

The Roles of Regional Partners in Supporting an International Earth Science Education Program

WILLIAM R. PENUEL, LINDA SHEAR, CHRISTINE KORBAK
Center for Technology in Learning, SRI International, Menlo Park, CA 94025, USA

ELENA SPARROW
School of Natural Resources and Agricultural Sciences, University of Alaska Fairbanks, Fairbanks, AL 99701, USA

Received 28 July 2004; revised 13 December 2004; accepted 9 January 2005

DOI 10.1002/sce.20079

Published online 19 August 2005 in Wiley InterScience (www.interscience.wiley.com).

ABSTRACT: This study explores the roles that regional partners play in helping to support implementation of the GLOBE program, an international earth science and education initiative. Researchers at SRI International conducted case studies of two GLOBE partners' practices in an effort to identify the factors that contribute to effective implementation of the program within a teaching approach that emphasizes student research. The chief finding of the case studies is that intermediary organizations in GLOBE help teachers both to address obstacles to implementing GLOBE-based student research in their classrooms and to align their curriculum to state standards and assessments. Such intermediary organizations may play similar roles in other science education programs, helping teachers to find ways to make nationally or internationally oriented science curriculum materials locally relevant and easy to adopt in diverse school settings. © 2005 Wiley Periodicals, Inc. *Sci Ed* **89**:956–979, 2005

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 authors and do not necessarily reflect the views of the National Science Foundation.

Correspondence to: William R. Penuel; e-mail: william.penuel@sri.com

This paper was edited by former Section Editor Angelo Collins.

REFORM INTERMEDIARIES AS CATALYSTS OF CHANGE AND IMPLEMENTATION

This study explores the role that intermediary organizations play in taking an earth science program successfully to scale. Beginning in the late 1990s, implementation research has increasingly focused on the role intermediary organizations play in carrying out large-scale school reforms. Intermediary organizations are typically nonprofit companies, universities, or other entities which are not part of the K-12 school system, but maintain school improvement as a key goal. Many schools now employ these organizations to provide professional development, materials, and teacher support in the implementation of school reform. Researchers have argued that intermediary organizations may be critical to the reform process because they can provide the knowledge, skills, and resources necessary to scale up reform efforts (Cohen, 2000; Fullan, 2000; McDonald, McLaughlin, & Corcoran, 2000).

Getting an educational reform or program to scale is itself a difficult undertaking, and many successful educational reforms and programs 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 necessary skills within their organization to shift from sheltered implementation in a few classrooms to the support of broad-scale implementation. Furthermore, while some organizations do have the skills, they are rarely large enough to support implementation beyond a limited geographical area. The costs to support a national or international program quickly exceed the resources typically allocated to educational programs and reforms. As with the adoption of new technologies in business, the scale-up process inevitably comes to depend on people and organizations outside the direct purview of the reform designers (Moore, 2002). Therefore, reliance on intermediary individuals and organizations may not only be desired, it may be necessary if the goal of a reform is to scale up and reach many classrooms. Furthermore, as outsiders, intermediary organizations can be better positioned to pose challenging questions to entrenched interests within school systems that have historically blocked the implementation or scaling up of significant reforms.

For their part, teachers may need people from intermediary organizations to help them adapt new curricular materials to their own classroom situations. This may be especially true when the program or reform seeks to reach diverse national and international classroom contexts where the challenges teachers face vary tremendously. 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 policy makers in science education (Atkin & Black, 2003). In fact, teachers will always need to explore how a new reform fits into their existing curriculum, and adapt the reform to meet the unique demands of their classrooms, school, district, and state. As a result those providing local support should have a good understanding of the setting where teachers are expected to implement a reform, and maintain relationships with both the designers of the reform and the teachers who enact it (Carpenter et al., 2004).

Neither these claims about the need for intermediaries nor claims about their functions in implementing reforms and programs have been systematically investigated in science education. Even in studies of schoolwide reform, where the work of intermediaries has been closely studied, there remains little research on the capacity needed for such organizations to succeed or which strategies are needed to succeed (Nuefeld & Guiney, 2000). This study investigates some preliminary hypotheses about the roles that intermediary organizations can play in an international earth science education program in promoting broadscale

implementation of inquiry-oriented¹ curriculum materials, seeking to offer a 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 earth science and science education program focused on improving the scientific understanding of students by involving them in the collection of data for real-scientific investigations. The program is organized into several “investigation areas,” each focused on a particular topic in earth 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, land cover, and plant phenology. 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 a goal of broadscale adoption by teachers. Since its inception in 1995, GLOBE has scaled up significantly. More than 20,000 teachers from 14,000 schools in 104 countries have been trained in the scientific protocols that are at the heart of the program. Based on the results of a recent teacher survey, the GLOBE program has reached between 153,000 and 244,000 students worldwide; this estimate is based only on students in schools that have reported data to the GLOBE Web site in the past 3 years (Penuel et al., 2002).

This degree of program scale has resulted in significant challenges for the program’s limited staff. By 1999, the program could no longer manage the training and support of teachers directly from its headquarters in Washington, DC. In order to offer a broader network of support for teachers, headquarters staff instituted a program to engage regional GLOBE *partners* to recruit, train, and support GLOBE teachers on a local level.

Since that time, the attention of partners and GLOBE program staff 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 Data Archive each month, implying that only a small fraction of trained teachers 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 GLOBE data, very few students have this opportunity (Penuel et al., 2002).

Partners have the primary responsibility for implementing strategies to improve these results since they function as intermediaries between GLOBE and teachers, acting as the local training and support arm for the program. The partners are similar to reform intermediaries in other contexts in that they tend to be organizations outside the K-12 system that have as their mission the improvement of science education in schools. When describing benefits to participation in GLOBE, partners more often cite their involvement in helping to improve science teaching than their role in helping the program to scale (Penuel et al., 2004). As Figure 1 shows, just under half of partners who responded to a 2003 survey ($N=73$) are housed within universities; of the partners in these settings, moreover, most are within colleges of education charged with teacher preparation.

Like many other intermediary organizations, GLOBE partners face the significant challenge of finding their own funding for their activities. The GLOBE program includes a small staff that functions as partner support, but does not fund partners directly for their

¹By inquiry-oriented, we mean materials designed to promote the understandings and abilities of inquiry as outlined in the National Science Education Standards (National Research Council, 1996, 2000).

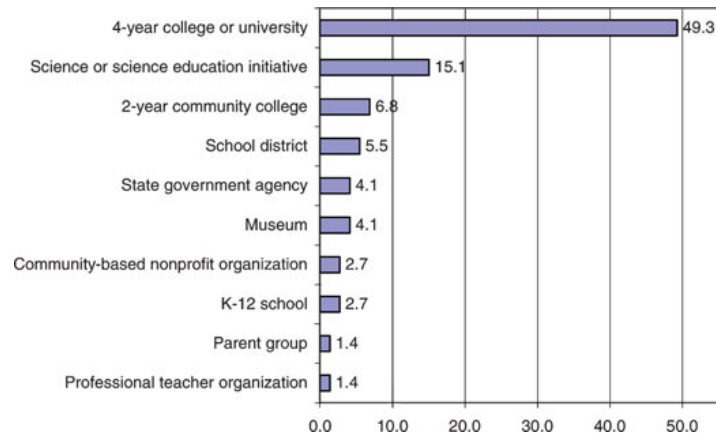


Figure 1. Partner organization type, percent reporting from partner survey.

activities. Partners generate financial resources from 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).

In the United States, GLOBE partners from different regions 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 conflicts with pressures to teach to state standards and perform well on accountability tests. In addition, more than two-thirds of US partners surveyed suggested that more resources are needed to follow up with teachers after their initial training to help them 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 conducted a set of case studies to help explain differences in the accomplishments of GLOBE partners. Case studies were selected to study these differences, because as a research team, we were interested in investigating more deeply a finding from our survey research of a broad sample of GLOBE teachers, which identified several post-training teacher support strategies that were associated with higher levels of data reporting (Penuel & Means, 2004). The focus of the case studies was further informed by alternative suggestions that have been articulated by different parts of the GLOBE organization (including partners) as to what partners should do to address implementation problems. This paper describes the design, findings, and implications of the case study research. Throughout the body of the paper, we will refer to the reform intermediaries that are the focus of the paper as partners or as GLOBE partners, since that is how they are known within the program.

DESIGN OF THE CASE STUDIES

Study Goals

This paper seeks to replicate and extend findings from an earlier study about the importance of particular implementation support strategies carried out by partners. The earlier study found that some strategies—particularly providing mentoring, equipment, and

supplementary materials—were all associated with higher levels of reporting GLOBE data (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 teachers perceived those supports as helping them to implement GLOBE, as well as the challenges that partners face in their work and strategies for overcoming them.

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 from partners to individual schools. Rather, our goal was to test several hypotheses about partners' challenges and successes. By testing these hypotheses, we sought to increase understanding of the potential roles of reform intermediaries in an earth science education program.

Study Design

We chose an explanatory multiple-case embedded design for this study (see Yin, 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 to carry them out. The primary unit of analysis is the *partnership* (the organization run by the partner), with its own mission, structure, staffing pattern, and organizational context; selected teachers were examined as embedded units of analysis “belonging to” the partnership.

Two partner cases form the basis of the analyses conducted for this paper. The 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 organizational structures. We describe below the similarities of the two cases as well as their 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): 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 teacher supports. Many earth science programs share with GLOBE several features that make them challenging to implement: field-based research that may require the establishment of data-monitoring stations outside the classroom, Internet-based data reporting, and a focus on content that typically comprises a smaller portion of the science curriculum standards in most states than other areas of science (Barstow & Geary, 2002; Feldman, Konold, & Coulter, 1999; Songer, Lee, & Kam, 2002). Research on intermediaries in earth science education, therefore, has the potential to inform how other programs address these challenges.

Hypotheses Guiding the Study

In multiple-case study designs, it is important to explore *rival hypotheses* that explain the phenomenon being studied (Yin, 2003). Researchers need to gather and analyze evidence that supports both primary or alternative, or rival, propositions as explanations for patterns in the data. By gathering data on rival hypotheses, researchers can reduce the risk that only their initial theories get serious consideration while alternatives are overlooked during case study analysis.

Our hypotheses and their rivals are drawn from the literature cited above and from our earlier studies of GLOBE partners. These hypotheses are used to guide the case study analyses that follow. We list and elaborate on each below:

HYPOTHESIS 1: MENTORING. *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 helping teachers overcome obstacles to GLOBE implementation.*

Evaluation studies of GLOBE have identified several barriers that make the program challenging for teachers to implement, including problems with obtaining equipment, limited Internet access, and difficulty with identifying appropriate data collection sites (Means et al., 1999, 2000, 2001; Means, Coleman, & Lewis, 1998). At the same time, our research indicates that face-to-face mentoring is an important predictor for different levels of data reporting (Penuel & Means, 2004). For purposes of this study, we began with a definition of mentoring as providing direct, one-on-one assistance to teachers on an as-needed basis. One GLOBE partner has suggested that face-to-face visits are the most important 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 one-third of partners surveyed reported that they are able to provide it. It would be advantageous if lower-cost alternatives could be identified to support mentoring.

HYPOTHESIS 2: SUPPORTING STUDENT RESEARCH. *Built-in GLOBE supports for student research are sufficient to encourage student research in classrooms around the world.*

RIVAL: *Specific work by intermediaries is necessary to support the implementation of student research in classrooms.*

In order to meet the educational goals of the GLOBE program, it is important not just for students to enter local data for use by scientists, but for students to take part in a process of scientific discovery related to those data. Student research can help students make connections among what they are learning in class, the research of actual earth scientists, and their own observations and experience in the world. The GLOBE program has a number of built-in supports for student research: for example, there are suggested research activities in the *GLOBE Teachers' Guide*, and a Web site makes data from local sites worldwide available for comparative analysis. However, research indicates that teachers need additional supports beyond standard curriculum materials to implement student-driven investigations in their own classrooms: they need opportunities to practice new teaching strategies in the context of their preservice and in-service preparation (Carpenter et al., 2004; National Research Council, 2000), access to experienced support providers (Carpenter et al., 2004), and professional development that is part of a coherent science education reform strategy (Garet et al., 2001) that is sustained over time to support the ongoing development of an "investigative classroom culture" (Supovitz & Turner, 2000). The GLOBE program office is insufficiently staffed to provide such supports to a broad range of teachers; however, GLOBE partners may be well positioned to offer some of these supports to teachers as a supplement to the supports and incentives within the GLOBE program.

HYPOTHESIS 3: CURRICULUM INTEGRATION. *The work partners do with teachers to align GLOBE activities with 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 often prevent them from implementing the program, despite the alignment efforts of partners.

Standards, large-scale achievement tests, and accountability systems are important drivers of educational reform throughout the United States and increasingly in other countries as well. Earth science typically does not occupy a central place in the standards or tests of most states, however (Barstow & Geary, 2002). In evaluation surveys and interviews, GLOBE teachers have reported 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. 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 4: SUSTAINABLE FUNDING. A few strategic relationships with other programs and with policy-makers allow partners to build a sustainable funding base.

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 (1) to seek a few strategic relationships of central importance or (2) to seek a broad portfolio of strategic relationships to reduce the 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

In a multiple-case study design, it is important to select cases that are either similar or for which the hypotheses driving the study would predict contrasting results (Yin, 2003). For this study, we selected two GLOBE program partners: 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 have as one of their primary goals supporting student research with GLOBE. They are also similar in how successful they are in training teachers who go on to implement GLOBE: these partners have the highest percentages of GLOBE-trained teachers who report data among U.S. partners.

The selected partnerships differ with respect to the geographical regions and student populations they support, as well as the specific support structures they have chosen to provide. In addition, we selected teachers to interview for this study who differed with respect to the types of support they received from their GLOBE partners, in order to be able to test our hypotheses about the importance of mentoring and other forms of post-training support for student research and standards alignment. We also sought teachers with different GLOBE 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 important categories of participants in partnerships and the schools they serve. A partner leader interview focused

on the structure of the partnership, funding strategies, and central challenges. A partner staff member interview was used with mentors, affiliates, and other people who assist with professional development or other teacher support functions. A school administrator interview focused on principals' perceptions of the program and its fit within their school. A teacher interview aimed at finding out 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 and in the field. These observations were designed to capture instructional goals, materials used, and sequences of activity. We attempted to capture dialogue and discourse throughout the observations in selected classrooms. Each of the observations lasted from 45–60 min.

The site visits took place in spring and summer 2003, and researchers spent a week in each state. Case study researchers visited each partnership in pairs, and set up visits to schools ahead of time. Where possible, researchers were asked to set up site visits in different regions of the states and to include both a rural and an urban school in their sample. Before their visits, case study researchers were given instructions on how to use each of the protocols and data capture forms, and were trained in their use in a session that included practice interviews in a roleplay format.

Analysis of Case Study Data

Upon return from case study sites, each research team completed two data capture forms. First, they completed a rubric for each school they visited, providing evidence in support of the rival hypotheses from interviews, observations, and artifacts they collected. The rubric was based on a model of GLOBE implementation developed for the evaluation of the program (Penuel, 2003). Rubric elements included not only implementation depth and quality but also the quality of external supports to teachers, including those provided by the GLOBE partner. Second, case study teams created a summary of five key themes from their case studies, providing evidence backing each theme. These themes were then reviewed by the partner leaders, as a check on their validity and to offer opportunity for comment.

Both these documents were used to 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 replications of one another: we reviewed one case, and then we conducted our analysis of the second case in light of the findings of the first. 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, schedules and other practical constraints precluded conducting these case studies as true replications, which would have necessitated the revision of site visit instruments after the first case to gather systematic data on the revised hypotheses.

In the reports that follow, we use the names of partnerships and their leaders, not pseudonyms. 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, and have found that they are open to discussing their challenges as well as their successes. Nevertheless, researchers independently developed the hypotheses and conducted the primary analysis on which this paper is based. As a further point of independent reference we look at partnership effectiveness from the viewpoint of teachers. All teacher and school names are pseudonyms.

GLOBE IN ALABAMA

GLOBE in Alabama, led by Greg Cox, has long been a significant and visible partner within the program. A lynchpin of its strategy in the recent past has been a system of mentors throughout the state who provide one-to-one support to teachers implementing GLOBE. Until recently, these mentors were led by another key staff member in the organization, Jennifer Lockett, who served as the original mentor and helped to organize mentoring activities throughout the state. GLOBE in Alabama has trained hundreds of teachers, many of whom have implemented GLOBE. The partner 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 GLOBE teachers have reaped the benefits. This success is a key reason behind selecting this partner for the case study.

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

In the following section, we explore teachers' experiences working with this partner, reviewing evidence related to our central hypotheses under each subsection. At the conclusion of the section, we consider revisions to our hypotheses that reflect what we learned in Alabama before turning to the Alaska case study.

Teachers' Introductions to GLOBE

The first necessary step in taking a program like GLOBE to scale is teacher recruitment. In Alabama, this step was supported strongly by the widespread connections of the GLOBE partner with other organizations related to earth science and earth science education. For example, GLOBE middle school teacher Fran Kastings is a member of a local hiking club and takes her students each spring to Oak Mountain State Park, a 10,000-acre park whose northern edge touches the school property; she heard of GLOBE through a ranger there who was working with a GLOBE mentor. Fifth-grade teacher Mary Castella first encountered GLOBE activities at her local arboretum, and was attracted to it "because the world is global," and local issues are global issues. In general, the GLOBE teachers in Alabama with whom we spoke encountered GLOBE through networks of people they already knew who shared their concern with the environment. These networks may be important supports to GLOBE's scaling in Alabama because they are trusted sources of information for teachers and thereby more effectively promote interest in the GLOBE program.

Mentoring in Alabama

Widespread implementation of GLOBE in Alabama has also been supported by Alabama's GLOBE mentors, who work to ensure that a high percentage of teachers trained will implement the program. The Alabama staff includes four paid, part-time mentors who are available to help trained GLOBE teachers through school visits, e-mails, and phone support. Each mentor is assigned to assist the schools in one or more geographic regions. They respond to teacher requests and make periodic visits to schools whose teachers they have helped train, aided by greater local proximity than is offered by the more centralized bases of GLOBE in Alabama.

The mentors in Alabama all have multiple affiliations, of which GLOBE is just one. Two of the mentors 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 mentor who also has teaching responsibilities has the least amount of time available to visit schools.

Mentors engage in various activities that they consider to be critical support for teachers implementing GLOBE. First, mentors provide models of GLOBE-teaching methods during visits to classrooms: the mentors model learning activities, protocols, and effective questioning strategies by demonstrating them while classroom teachers are in the room, either as observers or as assistants. Second, mentors collaborate on curriculum planning to help teachers see connections between GLOBE and local curriculum or state standards. Third, mentors help teachers set up equipment and solve problems related to taking measurements at study sites.

In each of the schools visited, teachers had received face-to-face visits from mentors. Fran Kastings 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 needs, and links to other GLOBE teachers (she works with an area high school teacher). According to Fran, these supports have been indispensable to her implementation of the program: on-site mentoring has allowed her to observe GLOBE teaching, helped her solve equipment problems, and given her another “team teacher” to work with, a support that is not otherwise available in her current school.

These mentoring activities appear to have had a significant influence on teachers’ ability to overcome obstacles to implementing GLOBE. The GLOBE program includes a vast array of data collection protocols and activities, and both Fran and Mary Castella characterized their initial training as “overwhelming,” despite the fact that it was spread over 5 months. Both teachers report that mentors were instrumental in helping them take their first steps to implementation. Mary was initially discouraged because other teachers in her school who had been trained were not implementing the program, and because she realized that she would have to wait an entire school year to purchase her instrument shelter (an important physical component of GLOBE) with school funds. She learned from GLOBE mentor Kathryn Royall that the partnership could provide the equipment at no cost to her school. Kathryn went to Mary’s school and helped her set up the shelter, and also brought a GPS unit, so that Mary could collect data about the study site.

In Cindy Kinnard’s case, she had gotten started with GLOBE on her own but got help from a mentor to re-implement GLOBE again after a 4-year hiatus. Cindy had suspended GLOBE implementation after changing schools, but learned from a colleague that GLOBE mentor Taylor was offering refresher-training courses. Cindy took the training with Taylor, and is once again using GLOBE with her students. She saw Taylor as someone who could help her get GLOBE started again in her new school. “He helps you remember how to do things,” she said.

According to Greg Cox, GLOBE in Alabama’s director, there are measurable qualities that make a good mentor, qualities that we observed mentors exhibiting. First, mentors should have some teaching experience, particularly in inquiry teaching, whether in a traditional 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. Second, the mentors need to be able to listen well to teachers and have the patience to manage a wide variety of situations. Careful listening is required to understand the serious obstacles to implementation that exist in schools and help teachers find solutions that are workable in their local settings. 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 foreign to them.

It would be a mistake, however, to attribute teacher success in overcoming obstacles to implementation to mentors alone. Fran Kastings, for example, had to wait for computer lab access before she could implement GLOBE; this was an issue that an outside mentor could not resolve. In addition, she teaches at a Christian school with a strong religious emphasis, and she was better positioned than an outside mentor to build a bridge between GLOBE and her school's Christian philosophy, presenting the program in a way that would be viewed as consistent with the faith of the school community. In some cases this required adaptations of the program; for example, Fran reports that some scientists' letters were omitted from the *GLOBE Teacher's Guide* for local use because of their inconsistency with school beliefs. Her principal's trust in Fran was a key factor in his decision to support GLOBE; he noted in our interview that Fran was critical in the school's effort to write its own science materials, and added that she would be a key participant in an upcoming school science summit.

GLOBE and Student Research

The GLOBE program can be implemented in a variety of ways in a given classroom. The minimum implementation that satisfies GLOBE headquarters is data reporting to the central GLOBE database that provides worldwide data for scientific study. A deeper implementation, and often a more meaningful one for educational purposes, includes student research and analysis related to the data collection they do in GLOBE.

Although GLOBE-trained teachers in Alabama have a relatively high rate of data reporting, the classrooms we observed provide little evidence of student research based on GLOBE data. One teacher reported that she would like to conduct a student research project but has yet to do so. Another said that she introduced her students to information about the local Alabama soil, but her students do not appear to understand why soils are important to study: one student wondered aloud when she came across a Web-based soil survey why anyone would do "such a boring thing." A third teacher has focused more on data collection and data entry than on data analysis in her classroom, and her students are neither familiar with patterns in their own data nor aware of what GLOBE scientists do with the data they report. Finally, while a third-grade teacher has been involved in a number of inquiry-based science initiatives and has her students begin all units by listing a set of testable scientific questions about the topic to be covered, these are unconnected to GLOBE activities.

While students in each class we observed appeared engaged and motivated, for reasons that ranged from comparing their own measurement activities to those of other classes to intrinsic interest in the measurement technologies, student research was not a successful focus of the partner activities. We have little evidence either that resources provided by GLOBE to support student research were used widely in Alabama, either. We did not see students looking at patterns in their data in classrooms we visited, and students did not report looking at their data with any regularity. A large incentive for research that the program office offered during the years of our study was GLOBE's learning expedition in Croatia. Students could submit reports to present there that posed original research questions that used GLOBE data they had collected in the analysis. Despite Alabama's many reporting schools, no students from Alabama were selected to present in Croatia.

Greg Cox confirmed that GLOBE in Alabama has placed less emphasis on student research, and he noted that his partnership's focus on encouraging data reporting is in response to an emphasis of GLOBE itself. He believes broader implementation will lead to higher quality data for scientists to use, so the partnership's efforts have been focused

on encouraging implementation and data reporting rather than on promoting student research.

Mentor Support for Curriculum Planning and Integration

One of the mentor roles identified as critical in Alabama is the support of teachers' planning for integrating GLOBE into their curriculum. Fran Hastings cited the opportunity to walk through her curriculum with her mentor, identifying areas of curriculum fit with GLOBE, as one of the important initial supports that gave her confidence to implement the program. Mary Castella noted that assistance from a mentor was particularly important in addressing her concern that there would not be enough time in her curriculum to integrate GLOBE, helping her to see the points of alignment between the required Alabama Course of Study and GLOBE. Despite integration support from the mentor, Mary still found that available time for GLOBE was limited in her self-contained elementary classroom, which demands coverage of all subjects during the day. Her solution was to make GLOBE into a centers activity, exposing only some students to deep involvement in GLOBE activities.

The perception that GLOBE would not align with local curricula was not a problem for Cindy Kinnard. Her school district was in the process of a 5-year reform of science education that emphasized student inquiry, and GLOBE content easily aligned with reform goals. Furthermore, while state accountability tests at the elementary level do not typically focus on science, parent advocacy at her school had resulted in a schoolwide emphasis on science. A room was dedicated to science at each grade level, and a large lab was built for all grades to use. Cindy perceived GLOBE to be a perfect fit that met her both her district's reform goals and her parents' demand for science education. As a result, she was able to perform all the needed alignment without support from her mentor in this area.

Sustainability in Funding for GLOBE in Alabama

A key to the success of the Alabama GLOBE partnership has been its ability to establish the funding and infrastructure to support mentors, equipment, and other activities, in part by creating a place for GLOBE within the state's mathematics and science initiatives. Their funding strategy has been to seek financial support from a combination of private and government sources. The mentor program has been funded by two state sources: the Department of Community Affairs, which gave the program approximately \$125,000, and the State Department of Education, which contributed another \$145,000. These contributions were significant for establishing GLOBE in Alabama, but they do not ensure its sustainability, as the flow of state resources to GLOBE can be affected significantly by a change in administration. As government funding is invariably unpredictable, and there has been little continuity of funding over the years, Greg Cox is looking to raise additional funding from the private sector to fully fund GLOBE in Alabama.

The sustainability of partnership programs like mentoring is further supported by GLOBE's successful alignment with Alabama math and science initiatives. The GLOBE program is seen as a valuable component of math and science teaching in the state; as a result, GLOBE training is now integrated with several other science initiatives, which helps to sustain training programs and broaden GLOBE's reach to more teachers and mentors.

REVISITING HYPOTHESES ABOUT GLOBE PARTNERS

Before turning to an analysis of GLOBE and the University of Alaska Fairbanks partner, we consider how our hypotheses about the role of partnerships in supporting implementation

might be revised or refined to better reflect findings from the Alabama case study. The revised set of hypotheses will serve as a guide to our analysis of the Alaska partnership.

HYPOTHESIS 1: MENTORING. 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 helping teachers overcome obstacles to GLOBE implementation.

Given that all the teachers we interviewed in Alabama had received face-to-face mentoring and all cited this assistance as essential to implementation, the Alabama case does not offer any evidence to contradict the hypothesis that this form of mentoring is necessary to overcome obstacles to implementation. For each of these teachers, evidence supports the claim that face-to-face interaction with mentors helped them implement the program in their classrooms. It must be acknowledged, however, that even with support from mentors, teachers continue to play a central role in overcoming obstacles to implementation.

The Alabama case study further revealed that mentors, through their own participation in social networks of science educators, are critical agents in the program's scaling process. Two of the three teachers in our study had encountered GLOBE through the people who became 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; whether this strategy might work as a recruiting tool in other partnerships merits further investigation.

HYPOTHESIS 2: SUPPORTING STUDENT RESEARCH. Built-in GLOBE supports for student research are sufficient to encourage student research in classrooms around the world.

RIVAL: Specific work by intermediaries is necessary to support the implementation of student research in classrooms.

In Alabama, we did not find examples of students engaging in research using GLOBE data. We may have missed such examples because we focused more on elementary schools, where student research is less likely, but in previous visits to Alabama middle- and high-schools we found little evidence of student research in those settings either (Means et al., 2000). The examples mentors put forth for inquiry were instead good examples of hands-on activities that engaged students' curiosity. In the one classroom we visited where students posed their own questions to guide inquiry in the classroom, these were not connected to GLOBE activities.

From our case studies in Alabama, therefore, we found little evidence to support either the idea that GLOBE's own incentives and supports were adequate for encouraging student research or the idea that mentors' activities encouraged it. Only one of the teachers we interviewed, Cindy Kinnard had clear ideas about how to foster student-directed research in the classroom, and in her case, the school district and parents were the primary drivers. The district provided professional development to support the adoption of inquiry teaching in science, but promoting student research in GLOBE was not part of that effort. To support teachers in promoting student research may take a much more concerted effort that involves coordination among GLOBE partner staff, district staff, and teachers.

HYPOTHESIS 3: CURRICULUM INTEGRATION. The work partners do with teachers to align GLOBE activities with 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 often prevent them from implementing the program, despite the alignment efforts of partners.

GLOBE teachers in Alabama listed curriculum integration among the critical supports they received from their mentors. One of the key activities in which mentors engaged was to help teachers map GLOBE to the Alabama State Course of Study. They did not just provide teachers with a list of standards; instead, they worked side by side with teachers to identify opportunities to integrate GLOBE into their curriculum in ways that helped them meet state standards. In that respect, both mentors and teachers felt the work that mentors did to help teachers see alignment with standards as critical to supporting implementation.

At the same time, neither partners nor mentors are completely able to overcome the difficulties teachers face in integrating GLOBE with their curriculum. In some cases, teachers had to map to parochial school standards and educational values with which the mentor was unfamiliar. In other cases, teachers needed to see the connections between GLOBE and their state's curriculum frameworks and standards for themselves. Where teachers perceived particular protocols to be both difficult to implement and only partially aligned to standards, they chose not to implement the protocols. As one teacher said of the soils protocol—a favorite of her mentor: “It’s a great idea, but I wasn’t going to do it” because it did not fit with her school’s curriculum.

HYPOTHESIS 4: SUSTAINABLE FUNDING. A few strategic relationships with other programs and with policy-makers allow partners to build a sustainable funding base.

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

GLOBE in Alabama has proven continuously resourceful with respect to funding, pursuing both small and large funders. Overall, the program has focused on a few strategic relationships with state officials and major partners, such as NASA. This focus has paid off in terms of helping to ensure GLOBE’s place in Alabama’s major mathematics and science initiatives. Yet neither state nor federal grant funds have proven to be consistent or reliable over time; funding has fluctuated greatly from year to year. More data, over a longer period of time, are needed to understand what kinds of strategies may be successful in producing a sustainable funding base for Alabama over the long term.

UNIVERSITY OF ALASKA FAIRBANKS

The GLOBE program at the University of Alaska Fairbanks is headed by soil microbiologist Elena Sparrow, who is also a GLOBE scientist in the area of phenology. The Alaska partnership started with funding from a handful of small grants and has grown to its current position as one of the most active and visible of the GLOBE partnerships. A distinguishing feature of the partnership is its successful blend of educational, scientific, and cultural concerns in its teacher-training activities combined with its strong support of GLOBE in local communities. The program has engaged scientists, teachers, and Native elders to explore how GLOBE can become one lens, along with other scientific and cultural ways of knowing, for observing changes in the local environment.

Like GLOBE in Alabama, the University of Alaska has developed partnerships with other science and education programs as well as statewide initiatives, which have in turn helped the GLOBE program to scale. One such initiative is a statewide attempt to integrate Native

Alaskan cultural knowledge with science education, which has provided an opportunity to align GLOBE more effectively with standards for reaching Native communities. Another important program component in Alaska is the summer teacher institute, a 2-week workshop that weaves together the three strands of science, best teaching practices, and culturally relevant curricula. Our site visit included an observation of the teacher institute, as well as a visit to a summer elementary program in a remote village that utilized GLOBE. We also interviewed several other teachers either in person or by phone.

In this section of the paper, we explore the Alaska partnership's primary strategies and how they have been experienced by teachers and students. We review evidence related to each of our hypotheses, and finally consider how the hypotheses should be adjusted to reflect new insights gained in Alaska.

GLOBE and Student Research in Alaska

The majority of GLOBE teacher preparation in Alaska is conducted within the observing locally, connecting globally (OLCG) program at the University of Alaska Fairbanks, funded by an NSF grant since 2000. The goal of the OLCG program is to provide Alaskan teachers and students the opportunity to engage in original global change research and to promote education on global change, while presenting students with culturally relevant opportunities to learn. The project's 2-week summer training institute includes the participation of Native elders and other local earth science experts to examine issues of culturally -responsive teaching and curricula as applied to GLOBE protocols and learning activities, and local earth science issues. Integrated throughout the science and cultural content, leading education professionals provide instruction on the inquiry cycle and other best practices in science and math education, including strategies for supporting 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 Alaska's GLOBE program have more varied opportunities to learn about inquiry science teaching than do most GLOBE teachers. Most standard GLOBE training focuses on mastery of the protocols, devoting less time to classroom implementation planning or to student research, and many partners report that their GLOBE teachers are not familiar with inquiry science teaching (Penuel et al., 2004). The added attention to inquiry and student research within the OLCG summer institutes offers a more comprehensive introduction to best practices in science education than is available to most GLOBE teachers.

In addition, GLOBE/OLCG staff report that they try hard to teach strategies that make GLOBE research relevant, capitalizing on students' innate questioning and curiosity rather than "assigning curiosity." This approach, they maintain, is well suited to the extremes of the Alaskan environment: in a natural setting where daylight and temperature vary drastically by season, and climate change is immediately visible in the changing patterns of ice breakup or the height of tundra plants, questions about the environment come naturally to students and can easily connect to possible topics of research.

Another mechanism the Alaska GLOBE team has used to expand its focus on student research has been to establish collaborative partnerships with other inquiry-based science education programs. GLOBE protocols are positioned as the data collection arm for existing inquiry science programs such as the Schoolyard Long-Term 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, GLOBE students in Alaska seem to have more opportunities to encounter inquiry with GLOBE than do students in other regions.

This increased statewide emphasis is reflected in Alaska's representation at the recent GLOBE Learning Expedition (GLE) in Croatia, a worldwide conference whose U.S. participants were selected competitively based on the quality of GLOBE student research reports they submit. Two students, each with their own project in the Fairbanks area, were selected to participate. One winning project was designed by a high school student, who chose to focus on the effects of hot water discharge from a local power plant on the dissolved oxygen levels of the nearby Chena River. She used GLOBE data to investigate the hypothesis that levels might be unusually low near the plant and therefore unable to support life. Her report incorporates a number of conventions of scientific communication: citation of prior work that frames the study, a clear explanation of the problem and its significance, a description of procedures she followed, and a statistical significance test to compare dissolved oxygen levels at two different sites along the river. Students from other schools have competed successfully at the Alaska Statewide High School Science Symposium and have presented at other international conferences.

For younger students, the research goals we observed were more modest. In a summer school class with students in grades 1–5, very little formal data analysis was conducted, but teachers did regularly engage the whole class in discussions of what their data might mean to help them better understand the science behind the measurements they were making. In this Native village, teachers drew upon local perspectives to add to the relevance of the activities; for example, the water cycle was introduced with a book called *Go Home River*, about a trip taken by a Native Alaskan boy and his father to experience the river from its origin to the sea.

Mentoring and Posttraining Support

Observations and interviews with teachers in Alaska are consistent with findings in Alabama that led us to conclude that mentors and teachers each make a significant contribution to overcoming obstacles to implementation. GLOBE in Alaska attributes the high statewide implementation rate to a strategy of closely following teachers after training and providing them with needed support. According to partner staff, GLOBE in Alaska judges the success of the partnership not on how many teachers are trained but on the level and quality of implementation at the schools. High quality implementation is considered to be contingent upon regular follow-up with teachers.

A key vehicle for maintaining face-to-face contact with teachers is through annual GLOBE/OLCG conferences held in Alaska. At these conferences, teachers receive follow-up training in both GLOBE protocols and in GLOBE-teaching strategies. 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 teachers up to date on the program.

Despite the vast distances that separate many schools from the partner headquarters in Fairbanks, Elena and her staff work hard to make site visits and provide hands-on support for teachers. Where possible, face-to-face support is offered for each of the program's three strands: (1) science (for example, troubleshooting GLOBE data collection challenges), (2) best practices and pedagogy (for example, OLCG co-principal investigator and GLOBE

trainer 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 (3) culturally responsive curriculum (for example, OLGCo-PI and GLOBE trainer Sidney Stephens often helps to identify local Native elders and facilitates their participation in the classroom). According to one teacher, this active support is “invaluable. . . the crucial thing that makes this program work.”

In addition, e-mail and telephone support on each of the three strands are extensive. Although the vast differences between villages in Alaska preclude the level of face-to-face contact during the school year that can be provided in Alabama, one remote teacher we interviewed told us that partner staff are “there for us if we ask for support.” Another teacher said that partner staff have been essential immediate resources to call, and that she has “huge stacks of e-mail” from them with practical ideas and suggestions. This teacher found this specific local advice particularly important in an extreme environmental setting with many practical challenges to hands-on research—for example, “solar noon” for data collection is after the end of the school day, and permafrost prevents many types of data collection during most of the school year. While partner staff work hard to be responsive to teachers who ask for help, however, they suggested that many teachers do not avail themselves of the opportunity, and distance makes it more difficult to stay visible as a source of support.

Finally, the Alaska partnership promotes implementation after training by providing incentives and accountability for implementing the program. Once trained, teachers are asked to submit journals of their teaching as well as student work samples to the partnership during the school year. These 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 Alaska GLOBE conference. Teachers are motivated to complete the work because they receive course credit at the university, which is contingent on them either reporting data or demonstrating through journals and student work samples that they have conducted GLOBE-related learning activities. As an additional incentive, many teachers receive grant funding to subsidize tuition expenses at the university and pay for travel to the summer training institute and the annual conferences.

Alignment with Standards in Alaska

As in Alabama, the Alaska partnership has worked actively to demonstrate alignment with state science standards. Elena Sparrow, Leslie Gordon, and one of the GLOBE teachers with whom we spoke serve on a committee to revise the standards, and they are discussed in the context of GLOBE training. Also as in Alabama, teachers play a very important role in helping to make connections to standards that allow them to implement GLOBE. One teacher described a collaborative curriculum integration process among the science team at his school; another described the way she must defend the use of GLOBE to school leadership. A third teacher serves on the state science standards committee, and uses resulting understanding of the alignment process to help her make connections between GLOBE and standards.

In addition to alignment with state science standards, the Alaska GLOBE partnership has sought to align the program with a set of standards that specifically address the needs of Native Alaskan students. The state developed these additional standards, called the *Alaska Standards for Culturally Responsive Schools* (Assembly of Alaska Native Elders, 1998), to inform the design of instruction for the state’s many Native students. These standards call on educators to identify ways that Native ways of knowing intersect with the forms of knowledge valued in school and in scientific disciplines, as represented by the science

standards. They also promote ways of involving Native communities as active participants in education.

Culturally responsive curriculum design is one of three core strands of instruction in the summer teacher institute. The institute includes explicit discussion of culturally relevant instructional models as a guide to curriculum development. It also integrates contributions from a number of Native participants who talk about traditional knowledge and observations of climate change: for example, elders leading a boat trip talked about respect for the land and changes over time, and a Native teacher from the northern whaling village of Barrow described a Native/scientist partnership that informed international policy on whaling restrictions.

Working locally with elders and other members of the local community is also promoted through ongoing facilitation by partner staff, who help make contacts and coach teachers in respectful relations and in creating opportunities for community participation in the classroom. Teachers consistently cited the ongoing challenges of involving elders—elders are far less visible and accessible in cities than in villages, for example, and their conceptions of time and topic may depart from the common workings of the classroom. The mentoring they receive from the program on these topics, according to teachers, is invaluable.

GLOBE teachers have reported that elder involvement can help to overcome resistance from school leaders to implementation. Sandy Hamilton, who also teaches in a school that is comprised primarily of Native students, says she gets little support for GLOBE from her principal and colleagues. 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.

The experiences of teachers in Alaska we have documented in our case studies indicate that there are actors other than teachers and partner staff who can play an important role in supporting implementation. Community members can inspire teachers and students, particularly by helping to demonstrate the relevance of GLOBE to local issues and to ways of living that are valued within the cultural traditions of students, and these partnerships can help rebuild trust of the educational institution in Native areas that have long felt a disconnect with White-run schools. Partner staff agree that so far too few successful examples exist of the desired integration of Native communities into the life of the science classroom. Nevertheless, early signs demonstrate that this approach can help bridge science standards, the scientific approach to data collection represented by GLOBE, and environmental awareness that is sanctioned by the community.

Alaska’s Strategy for Sustainability

Elena Sparrow has a successful track record of pursuing grants to fund work with GLOBE and to build capacity for the Alaska partnership. Her grant strategy has been to begin by applying for small grants of just \$5,000–10,000, and then gradually seek larger sources of funding. She has also built capacity by partnering with a network of trainers, scientists, and

other science programs. These partnerships contribute to Elena's salary and fund trainers, as well as providing important in-kind benefits in the form of access to large groups of teachers and integration with existing curricula and classroom projects. Altogether, at least 14 major partners and grant programs support the work of the University of Alaska-Fairbanks partnership, including both national and local sources.

Elena's approach is to view GLOBE as a way of supporting other science and education initiatives, which in turn support the dissemination of GLOBE. For example, GLOBE protocols are used to monitor coastal change in the Improving Understanding of Climate Change Variability program. Additionally, 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, components in the earth system. By partnering with programs like these, GLOBE has become valuable to local scientists and educators alike by providing tools to address immediate needs faced by other earth science programs. As a result of these partnerships, GLOBE is well integrated with a number of major state initiatives in earth science education.

DISCUSSION: FURTHER REFINEMENTS TO HYPOTHESES ABOUT GLOBE PARTNERS

The Alaska partner's experience as reported here indicates that further refinements to our working hypotheses are needed to more accurately reflect the experiences of students, teachers, and partner staff in GLOBE. In each of the central areas of focus—important supports for student research, partner support, standards alignment, and funding—we found evidence that effective partnerships function in ways not anticipated at the outset of our study.

HYPOTHESIS 1: MENTORING. 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 helping teachers overcome obstacles to GLOBE implementation.

Alaska provides a different kind of face-to-face encounter with partners than does Alabama, and the partner has developed effective strategies that do not rely on regular encounters with teachers throughout the school year. In addition to telephone and e-mail support, an important venue for mentoring is the annual Alaska GLOBE conference, which provides teachers with opportunities for sharing, for refresher training in protocols, and for implementation suggestions tailored to the local environment. Moreover, providing course credit for participation in GLOBE professional development activities appears to be a successful strategy for promoting implementation at a distance. Although teachers do not meet in person during the school year, they provide documentation to the partnership of their GLOBE activities, and credit is dependent not just on attendance at training but on successful program implementation. Teachers described their level of contact with the partnership as high despite limited face-to-face mentoring, providing support for the idea that these kinds of incentives may be a low-cost alternative to visiting schools regularly, especially in geographically disperse regions like Alaska.

HYPOTHESIS 2: SUPPORTING STUDENT RESEARCH. Built-in GLOBE supports for student research are sufficient to encourage student research in classrooms around the world.

RIVAL: Specific work by intermediaries is necessary to support the implementation of student research in classrooms.

In contrast to Alabama, the Alaska partnership specifically promotes student research in GLOBE through its professional development offerings. It also provides accountability and incentives to teachers for implementing GLOBE, a strategy that is relatively uncommon in the program. Together, these supports appear to pay off in terms of concrete student research projects.

At the same time, the coordination of Alaska's own incentives and the GLOBE office's competition for students to go to Croatia may have worked together to promote some projects. Alaska sent multiple student groups to the GLE and other international conferences, more than any other single partnership in the United States. Their experience suggests that GLOBE's own models and rubrics *can* be a guide partners can use, but it is important for the partners to share those as part of their professional development and provide follow-up to support student research with GLOBE as it gets underway.

HYPOTHESIS 3: CURRICULUM INTEGRATION. The work partners do with teachers to align GLOBE activities with 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 often prevent them from implementing the program, despite the alignment efforts of partners.

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 composed of students who are more than 80% Native Alaskan. These students' cultural backgrounds are a rich source of knowledge about the environment, and GLOBE through OLCG 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.

HYPOTHESIS 4: SUSTAINABLE FUNDING. A few strategic relationships with other programs and with policy makers allow partners to build a sustainable funding base.

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

Although not all individual sources of funding have been stable, the Alaska partnership's approach of creating a broad portfolio of strategic relationships has helped transcend the unpredictability of single relationships and funding sources to establish a sustainable funding base over time. Each of the organization's partners provides either a source of funding or direct support for broader implementation. Moreover, through Elena's dual role as soil microbiologist and educator the organization has sought both science and education partnerships, securing a more diverse portfolio of supports for the mission of GLOBE.

WHAT THE CASE STUDIES REVEALED ABOUT THE PARTNERS AND THE GLOBE PROGRAM

A hallmark of both these partners was the diverse strategies they used to mentor teachers, with similar positive effects on implementation. The case study research outlines a range of successful forms that mentoring can take. 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 its 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 appear more likely to follow through than they would be if credit were tied solely to attendance at the training. Although these posttraining activities serve as incentives for promoting implementation, 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.

Partners were not the only important agents in supporting implementation in either state. In Alabama, teachers themselves played a critical role in gaining principal support for their participation in the program and in forging connections between their work in GLOBE and other local initiatives in science. In Alaska, teachers in some cases called in Native elders to support their work and to help them justify to their school leaders why GLOBE could be an important educational experience for village youth. Certainly both GLOBE-created and partner-generated materials may have supported these teachers, but the work they did on their own was critical to overcoming barriers to implementation.

The contrast between the two partners' approaches to promoting student research also resulted in different levels of student research with GLOBE. In Alabama, where mentors promoted the idea of inquiry as hands-on activities designed to spark student curiosity and where we saw few students who looked at patterns in their schools' data, there was little evidence of sustained student research. By contrast, in Alaska where student research was promoted through formal professional development, students sought out and won several successful entries for spots in the GLOBE Learning Expedition, other international conferences, and statewide science symposiums. It may be that the clearer definition of student research, coupled with the incentives and resources provided by the partner and by GLOBE during the year of our study, worked together to promote student research in GLOBE. If that is the case, it is likely that in other partnerships, such a concerted effort may be needed to make the vision of students doing research that uses GLOBE data a reality.

These findings have some implications for GLOBE's new strategy of emphasizing the creation of "GLOBE learning communities" or GLCs. GLCs are a new idea in GLOBE, with the idea of encouraging 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 not found it easy to do so. 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.

It appears that resources on standards alignment provided by GLOBE headquarters and posted on the program's Web site had little influence on teachers' thinking, but the work partners did to help teachers see the alignment between GLOBE and their states' standards did influence them. The joint activity of "cross-walking" among teachers' existing curriculum, state standards, and GLOBE activities was particularly helpful in facilitating implementation, according to mentors and teachers in both Alabama and Alaska. It is not known whether such cross-walks, if simply handed to teachers, would have been as effective as the joint work that the partners engaged teachers in to construct these in the context of planning for GLOBE implementation. Future research might investigate this possibility,

since it may be either the joint work of mentors and teachers that is the critical factor or the local relevance that is important to making it easier for teachers to implement GLOBE.

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.

ALABAMA AND ALASKA PARTNERS AS INTERMEDIARIES IN EARTH SCIENCE EDUCATION

Both the Alabama and Alaska partners functioned as intermediaries do in systemic and school wide reforms that have been studied elsewhere. Like comprehensive school reform models where intermediary organizations have been helpful in the past, the partners focused on helping teachers reach a challenging goal: implementing a program that requires intensive and regular field study that only partially maps onto teaching practices with which teachers are already familiar. The partners, like other intermediaries, provided the necessary support to help teachers solve problems associated with the enactment of inquiry science activities in their curriculum (with differing degrees of success). By helping solve problems and providing models of teaching, they helped to lower barriers to the adoption of inquiry teaching approaches in science.

As intermediary organizations, both partners played an important part in helping to *localize* an international curriculum supplement. By localization, we mean the process of making connections between the broad goals of the curriculum and the local goals of educators and helping teachers adapt the program activities to fit within the constraints and demands on teachers. Such localization was a critical focus of the Alabama and Alaska partnerships' activities, and although teachers often adapted curricula on their own to meet local circumstances and in some cases had do so without much help from others, our study indicates that partners as reform intermediaries can help teachers by making explicit through conversation the opportunities for curricular integration, the kinds of student encounters with curriculum materials that may be more productive, and the ways activities may have to be adapted to fit a particular school schedule or set of grade-level content standards.

Localization has another meaning specific to earth science education as a field. Of particular import to engaging students in inquiry in earth science education is helping students and teachers identify questions to investigate that have particular relevance to the local environment. In Alaska, for example, the unique conditions of permafrost permit students to ask questions that cannot be posed or investigated directly by students in Alabama. The milder temperate climate in Alabama enables students to go outside to collect temperature and precipitation data throughout the year and address a different set of student questions about weather and climate. Intermediaries can help teachers and students identify earth science questions of local significance that are feasible to investigate as part of a classroom or after-school activity.

As intermediary organizations, moreover, these partners may have played a role in improving the quality of teachers' adaptations of inquiry curriculum. An enduring concern of science inquiry curriculum developers has been the degree to which teachers' adaptations of their curricula result in "lethal mutations" of the program's design (Brown & Campione, 1996; Brown & Edelson, 1998; Cohen, 1988; Reiser et al., 2000). In our case

studies, we saw evidence of different kinds of scaffolds to improve the quality of teachers' implementation of curriculum, including structuring incentives and formats for reporting on implementation and providing models of how to facilitate student inquiry. Although we do not have evidence from the present study that implementation was comparatively more effective in the classrooms where intermediaries provided support, we do know from earlier research that there is greater overall fidelity of implementation when teachers are mentored by intermediary organizations (Penuel & Means, 2004).

Despite the critical roles that these intermediaries appear to play in GLOBE, both organizations we studied faced considerable and ongoing obstacles to sustainability. They are not atypical of GLOBE partners in this regard, and their dependence on a patchwork of small and short-term grants limits their ability to work on an ongoing basis with the teachers they serve for multiple years. It has been widely recognized, however, that the school reform process is a long and slow one. Reform intermediaries like the partners we studied need more stable sources of funding and tighter integration among diverse curriculum initiatives if intermediaries are to achieve the kinds of "revolutionary" changes in earth science education that have been called for by reformers.

REFERENCES

- Assembly of Alaska Native Elders. (1998). *Alaska standards for culturally responsive schools*. Anchorage, AK: Alaska Native Knowledge Network.
- 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.
- Brown, A. L., & Campione, J. (1996). Psychological theory and the design of innovative learning environments: On procedures, principles and systems. In L. Schauble & R. Glaser (Eds.), *Innovations in learning: New environments for education*. Hillsdale, NJ: Erlbaum.
- Brown, M., & Edelson, D. C. (1998). Software in context: Designing for students, teachers, and classroom enactment. In A. S. Bruckman, M. Guzdial, J. L. Kolodner, & A. Ram (Eds.), *Proceedings of ICLS 98: International Conference on the Learning Sciences* (pp. 63–69). Charlottesville, VA: AACE.
- 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. (1988). Educational technology and school organization. In R. S. Nickerson & P. P. Zoghbiates (Eds.), *Technology in education: Looking toward 2020* (pp. 231–264). Hillsdale, NJ: Erlbaum.
- Cohen, G. (2000). *Lessons from the Annenberg Challenge: Intermediary organizations as persuasive agents of change*. Unpublished master's thesis, Harvard University, Cambridge, MA.
- 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, LA.
- 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., Coleman, E. B., & Lewis, A. (1998). *GLOBE Year 3 evaluation: Implementation and progress*. 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.
- Means, B., Penuel, W. R., Korbak, C., Lewis, A., Murphy, B., Vinson, E., et al. (2001). *GLOBE Year 6 evaluation: Explaining variation in implementation*. 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. (1996). *National Science Education Standards*. Washington, DC: National Academy Press.
- 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, LA.
- Penuel, W. R. (2003). *Developing a rubric for characterizing curriculum integration in GLOBE*. Menlo Park, CA: SRI International.
- Penuel, W. R., Korbak, C., Lewis, A., Shear, L., Toyama, Y., & Yarnall, L. (2002). *GLOBE Year 7 evaluation: Exploring student research and inquiry 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), 294–315.
- Reiser, B. J., Spillane, J. P., Steinmuler, F., Sorsa, D., Carney, K., & Kyza, E. (2000). Investigating the mutual adaptation process in teachers' design of technology-infused curricula. In B. Fishman & S. O'Connor-Divelbiss (Eds.), *Fourth International Conference of the Learning Sciences* (pp. 342–349). Mahwah, NJ: Erlbaum.
- 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.
- 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.