A Model for Enabling an Effective Outcome-Oriented Communication Between the Scientific and Educational Communities

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ABSTRACT

Traditionally, there has been a large gap between the scientific and educational communities in terms of communication, which hinders the transfer of new scientific knowledge to teachers and students and the understanding of each other's needs and capabilities. In this paper, we describe a workshop model we have developed to facilitate communication, enriching and enlightening those immediately involved and can be successfully implemented as part of any outreach activity, whether the scientific/technical or educational community initiates it. The workshop model is composed of preworkshop, workshop, and postworkshop elements that strategically scaffold the participants' experience through extended cross-community breakout and networking time. This model has enabled deeper understanding in each community of the other's needs, and in many cases has resulted in a concrete outcome in the form of an online Earth Exploration Toolbook chapter that can be used effectively in educational contexts beyond the workshop participants. © *2012 National Association of Geoscience Teachers*. [DOI: 10.5408/11-234.1]

Key words: Earth science data, data analysis skills, data analysis tools, transdisciplinary communication, interdisciplinary communication, transdisciplinary workshops, interdisciplinary workshops

INTRODUCTION

Traditionally, there has been a large gap between the scientific and educational communities in terms of knowledge transfer and meeting each other's needs. However, scientists are increasingly mandated, as a requirement of their funders, to make their data and knowledge accessible, useful, and have an impact beyond the scientific community. In addition, educators are pressured to enable their students to develop a deeper understanding of scientific topics through inquiry and other active learning approaches. Communication between scientists/technologists and educators/curriculum developers has always been difficult. Scientists generally do not really know what the teachers need to effectively teach their students and have a hard time translating their technical language into terms that teachers and students understand. Educators, on the other hand, generally do not know what scientific data and/or information they need to be effective, and if they do, they don't know how or do not have the time to obtain a data set and put it into a form they can use.

There have been efforts to bridge the gap between the scientific and educational communities with respect to knowledge transfer and effective access to scientific data sets. Many of these involve the participation and contributions of teachers on scientific research teams communicating both the excitement of the effort and the scientific discoveries that are being made to students in the classrooms, and creating educational materials to extend the impact to a broader range of educators and students (Dahlman, 2007; Cattadori et al., 2009; St. John et al., 2009; Niemitz et al., 2010).

Other mechanisms that have been implemented to facilitate the transfer of scientific knowledge between the scientific and educational communities are the student–scientist, teacher–scientist, and student–teacher–scientist partnerships. In these efforts, students and/or teachers are integrally involved in the research and not only develop a deeper understanding of the science that is the subject of their research, but an appreciation of the process of conducting that research (Lawless and Rock, 1998; Brooks et al., 2003; Ledley et al., 2003a, 2003b; Rahm et al., 2003).

In addition to the efforts that directly involve teachers and students in scientific research, scientific research organizations that archive scientific data sets and have computer simulation models for use by the scientific community have developed search, data analysis, and visualization tools that can enable educators and students to access and use the their data and tools (Bowden, 2006; Acker and Leptoukh, 2007; Chandler, 2007; Carter et al., 2008; Ward, 2008; Riebeek et al., 2009).

Each of these efforts has been successful to varying degrees in improving the transfer of scientific knowledge and enabling a broader use of scientific data sets in educational contexts. However, most of the knowledge transfer is from the scientific to the educational community, with the scientist in charge of the research program making their data and tools available to educators or providing input into educational materials at an advisory or review level. Input from the educators is generally directed to the research team's education and outreach staff, and the educators are usually in a subordinate position to the scientific/technical

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staff. In a few cases where scientists and educators were put together in an educational setting to develop and implement a teaching plan with the intent of mutual professional development, most of the partnerships defaulted to a consultation relationship rather than a full partnership (Nelson, 2005). In a study of knowledge interactions between scientists and teachers involved in partnerships, the cultural issues that were identified as impacting the degree of success of the partnership included the lack of "the scientists' knowledge of classroom realities" and "the perception of the scientists having higher status or power in the relationship" (Sussman, 1993; Drayton and Falk, 2006). The focus of most of these activities has been on the professional development of the educator with respect to science content, and not the professional development of the scientist with respect to science education.

The AccessData project and the preceding Digital Library for Earth System Education (DLESE) Data Services project (hereafter referred to together as AccessData) developed a model to facilitate two-way communication between the scientific/technical and educational communities by treating all participants as equals who bring valuable expertise to the conversation, thereby enriching and enlightening those immediately involved. This model can be successfully implemented as part of any outreach activity, whether the scientific/technical or educational community initiates the activity. This model was developed over 6 y with annual workshops from 2004 to 2009, and it is based on workshop results from an iterative evaluation method and efforts to effectively produce educational activities that could be used successfully by educators.

The Importance of Communication

Scientists are always being asked in their research proposals to describe the "broader impacts" of their work. While this does not exclusively mean an "education and outreach" effort, this is often the avenue that scientists pursue. To address broader impacts, many scientists describe their efforts to make their data available freely online, leverage education and outreach funding efforts at their universities and in local museums, give talks to students and teachers in informal science education settings and in schools and school districts, or attend workshops on how to engage educators (Morrow and Dusenberry, 2004; Peticolas et al., 2007; Carter et al., 2008). However, data made "freely available online" are often buried in a Web site or are so cryptic that even scientists just outside of the original research scientist's field have trouble accessing the data (Ledley et al., 2008). Leveraging educational and outreach activities developed by others outside the context of the scientist's research and providing talks to groups of students and teachers generally provide a limited exchange of information and no real or meaningful communication.

The goal of the AccessData projects has been to enable a deep and meaningful communication between the scientific/technical and educational communities. Two broad outcomes are inherent in our intent to attain this goal: broadening the data use perspective of participants and building educationally relevant data-use activities.

Through participation on an AccessData team (referred to as "the team"), scientists/technologists learned firsthand the needs of the educational community with respect to scientific data and knowledge, the requirements of the educational system that might constrain access to that information, whether intellectual or logistical, and how to interact with the educational community in an effective, ongoing way. Educators learned firsthand what scientific data and knowledge is available, conveyed to the scientific/technology community their specific data-access and data-analysis needs, and developed professional relationships with scientists/technologists, establishing a forum of equals that can facilitate future interactions.

The second outcome was the development of an online educational activity, built around the data, scientific knowledge, and educational needs discussed by the participants, in the form of an Earth Exploration Toolbook (EET; http://serc.carleton.edu/eet) (Ledley et al., 2006, 2011) chapter and DataSheets (educationally relevant metadata about the data sets used in the EET chapter, (Ledley et al., 2008)), which can effectively make the scientific data and knowledge available to a much larger number of teachers and students (Ledley et al., 2008).

EVALUATION METHODS

We employed an iterative evaluation method, administered by a professional external evaluator, where evaluations were used to serve the need of improving the workshop method. The iterative evaluation of the workshop through the course of the 6 y ensured that both the event and the evaluation protocol were enhanced and improved each year. Both quantitative and qualitative data were collected. Analysis of the evaluation data allowed the evaluator to suggest new opportunities to the project managers and support them in fine-tuning the experience for their participants. An additional benefit of this evaluation design was that each year's evaluation could be customized to address the different features of each workshop (e.g., specific talks and ToolTimes). Iterative evaluation also allowed project managers to monitor the change of attendee experiences over time with regard to the use of scientific data in educational settings. Information collected each year revealed attendees' experiences using scientific data for educational purposes; analysis of multiyear data sets revealed how these experiences changed over time.

Formative evaluation was included in the form of the brief, daily feedback surveys. Project managers met with the evaluator after each day's sessions, and feedback from the daily surveys was discussed. Problematic logistical and schedule issues were often addressed by program staff immediately, so that the remaining days of the workshop could be improved as they occurred, and were used as a guide for future years.

Survey instruments were fine-tuned each year to make them more robust and to add items particular to each year's workshop focus. For example, Google Earth did not become popular until 3 y into the project. This was added as an option for data formats and tools as Google Earth became widely available in the public domain (Kerski, 2008).

In addition to the surveys and workshop observations, telephone interviews with members of each team were

TABLE I: Number of workshop surveys used for evaluation.

Year	Daily Surveys	Data Use Survey	Final Survey	Poster Session Survey	Total Surveys
2004	4	1	1	1	7
2005	3	1	1	1	6
2006	3	1	1		5
2007	2	1	1		4
2008	2	1	1		4
2009	2	1	1		4

included in the evaluation for the last 3 y of the project. This provided an opportunity to collect rich qualitative feedback from a team perspective on how to improve the next year's workshop.

As the evaluation protocol and workshop design were refined, the number of surveys was reduced from seven in 2004 to four during 2007 through 2009. The poster session survey was integrated into the final survey in 2006, and the last-day survey was integrated into the final survey in 2007 (see Table I).

ELEMENTS OF A MODEL FOR EFFECTIVE COMMUNICATION BETWEEN THE SCIENTIFIC AND EDUCATIONAL COMMUNITIES

During each AccessData workshop, we facilitated, on average, 10 teams. However, the model we are describing can be applies to a single team or as many teams as is relevant for the scientific and educational communities involved.

The key elements of this model include:

- building the team (focus on the scientific data and analysis tool to be used),
- preworkshop team facilitation (setting expectations and goals, getting everyone on the same page, getting the initial work of the team under way),
- face-to-face workshop (outlining the storyline of an educational activity that uses scientific data to investigate a scientific concept or issue, and the steps to conduct that investigation), and
- postworkshop follow-up (completing the EET chapter and DataSheet, and making them available to others).

Building the Team

The core of this model is the AccessData team (again referred to as "the team"). Each team has five or six participants representing five areas of expertise. These areas of expertise include:

- the **data provider**, someone who knows the data sets and how to access them;
- the **tool specialist**, someone who knows how to use a data-analysis tool that can be used with the data;
- the **scientist**, someone who knows the scientific context of the data;
- the **curriculum developer**, someone who knows how to develop curriculum materials and will complete the EET chapter after the workshop; and
- the **educator**, someone who knows what needs to be and can be taught at a specific level and understands the scaffolding needed to make it effective for teachers and students.

Scientists, data providers, and tool specialists were considered members of the "scientific/technical community." Educators and curriculum developers were considered members of the "educational community." Any one participant might have had more than one area of expertise (Table II); however, all areas were required to be represented on a team. Nearly all participants identified themselves as having secondary roles, with the average number of secondary roles indicated on the final evaluation surveys for the workshops from 2006 through 2009 exceeding one for each area of expertise (Table II). A team was required to have five or six members with a balance of community representation. If a team had fewer members, there would not have been enough voices for rich discussion, and if there were more team members, all voices would not effectively be heard.

The building of the team began with the identification of the data archive, specific data set, or scientific research project that would be the focus of the team. This meant identifying the data provider (a member of the scientific/technical community). In order to establish a viable team, the data provider needed to understand the nature of the team effort. This was an effort to integrate some part of the data provider's scientific data into an educational activity and not a general discussion about education and outreach. As such, the data

TABLE II: Primary and secondary roles as self reported by participants. Data collected from 2006–2009 final surveys.

		Secondary Roles							
		DP	TS	SC	CD	ED	Primary Role	Average Number Secondary Roles	No Secondary Roles
Primary Role (160 total participants)	Data Provider (DP)		16	12	1	6	26	1.3	4
	Tool Specialist (TS)	11		8	8	6	22	1.5	2
	Scientist (SC)	16	6		8	17	31	1.5	2
	Curriculum developer (CD)	1	6	4		20	28	1.1	7
	Educator (ED)	5	7	18	35		53	1.3	11

provider required a limited but extended commitment from their organization that would permit two to three employees to attend the workshop. Initial discussions with the data provider revolved around identifying the individuals who would bring the expertise of the data provider, tool specialist, and scientist to the team. It was essential that all three of these areas of expertise be represented on the team by at least two and preferably three individuals, even if each individual had multiple areas of expertise.

Once the scientific/technical members of the team were determined, we identified the curriculum developer and educator. The curriculum developer was identified based on the match between the focus of the proposed team and the scientific interests of the curriculum developer as well as their knowledge of the data-analysis tool being suggested for the team. While not required, we found that curriculum developers with knowledge of the AccessData process and the requirements of an EET chapter were in a much better position to move the team forward and ultimately complete the EET chapter. The educator was identified based on their scientific interest and the grade level that was intended for the completed EET chapter. In most cases, once the data set was identified and the complexity of the access and analysis tools understood, the team was able to identify the intended grade level of the EET chapter. This could in principle be at the middle-school, high-school, or undergraduate level. However, as a particular data set could be useful at multiple grade bands, while an EET chapter is generally written at the high school or undergraduate level, in most cases it can be adapted to another level, e.g., middle school or undergraduate level for an EET chapter written at the high school level. In some cases, when the application of the data or the tool could cover a broad range of grade levels, having two educators that spanned two grade-level ranges was useful, such as having both a high-school teacher and college-level instructor on one team.

In building the teams, we worked to establish a balance between the scientific/technical and educational communities. We were able to achieve that balance as indicated in the final AccessData Workshop surveys (Table II). The scientific/technical community, whose primary roles were data provider, tool specialist, and scientist, made up 49% of the participants, and the educational community, whose primary roles were curriculum developer and educator, made up 51% of the participants. While it was expected that that members of the scientific/technical or educational communities would indicate a secondary role within the same community, we found that about 55% of the scientists who participated in the AccessData workshops also considered themselves educators in a secondary capacity. This was probably true because many scientists also held university teaching positions. Similarly, we found that 34% of the educators considered themselves scientists as a secondary role (Table II). This finding was important in that these particular team members were identified as "bridge builders"—potential facilitators and/or note takers—who were critical in ensuring team productivity.

Preworkshop Team Facilitation

The iterative evaluation method used for assessing workshop outcomes revealed a common workshop issue: Participants spend very little time preparing in advance for the workshop on their own. Instead, participants spent valuable workshop time becoming acquainted with the goals of the workshop and less time working as a team. As a result, participants from 2004–2006 were generally unable to complete one primary workshop outcome: an EET chapter. Starting in 2007, in order to make each team as effective and productive as possible during the workshop, it was helpful to have an AccessData project staff member hold at least two virtual 1 h meetings with each team before the start of the workshop. As a result, teams arrived at the workshop with goals in mind and ready to achieve team outcomes. It is worth noting that the original workshop in 2004 spanned 4 days. The latter workshops were reduced to 2.5 days, in part due to the effective utilization of preworkshop virtual meetings.

The essential goals of the preworkshop virtual meetings were to

1. introduce the team members to each other,
2. make sure all team members were aware of the expectations of the workshop and were familiar with the workshop logistics,
3. identify which of the data sets would become the focus of the EET chapter that would be developed and start a DataSheet on each of those data sets,
4. identify the data-analysis tool and type of analysis that would be used in the EET chapter, and
5. begin to brainstorm what the storyline of the EET chapter would be.

In the first virtual meeting, goals 1 and 2 were accomplished, and progress was made toward achieving goals 3 and 4. At the end of the first virtual meeting, the team had a good idea of the data sets they might be using, and the science/technical members of the team were assigned to complete as much of the DataSheet as they could. The completion of a DataSheet was the first important step in the collaborative process, requiring the input of both the scientific/technical and educational members of the team.

During the second virtual meeting, ideally two weeks later and at least one week before the workshop, the DataSheet was reviewed by the entire team, and the curriculum developer and educator were tasked with completing the educational information needed prior to the workshop.

At this point, all team members were familiar with the data sets and data-analysis tools that were planned for their EET chapter. They accomplished goals 3 and 4 and began to address goal 5: brainstorming the storyline for the EET chapter. The more polished the storyline was prior to the workshop, the more the team accomplished at the workshop in terms of identifying the cognitive and procedural steps needed for the eventual EET investigation.

AccessData Workshop

The AccessData workshop had to strike a balance among the effective and efficient working of teams, interaction of participants with others beyond their own team, participants learning about new data sets and/or

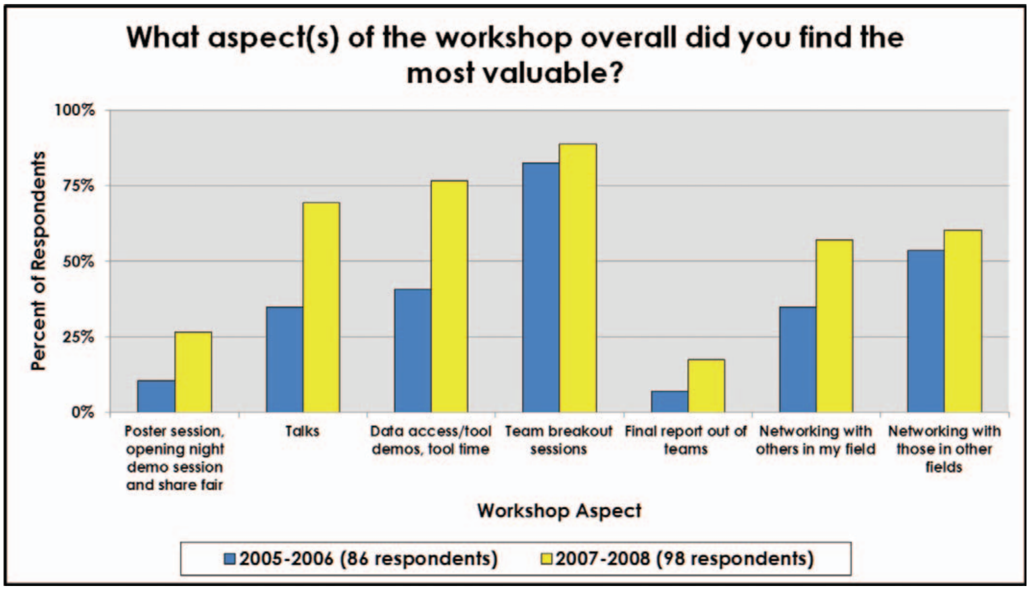

FIGURE 1: Valued aspects of the workshops held in 2005 and 2006 compared to those in the workshops held in 2007–2008. Significant changes were made to the workshop program in 2007. In 2005 and 2006, the team breakout sessions and networking were the most valued aspect of the workshops. After significant changes were made to the workshop program in 2007, participants noted that plenary talks, ToolTime, and team breakout sessions were most valuable, indicating a better overall balance of workshop activities.

analysis tools, and showcasing participants' ongoing work at their home institutions. This last item was sometimes a condition of the home institution for the team member (particularly scientists working for government agencies) to participate in the workshop.

The workshops in 2004 and 2005 consisted of breakout sessions for the teams, plenary talks, discussion questions engaging all participants, a breakout session by participant role, and a poster session. Final workshop evaluations of the workshop from 2005 and 2006 indicated that the most valued aspects of the workshop were the team breakout sessions and the ability to network with participants outside their field of expertise (Fig. 1). Participants also indicated a desire for a reduced number of plenary talks. As a result, the workshop evolved from an entire day of plenary talks and five team breakout sessions over 4 days (all team members were present on only two of those days in the first year [2004]) to eight breakout sessions and two morning plenary talks over 2.5 days in the last 3 y, 2007–2009. Final workshop surveys in the later years indicated a much better balance in perceived value of the workshop activities (Fig. 1). The poster session evolved into a Share Fair/Demo Session combined with a reception to enhance networking opportunities. The discussion questions session and the breakout session by role, which were not found to be effective, were replaced with ToolTime sessions. ToolTimes were opportunities for the participants to learn about a data-analysis tool that was not being used by their team, enabling the participants to learn something new and extend networking opportunities. The modifications we made to the workshop structure and agenda over the years clearly improved the perceived value of all aspects of the workshop. However, in aggregate, participants overwhelmingly valued team breakout sessions as the most valuable aspect of the AccessData workshops, indicating the importance of face-to-face, cross-expertise communication (Fig. 1).

Team Breakout Sessions and Online Workspace (Wiki)

A member of each AccessData team was designated as the *team facilitator*. While all members of the team were made aware of each breakout session goal, and these goals were listed on the online workspace (the wiki), the role of the *team facilitator* was to actively move the team toward these goals and to ensure that all voices on the team were heard. In addition, a team member was designated the *note-taking coordinator*. The role of the *note-taking coordinator* was to ensure that during the team conversations notes were taken and captured in the wiki. The *note-taking coordinato*r could either take all the notes themselves or assign the duty to different team members on a rotating basis from one breakout session to the next. The record captured in these notes included ideas that were brought up for discussion as well as images and links to suggested resources that might be used in the EET chapter being developed. This online record would be available to all team members after the workshop and was a resource for the curriculum developer as they developed the EET chapter.

Each breakout session had a goal that would ultimately get the team to a workable draft of an EET chapter by the end of the workshop. In many cases, the team discussion might not exactly fit the stated goals; however, stating these goals up front gave the team facilitator the authority to move forward if the discussion became stalled. The stated goals for the eight breakout sessions (which ranged in length from 45 min to 2 h) at the last AccessData workshop in 2009 are shown in Table III.

The Report Out session had two purposes. The first was to consolidate in the minds of the team members the exact data sets, data-analysis tools, and storyline they planned to use in the development of the online data-rich activity in the form of an EET chapter. The second purpose was to provide the AccessData project staff a concise summary of the plans of each team without having to discern it from the much more extensive team notes. We ran three concurrent Report Out sessions, facilitated by AccessData project staff, with only three or four teams reporting out in each session. This meant that each team had to listen to only two or at most three teams report, which only took half an hour. This Report Out structure was put in place in later years (in the initial years, the Report Out was a longer single session with all participants attending) in response to earlier final evaluation surveys that indicated the participants did not value those sessions (Fig. 1). It also had the benefit of permitting the increase of time for breakout sessions, one of most highly valued aspects of the workshop.

Networking Time and Venue Requirements

Networking with participants both outside and within each individual's field of expertise was highly valued (Fig. 1). Therefore, we worked to incorporate networking opportunities within the formal workshop agenda. Networking opportunities within the agenda included the Share Fair/Demo Session, with a reception the night before the workshop, and the ToolTime sessions, as well as breaks and meals. In some years, these opportunities were enhanced with a field trip prior to or after the workshop.

In order to provide as much networking time as possible, venues for the workshop had to have social spaces or facilities favorable for interaction. In order to maximize opportunity, the meeting spaces and lodging accommodations had to be collocated, with access to multiple dining options.

The nature of the AccessData workshop activities—extensive exploration of online Earth science data sets and data-analysis tools—put another specific requirement on acceptable venues: robust, reliable Internet access at a reasonable cost. In the initial years of the workshop (2004–2006), with approximately 70 participants attending each, this was an unusual requirement and rather difficult for most venues to accommodate at any cost. Fortunately, with improved wireless technology, finding appropriate venues at a reasonable cost became viable for the last 3 y of the workshop. It is worth noting that testing Internet access for both computer platforms prior to each workshop was crucial, as participants brought their own Mac or PC laptop computers to the workshops.

Share Fair/Demo Session

Initially, the poster session/reception was scheduled for the end of the first day of the workshop and was intended as a venue to allow participants to showcase their ongoing work. Evaluations indicated that most of the participants did not gain much from the individual posters; however, they did indicate that the session was useful for networking, especially with colleagues outside their own expertise. In order to enhance this experience and allow more time for team breakout sessions, the poster session was changed to a Share Fair/Demo session with reception on the evening before the workshop. This opened up much-needed time the afternoon of the first day of the workshop for an additional team breakout session.

TABLE III: AccessData workshop breakout session goals in 2009.

Session	Session Goals
1	Meet the team members and learn about the data, tools, and expertise represented on your team.
	Review DataSheet(s) and explore data and tools.
	Narrow down the range of data sets to a manageable number.
2	Brainstorm a set of possible storylines for valid investigations of the data set(s) the team had selected.
	Narrow down storylines to 1 compelling scenario, based on a genuine scientific question, that includes technological steps necessary to perform analysis of the data. (The team was provided with an Activity Outline Guide, http://serc.carleton.edu/usingdata/accessdata/workshop09/team/activity_outlin.html, to facilitate keeping this process on track.)
3 & 4	Select a data-use scenario and perform a proof-of-concept check. Use the complementary expertise on the team to check that the task envisioned can actually be completed in an educational setting
	Identify a target grade level for the activity and choose a working title
	Discuss and agree upon the content limits of the activity. Consider that the major goal of these activities is to develop user familiarity with the data and tools.
5 & 6	Finalize the storyline and outline the procedures for data access and analysis, including image captures for the procedures.
7	Enhance the step-by-step procedures by adding "About" sections to the EET chapter to provide extra information. Fill in any gaps in the activity outline and add sections that can help users make meaning of the data. Suggest several ideas for the "Going Further" section that challenge users to work with the data in current investigation and/or in other investigations. These suggestions provide launching points for scientific inquiry, which is facilitated by the skills learned in the activity.
8	Finalize the Activity Outline and DataSheet(s) and generate a 3-slide presentation for Team Report out session.

ToolTime Sessions

In 2004 and 2005, the workshop included plenary presentations of data-analysis tools. This did not prove successful, as participants felt a need to engage with the tools themselves to get a sense of their power and applicability to their own needs. Since each AccessData workshop had on the order of 10 data-analysis tool specialists as participants on the various teams, we instituted ToolTime sessions in 2006 (Table IV). By far, the most popular ToolTime sessions were on Google Earth and MyWorld GIS. A ToolTime session went beyond a simple demonstration of a data-analysis tool and instead offered participants first-hand experience in learning how a data-analysis tool could support a variety of learning outcomes. Session leaders actively engaged participants by leading them through an analysis of some data using the tool on their own computers. In addition, tool developers found it useful to present their tool to a broad group. We encouraged participants to go to ToolTime sessions featuring tools that were not being used by their team or to be inspired in considering new tools. In fact, during the 2009 workshop, a popular tool known as GeoMapApp was demonstrated during ToolTime alongside a brand-new, similarly developed tool, known as Virtual Ocean (http://www.virtualocean.org). The next day, a team considering using GeoMapApp learned that Virtual Ocean 2.0 was about to be released and decided to switch to Virtual Ocean, since the new tool provide a more familiar, Google Earth–style interface.

Postworkshop Follow Up

Following the AccessData workshops, participants were asked to complete the EET chapters outlined at the workshop. We the members of each team to remain responsive to questions by electronic mail and phone from the team curriculum developer. The curriculum developers were hired as consultants following the AccessData workshop to complete the EET chapter started by their teams. While the hiring of the curriculum developers as consultants proved effective in moving the team EET chapters forward (this funding was not available in the first 3 y, resulting in fewer completed chapters), it was still insufficient to bring them to completion. Bringing EET chapters to completion required hiring curriculum developers experienced in (1) developing data-rich inquiry activities, (2) the structure and requirements of an EET chapter, and (3) the use of the Science Education Resource Center's (SERC) Content Management System (CMS) (Fox et al., 2005), which is the technical infrastructure that supports the EET as an online resource.

The need for postworkshop follow-up was reflected in the comments of workshop participants in a survey conducted in 2009–2010 addressing the longitudinal impacts of the AccessData workshops (Lynds and Buhr, 2010b). Many participants felt that the team was waiting for the curriculum developer to move things forward; they felt that multiple postworkshop deadlines might help alleviate this problem. In 2009, we focused on following up with teams on their EET progress. As a result, our structured postworkshop follow-up succeeded in that of the 2009 workshop participants who responded to the longitudinal evaluation survey, only one was frustrated with the pace of EET chapter completion.

Completion of EET Chapters

Completion of EET chapters is an indicator of the success of the AccessData workshop model (Table V); however, it is an area in which we struggled. Many are familiar with the difficulty of keeping up the momentum of an initiative started at a workshop or meeting once the participants have returned to their home institutions and their attention is dispersed to their various other responsibilities. This was an issue that was encountered throughout the 6 y of the AccessData workshops. This was particularly difficult in the first 3 y, when funding for the curriculum developers to complete the EET chapters was not included in

TABLE IV: ToolTime sessions in 2006–2009. Numbers indicate how many sessions were offered during the workshop.

Tool Presented	2006	2007	2008	2009
NASA NEO http://neo.sci.gsfc.nasa.gov/Search.html	1	1	1	
MyWorld GIS http://www.myworldgis.org	1	1	1	1
Google Earth http://www.google.com/earth/index.html	2	2	1	1
ImageJ http://rsb.info.nih.gov/ij/	1			
Unidata Integrated Data Viewer (IDV) http://www.unidata.ucar.edu/software/idv/	1		1	1
Microsoft Excel http://office.microsoft.com/en-us/excel/	1			
Paleontological Stratigraphic Interval Construction and Analysis Tool (PSICAT) http://portal.chronos.org/psicat-site/		1		1
ArcGIS Explorer http://www.esri.com/software/arcgis/explorer/arcexplorer.html		1	1	
Stella http://www.iseesystems.com/softwares/Education/StellaSoftware.aspx		1		
NASA's Image2000 http://opensource.gsfc.nasa.gov/projects/nasaimage2000/index.php		1		
GeoBrain http://geobrain.laits.gmu.edu/			1	
GeoMapApp http://www.geomapapp.org				1
EdGCM http://edgcm.columbia.edu/				1

TABLE V: The number of teams facilitated at the AccessData workshops and the resulting number of completed chapters.

Workshop Year	Number of Access Data Teams	Number of EET Chapters Completed[1]
2004	10	6
2005	12	1
2006	12	0
2007	11	7
2008	10	5
2009	8	8

[1]Additional funds were obtained to complete some of the 2004 EET chapters. Those additional funds were not available for 2005 and 2006 teams. Funds were built into the budget for 2007, 2008, and 2009 to complete EET chapters. Four additional EET chapters were completed as a result of partnerships developed during the AccessData effort.

the budget. During that period, we facilitated 34 teams and completed seven chapters (Table V), an ~21% completion rate. Even with added funding in the last 3 y, we found that consistent follow-up with team curriculum developers and the addition of curriculum developers experienced with the SERC CMS and with EET chapter development were needed. With the additional support during the last 3 y, we facilitated 29 teams and completed 20 EET chapters (Table V), an ~69% completion rate. There were seven additional chapters that were developed enough by the teams to be viable for completion; however, they were not completed due to lack of funding.

As part of the EET chapter completion process, we conducted an internal review of the chapter by a curriculum developer who was not an author or involved with the team. Once revisions were made to the chapter based on that review, we solicited external reviews by both educators and scientists (Ledley et al., 2006). Many of the EET chapters were also featured in teacher professional development programs (Haddad et al., 2008; McAuliffe and Ledley, 2008). The process of going through the materials with teachers who were learning from and adapting them to their classrooms provided additional feedback for improving the EET chapters. The Earth Exploration Toolbook (2012) has received the Science Prize for Online Resources in Education from the *Science* magazine (Ledley et al., 2011).

BROADER IMPACTS

Emergence of Self-Organized Teams and the Contribution of Independently Developed EET Chapters

As would be expected with any new program, the initial effort required to engage the scientists, data providers, and tool specialists in a multiple-day workshop to develop an educational resource was difficult. However, the impact of the initial workshops on the participants made the effort in the following years much easier, with engagement of the scientific/technical community occurring within days/weeks rather than weeks/months. This evolved during the final 3 y of the funded effort, when past participants began to self-organize teams and approach us to participate in the next workshop.

In addition, a number of curriculum developers who participated in the AccessData workshops created activities based on data and data-analysis tools independently. These curriculum developers realized that their work could get broader exposure and use through visibility in the EET; they ultimately contributed three EET chapters based on this earlier work.

Participants Ran Other Workshops Based On This Model

The effectiveness of the structure and facilitation of the AccessData workshop model is also reflected in the comments made by various workshop participants in our postworkshop evaluation and longitudinal evaluation surveys.

"The workshop format has also become a model for other workshop efforts in which we have participated or organized" (Lynds and Buhr, 2010b).

"We have used the team format from the workshop to develop other modules" (Lynds and Buhr, 2010b).

"This is my third AccessData workshop, and I have actually used this model for smaller workshops that I've managed" (Lynds and Buhr, 2008).

The AccessData project staff has engaged participants in a number of large-scale, federally funded scientific research projects over the years. We worked with several these groups and conducted workshops or activities that had similar goals to the AccessData workshops. These included workshops focused on the data sets collected by large-scale research programs, such as RIDGE (Taber and Ledley, 2004; Swenson, 2006) and EarthScope (Olds et al., 2008). We also conducted a workshop for the National Aeronautics and Space Administration (NASA) in August 2008 to develop a Citizens and Remote Sensing Observation Network (CARSON) guide (Acker et al., 2008).

The workshops run for RIDGE, EarthScope, and the CARSON guide were similar in structure but smaller than the AccessData workshops. They each had three or four teams focused on data collected by, or of specific interest to, the organization requesting the workshop. EET chapters resulted from the RIDGE and EarthScope workshops, and an online citizen scientist guide resulted from the CARSON guide workshop (Table VI).

We piloted the implementation of the AccessData workshop model into the ongoing semi-annual meetings of the Federation of Earth Science Information Partners (ESIP Federation; http://www.esipfed.org). The ESIP Federation is a consortium of more than 120 organizations that collect, interpret, and develop applications for Earth observation information. The Air Quality Workgroup had been developing mechanisms to enable the use of air-quality data to inform environmental, health, and emergency decision-making. We engaged this group as a single team through a similar process to that of the larger workshops, using the breakout sessions of the ESIP Federation's semi-annual meeting to facilitate the team's development of an EET chapter, enabling the use of their data in education. The resulting EET chapter, "Tracking Wildfires Extent and

TABLE VI: EET chapters and similar resources resulting from implementation of AccessData workshop model for specific interest groups.

Workshop	Resource Title	URL
RIDGE	Exploring Seafloor Topography	http://serc.carleton.edu/eet/seafloor/index.html
EarthScope	Analyzing Plate Motion Using EarthScope GPS Data	http://serc.carleton.edu/eet/platemotion/index.html
CARSON Guide-NASA	The Citizens and Remote Sensing Observation Network (CARSON)	http://earthobservatory.nasa.gov/Experiments/

Aerosol Dispersal Using Satellite Imagery and Smoke Aerosols Data Sets" is still under development.

We have implemented this model in another venue that had a completely different expected outcome. The Climate Literacy and Energy Awareness Network (CLEAN) Pathway project is stewarding a collection of education resources that directly address the Climate Literacy: Essential Principles of Climate Science guide (USGCRP, 2009). A rigorous review process has been put in place for resources to be accessioned into the collection. As part of that review process, we instituted a CLEAN Review Camp (2010; http://cleanet.org/clean/about/2010_camp/index.htm), which was first held in July 2010. In this case, each of six teams had four members and included the expertise of the scientist, educator, and project resource collector. We used the model of the AccessData workshops to identify the teams, set the goals for each team, prepare the participants prior to the workshop to participate on the team effectively, and put in place the infrastructure to assure success.

Longer-Term Impacts Based on Longitudinal Evaluation Survey

It was apparent from the evaluation results after each annual workshop (Buhr and Lynds, 2004; Lynds and Buhr, 2005, 2006, 2007, 2008, 2009) that participants from each community of expertise appreciated and benefited from the extended contact with participants who had expertise in the other areas (Fig. 1). This was reiterated in the "2010 Impacts Workshop Evaluation Report" (Lynds and Buhr, 2010a) and the "Longitudinal Impacts Survey Results" (Lynds and Buhr, 2010b) and indicates the power and effectiveness of the AccessData workshop model in effectively bridging the communication gap between the scientific/technical and educational communities. Some of the comments from the longitudinal evaluation survey, along with the community of expertise of the respondent, are shown in Table VII.

Throughout the implementation of the AccessData workshop, all participants were treated as peers regardless of their area of expertise. A number of the curriculum developer and educator participants commented that it was

TABLE VII: Comments from longitudinal evaluation on the long-term impacts of the AccessData workshops.

Expertise	Comments
Data Provider	"It allowed meeting others who were interested in this approach to Earth Sciences and had discussions beyond our specific group meetings."
Tool Specialist	"I value very much the opportunity to work in multidisciplinary teams like this workshop format made possible. Scientists, software developers, educators, curriculum and data specialists too rarely get to work closely on a project. I only wish I could work in an environment all the time like this! But, since that's not an option I would very much appreciate more opportunities like the AccessData workshop presented."
Curriculum Developer	"I have become a better educator because of these workshops. I have learned multiple methods to introduce technology and data to teachers and students. I have gained new perspectives and an appreciation of working with a range of disciplines and expertise through these workshops. I enjoy the teamwork these workshops have modeled for me."
Curriculum Developer	"The networking and interaction with the wide range of professionals in my field has been invaluable!"
Educator	"My level of confidence working with the tools I learned about through the workshops has increased as has my interest in learning about other tools and databases to teach the geosciences in a more data driven and quantitative format."
Educator	"My participation and exposure has made me realize how much of a need there is for this type of work. Educators need tools like the ones developed for the EET and don't have time to develop them on their own. Scientists and technical people have a desire to have what they know via their data applied in educational settings, and so having these team efforts used to create resources for educators provides a significant service."
Educator	"These workshops provide additional reasons (through collected data) for the need for good data interfaces, contextualization of data and their interfaces, and for tutorials. Plus there are many common issues that many of us face but often don't have a community where these issues can be discussed; these workshops provide such a venue for creating and maintaining these connections. It was an amazing workshop with a lasting impact. Thanks!"

the first time that they had been respected and valued for the expertise that they brought to the work of the team and treated as equals by the participants who brought scientific and technological expertise.

SUMMARY AND RECOMMENDATIONS

The aspects of the AccessData workshop model that were essential to the success of the implementation in other venues include:

1. explicitly stating goals and product(s) of the workshop;
2. identifying expertise needed to accomplish the goals and contribute to the development of the products;
3. the formation of a team of five or six people with all areas of expertise represented;
4. identifying the steps that need to be taken in order to accomplish the workshop goals and product(s);
5. determining which steps can best take advantage of face-to-face workshop time;
6. facilitating team members accomplishing the preliminary steps prior to the workshop (teleconferences and online collaboration space);
7. providing an online workspace for each team for the capture of information and documents prior to and during the workshop, including wiki discussion and suggested resources to use in the final product(s); and,
8. the development of a workshop agenda that focuses on
    a. team breakout sessions as a majority use of the time,
    b. plenary talks that are of general interest to all but limited to one at the beginning of each day,
    c. an online workspace that identifies the goals of each breakout session and provides space to capture the discussion, and
    d. a team facilitator and note-taking coordinator identified and prepared by workshop organizers prior to workshop.

In this paper, we have described a workshop model that provided successful communication between the scientific/technical and educational communities in meeting the goal of creating educationally relevant access to and use of scientific data. The workshop model is composed of preworkshop, workshop, and postworkshop elements that strategically scaffold the participants' experiences, which allow for deeper cross-disciplinary understanding, rather than one community engaging the other community in disconnected activities. We strongly recommend that the scientific/technical community in preproposal stage adopt the AccessData workshop model as a critical component of their "education and outreach" activities, including the iterative evaluation model. We strongly recommend that the educational community reach out to large, scientific data centers in order to engage them in adopting the AccessData workshop model.

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