teachers and integration with existing curricula and classroom projects. Altogether, there are 14 major partners supporting the work of the University of Alaska-Fairbanks partnership, as indicated in Figure 1 below.

Figure 1. Partners of the University of Alaska-Fairbanks Partnership

Global Change Education Using Western Science and Native Observations
(sometimes called OLCG)
Bonanza Creek Schoolyard Long Term Ecological Research Program
Improving Understanding of Climate Change Variability and Its Relevance
to Rural Alaska Program
Alaska Rural Research Partnership, Education Outreach of the Alaska

Environmental Education Outreach (EEOP) Program in the Institute for Tribal Environmental Professionals at Northern Arizona University
The Alaska Boreal Forest Council Education Outreach Project on Tapping Into Spring
the Calypso Farm and Ecology Center
GLOBE Arctic POPs (Persistent Organic Pollutants)
GLOBE Norway and the Norwegian Air Institute (NILU)
BLM Campbell Creek Science Center
GLOBE Partnership at Anchorage
Van Waggoner
Alaska Challenger Center GLOBE Partnership in Kenai
Alaska Teacher Enhancement Program

Elena's strategy is to view GLOBE as a means for supporting other science and education initiatives. For example, GLOBE protocols are used to monitor coastal change in the Improving Understanding of Climate Change Variability program. Schools participating in the Schoolyard Long-Term Ecological Research Project are encouraged to use GLOBE protocols as a means to monitor changes in their local environment. These kinds of connections make GLOBE extremely valuable both to local scientists and educators, because they provide needed solutions to immediate problems faced by these other programs. As a result of these partnerships, GLOBE is well integrated with a number of major state initiatives in environmental science education.

Discussion: Further Refinements to Hypotheses about GLOBE Partnerships

The Alaska partnership suggests that some further refinements to our hypotheses are warranted, in order to reflect more accurately the experiences of students, teachers, and partner staff in GLOBE. In each of the central areas of focus—reasons for implementing GLOBE, important supports for inquiry, partner support, standards alignment, and funding—we found evidence that suggested ways that effective partnerships functioned in ways we had not anticipated at the outset of our study.

Although many of the Alaska teachers were similar to Alabama teachers in that they had defined more locally-relevant answers to the question, “Why GLOBE?” others made reference to GLOBE’s scientific goals. They noted frequently that GLOBE was “real science,” and in one case that they were motivated by the awareness that students are contributing to the work of scientists. For their part, many GLOBE students in Alaska are doing some form of real science, as demonstrated by their reports of research featured at the GLOBE Learning Expedition in Croatia. We would suggest that our data do not contradict the idea that students’ contributions *are* important to GLOBE scientists’ work, but it is clear these contributions do not figure strongly in teachers’ or students’ conceptions of GLOBE.

Alaska provides a different kind of face-to-face encounter with partners than does Alabama, and the partnership also has developed some effective strategies that do not rely on regular encounters with teachers at their school during the year. One important venue for mentoring is an annual GLOBE conference, which provides teachers with opportunities for sharing and for refresher training in protocols. Combining course credit for participation in GLOBE professional development activities with accountability appears to be a successful strategy the program has used to promote teachers’ implementation at a distance. Although teachers do not “meet” during the school year, they provide documentation to the partnership of their activities, and credit is dependent not on attendance at training but on successful program implementation. These kinds of incentives may be a lower-cost alternative—especially in geographically disperse regions like Alaska—to visiting schools regularly. Teachers certainly described their level of contact with the partnership as "high," even though this contact was not always in the form of face-to-face mentoring.

In Alaska, we found evidence for both rival hypotheses about how to make GLOBE meaningful for students. The models of inquiry teaching provided at the annual conference and at training provided teachers with ways into inquiry teaching. But the incentives for student research and alignments with inquiry programs also figured strongly in schools' experience. For example, schools participating in the Schoolyard Long-Term Ecological Research Project used GLOBE protocols to conduct research near their classrooms. The inquiry was organized and structured to reflect the LTER goals, not GLOBE goals. GLOBE protocols, however, were the methods employed by students in their own investigations of their school yard environments.

As in Alabama, we found evidence that both partners' and teachers' work to align GLOBE with standards and assessments was critical. But we also discovered that Native elders played a significant role in supporting curriculum integration. Many schools in Alaska are "minority-majority" schools; that is, their student bodies are comprised of students who are more than 80% Native Alaskan. These students' cultural backgrounds are a rich source of knowledge about the environment, and GLOBE has consciously sought to make their cultural traditions part of the program. This inclusion has proven successful in overcoming obstacles to implementation, and it has also helped to weave GLOBE more closely into the fabric of community life in small villages.

Although not all individual sources of funding have been stable, Elena's approach of creating a broad portfolio of strategic relationships has helped her transcend the unpredictability of single relationships and funding sources in establishing a sustainable funding base over time. Each of her partners provides either a source of funding or a way to support implementation directly. Moreover, she has sought both science and education partnerships, each of which has been able to make a contribution. Her position as a soil microbiologist and her close partnerships with educators make both these avenues of funding and implementation support more accessible to her than would be if she were solely an educator or scientist.

Possible Implications for the GLOBE Program and Its Partners

The GLOBE Headquarters plays an important role in supporting its regional partners, and is continually seeking ways to improve its partner support. Staff are dedicated to supporting different regions of the world. They provide tools on the GLOBE Web site to help partners monitor the activities of the schools they support, and at the annual GLOBE conference partners are invited to present and share their ideas for program improvement. The case studies described in this paper suggest several ways that GLOBE might best support its partners.

One possible implication for the GLOBE program as a whole is that it might choose to emphasize that GLOBE *is* real science, rather than encouraging teachers to see their data contributions *to* real science as the chief reason to implement GLOBE. This shift in emphasis is subtle, and it is important not to discourage students from reporting data that scientists can use. However, few teachers understand how scientists use student data, and it is unclear how consistently this information is communicated to students by partners in the first place. Moreover, to teachers the connection to scientists is primarily seen in terms of its educational value. The involvement of scientists seems to confer upon GLOBE legitimacy as a “real” science program, without watered-down or inaccurate content. Emphasizing this connection would reinforce a notion that many successful GLOBE teachers already have about what makes GLOBE special, while encouraging them to think about enacting GLOBE in their classrooms in ways that give the responsibility for “doing science” to the students.

Partners also need to be encouraged to understand their local teachers’ social networks and affiliations with different groups. Many partners already know about the educational groups in their areas, but science and environmental programs can also be significant in connecting teachers to GLOBE. Each of the teachers we interviewed could be described as having a real passion for the environment. Many belong to or participate in activities of groups that care for the environment. Partners who develop relationships with people inside those organizations may be successful in bringing in new teachers to the program, because those organizational representatives are trusted sources of information for participants.

The case study research supports the idea that follow-up support is critical and that some of this support must be provided in an ongoing way. Face-to-face support, especially mentoring, may be too expensive for all partnerships to undertake. Still, it has proven effective in both these partnerships. When distance prevents school-year visits, an annual conference—such as the one sponsored by Alaska—may be a good way to get teachers together. When cost prevents regular contact, providing the kinds of incentives that Alaska provides is students can be effective. Providing credit through distance learning courses to teachers promotes participation, and when incentives are tied to data reporting or implementation, teachers are more likely to follow-through than they would be if credit were tied solely to attendance at the training. These post-training activities, however, serve as incentives for promoting implementation, but they do not support implementation directly in the same way that mentoring does. Mentoring provides a window into a teacher's classroom and her context and often provides clues as to how a teacher may be adapting GLOBE (creatively, or unproductively) to their local context.

There are some implications for GLOBE's new work to emphasize the creation of "GLOBE Learning Communities" or GLCs. GLCs are a new idea in GLOBE, and the idea is to encourage partnerships to include more community-based organizations and members of the community in helping support GLOBE. Both Alabama and Alaska have found creative ways to include community members in GLOBE, although they have had to work hard to include the community in GLOBE. Especially interesting is Alaska's inclusion of Native elders in GLOBE. Although we did not begin our case studies with a focus on community involvement, the fact that these elders emerged as significant supports to implementation merits further attention in the program and in our research.

With respect to funding, it is clear that there is no magic solution to the problem of creating a sustainable base of funding. However, both partnerships have been strategic in forging partnerships with multiple organizations and with state organizations. As a result, they have been successful in finding a level of funding that has—through good times and bad—been able to keep the partnership moving forward. Both these partners' strategy of seeking funding from science and education sources has been critical to their success. Partners should certainly be encouraged to find leaders who are familiar with both these possible sources of funding.

References

Atkin, J. M., & Black, P. (2003). *Inside science education reform: A history of curricular and policy change*. New York: Teachers College Press.

Barstow, D., & Geary, E. (2002). *Blueprint for change: Report for the National Conference on the Revolution in Earth and Space Science Education.* Cambridge, MA: TERC.

Carpenter, T. P., Blanton, M. L., Cobb, P., Franke, M. L., Kaput, J., & McClain, K. (2004). *Scaling up innovative practices in mathematics and science*. Madison, WI: National Center for Improving Student Learning and Achievement in Mathematics and Science, Wisconsin Center for Education Research.

Cohen, D. K., & Hill, H. C. (2001). *Learning policy: When state education reform works*. New Haven, CT: Yale University Press.

Cohen, G. (2000). *Lessons from the Annenberg Challenge: Intermediary organizations as persuasive agents of change.* Unpublished master's thesis, Harvard University, Cambridge, MA.

Confrey, J., Castro-Filho, J., & Wilhelm, J. (2000). Implementation research as a means to link systemic reform and applied psychology in mathematics education. *Educational Psychologist, 35*(3), 179-191.

Elmore, R. F. (1996). Getting to scale with good educational practice. *Harvard Educational Review, 66*, 1-26.

Feldman, A., Konold, C., & Coulter, B. (1999). Network science, a decade later. *Hands On!, 22*(2), 1-2,16-18.

Fullan, M. G. (2000). Three stories of education reform. *Phi Delta Kappan, 81*(8), 581-584.

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal, 38*(4), 915-945.

McDonald, J., McLaughlin, M. W., & Corcoran, T. (2000, April). *Agents of reform: Role and function of intermediary organizations in the Annenberg Challenge.* Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, Louisiana.

Means, B., Coleman, E. B., Baisden, K., Haertel, G. D., Korbak, C., Lewis, A., et al. (1999). *GLOBE Year 4 evaluation: Evolving implementation practices*. Menlo Park, CA: SRI International.

Means, B., Korbak, C., Lewis, A., Michalchik, V., Penuel, W. R., Rollin, J., et al. (2000). *GLOBE Year 5 evaluation*. Menlo Park, CA: SRI International.

Moore, G. A. (2002). *Crossing the chasm: Marketing and selling products to mainstream customers*. New York: Harper.

National Research Council. (2000). *Inquiry and the National Science Education Standards*. Washington, DC: National Academy Press.

Nuefeld, B., & Guiney, E. (2000, April). *Transforming events: A local education fund's efforts to promote large-scale urban school reform.* Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, Louisiana.

Penuel, W. R. (2003). *Developing a rubric for characterizing curriculum integration in GLOBE*. Menlo Park, CA: SRI International.

Penuel, W. R., Korbak, C., Yarnall, L., Lewis, A., Toyama, Y., & Zander, M. (2004). *GLOBE Year 8 Evaluation: Understanding diverse implementation contexts*. Menlo Park, CA: SRI International.

Penuel, W. R., & Means, B. (2004). Implementation variation and fidelity in an inquiry science program: An analysis of GLOBE data reporting patterns. *Journal of Research in Science Teaching, 41*(3).

Songer, N. B., Lee, H.-S., & Kam, R. (2002). Technology-rich inquiry science in urban classrooms: What are the barriers to inquiry pedagogy? Journal of Research in Science Teaching, 39, 128-150. *Journal of Research in Science Teaching, 39*, 128-150.

Supovitz, J. A., & Turner, H. M. (2000). The effects of professional development on science teaching practices and classroom culture. *Journal of Research in Science Teaching, 37*(2), 963-980.

Yin, R. K. (2003). *Case study research: Design and methods* (3rd ed.). Thousand Oaks, CA: Sage.