The Earth Exploration Toolbook: Facilitating Access to Scientific Data and Tools

Tamara Shapiro Ledley — TERC, 2067 Massachusetts Ave., Cambridge, MA 02140, Tamara_Ledley@terc.edu

LuAnn Dahlman — TERC, 2067 Massachusetts Ave., Cambridge, MA 02140, LuAnn_Dahlman@terc.edu

Carla McAuliffe — TERC, 2067 Massachusetts Ave., Cambridge, MA 02140, Carla_McAuliffe@terc.edu

Nick Haddad — TERC, 2067 Massachusetts Ave., Cambridge, MA 02140, Nick_Haddad@terc.edu

ABSTRACT

In order to effectively make Earth science data accessible, usable, and useful by the educational community it is clear that there needs to be a spectrum of services and resources that address the obstacles and support the efforts starting from the research scientist and ending with the student. We describe resources and services here that address a number of components of this spectrum. The Earth Exploration Toolbook (EET, http://serc.carleton.edu/eet) is an online resource that contains chapters, each of which provides step-by-step instructions to walk users through an example of using data and tools in a way that is relevant and interesting to the teachers and students. We developed a mechanism to support the development of new EET chapters, offering scientists an effective mechanism to provide their data, analysis tools, and scientific knowledge to the educational community. In addition, we piloted a professional development workshop series to facilitate the use of EET chapters by teachers.

We have found that providing scientists with a partnership and mechanisms that help them facilitate the use of their data, analysis tools, and scientific knowledge by the educational community is very effective, and that providing professional development for the use of EET chapters is very important for facilitating the use of scientific data and analysis tools in education..

INTRODUCTION

The value of involving students in an inquiry process to learn Earth science concepts has been stated widely (AAAS, 1993; Barstow and Geary, 2001; National Research Council, 1996). Furthermore, master teachers have observed that students learn scientific concepts more fully if they use data to explore concepts themselves (Manduca and Mogk, 2002). This observation has been embraced by the geoscience and educational communities and several groups, both technological and educational, are actively working to bring real scientific data into teaching and learning (DLESE, 2001; Manduca and Mogk, 2000; Wright and Sumner, 2003).

On the technological side, recent advances have provided access to distributed scientific data sets as well as the tools to examine and analyze them. There are a number of efforts currently underway (e.g. THREDDS project (Domenico, 2004a; 2004b; Domenico, et al., 2002) and the interoperability efforts by the ESIP Federation (ESIP Federation, 2002)) to develop these tools in such a way as to facilitate them being used effectively by the educational community.

On the educational side several projects produce educational modules that facilitate access to educationally relevant subsets of large datasets and the tools needed to help teachers and students use them to improve their understanding of concepts in Earth system science (e.g.,the WorldWatcher project (Edelson, 2002), Planet Earth Science Expedition CD's (Planet Earth Science, 2002))

Despite th.ese efforts, educators still face obstacles when trying to access and use data and analysis tools to study the Earth system. Obstacles include finding data-rich educational modules or activities that 1) address the specific scientific concepts that educators need to teach, 2) are relatively easy to learn to use, and 3) are available at no or low cost (Dexter, et al., 1999; Hanson and Carlson, 2005; Macdonald, et al., 2005).

It is clear that in order to effectively make Earth science data accessible, usable, and useful by the educational community a full spectrum of services and resources is needed to address these obstacles and supports the effort starting from the research scientist and ending with the student. These services and resources include 1) mechanisms that support scientists, data providers, and tool developers offering their data, tools, and scientific knowledge to the educational community in a useful way, 2) detailed instructions for accessing and analyzing data and information about how working with the specific data matches educational standards and curriculum, 3) providing professional development for educators to guide them through the use of specific datasets and analysis tools, 4) support for educators to help them integrate the use of data into their teaching, and 5) further study to determine the effectiveness of using data for students in exploring and understanding Earth science concepts.

In this paper, we describe resources and activities that address numbers 1 through 3 in the spectrum described above. The Earth Exploration Toolbook (EET) is on online collection of computer-based activities, called chapters, which provide instructions for accessing and analyzing various Earth science datasets. They include pedagogical information to facilitate the integration of the use of those datasets and analysis tools into teaching and learning; this addresses number 2 in the spectrum above. In order to help scientists, data providers, and tools developers make their resources and knowledge available to the educational community, we have developed the EET chapter template that identifies the components of a successful EET chapter and offers guidance on what they should contain; this addresses number 1 in the spectrum above. In order to give teachers hands-on experience using the datasets and tools featured in EET chapters, we piloted a series of professional development online-telecon workshops. In

Figure 1. The Earth Exploration Toolbook homepage

the workshops teachers dial in to a toll-free teleconference and are online at the same time. Participants walk through a specific EET chapter, downloading the data and tool necessary and using them in a valid scientific investigation. Once they complete the chapter, teachers have the data and analysis tool on their own computers ready to use with students; this addresses number 3 in the spectrum above. Prior to and following these telecon-online workshops we administered surveys to learn of teacher's use of Earth science data in their teaching in the past, to find out how effective they felt the workshop was in helping them learn about how to conduct an inquiry investigation using data, and to discover how likely it was that they would use of these resources with their students.

THE EARTH EXPLORATION TOOLBOOK (EET)

The Earth Exploration Toolbook (EET, http://serc.carleton.edu/eet, see Figure 1) was initially conceived as a result of discussions in the scientific and educational communities. Initial discussions occurred at the Data Access Working Group meeting in February 2001 (DAWG_DLESE, 2001a; 2001b). Participants in this meeting, many of whom had developed methods of using their research datasets in their undergraduate classrooms, were concerned about how to enable other educators at the 7-16 level to effectively use these datasets and tools in their own classrooms. These discussions were followed by the development of a prototype that helped focus larger community input at the 2001 DLESE Annual meeting (http://www.dlese.org/annualmtg/2001/Sessions/Boyd_DAWG_workgroup.html).

The EET is a free online resource that overcomes many of the obstacles discussed above. It is made up of a set of case-study examples of educational uses of Earth science datasets and analysis tools. Each activity or "chapter" in the EET presents step-by-step instructions to walk users through an example of using data and tools in a meaningful context. Clear instructions guide users through the technology to analyze data that illustrates issues in Earth system science. Screenshots are available to help novice technology users complete complex operations. Chapters also offer suggestions for further exploration of the data and other ways to use the tool featured in the EET chapter.

EET chapters are designed for use by teachers of grades 7-12, undergraduate faculty, and their students. Each chapter features specific datasets and analysis or visualization tools, and typically users download software and data, and produce a product such as a map or graph, and perform analyses. The intent of the chapter is to provide enough experience and in-depth knowledge of these resources for a teacher or faculty member to be able to use and adapt them for use in their own classrooms, or assist students in using the resources to investigate aspects of the Earth system. In this way an activity described in a particular chapter which might be designed for a specific grade level might be used by different teachers for different levels of students by simplifying the investigation or making it more complex. For example the Investigating the Streamflow-Precipitation Relationship chapter (http://serc.carleton.edu/eet/module_discharge/index.html) is described as being a 9th-12th grade activity and has students examine the relationship between precipitation events and

EET Chapter Title	Data Featured	Data Analysis Tool Featured
Investigating Earthquakes: GIS Mapping and Analysis	Recent and Historical Earthquake Data	ArcVoyager GIS
Using GLOBE Data to Investigate the Earth Sytem	Student-Collected Environmental Data	GLOBE Online Graphing Tool
Annotating Change in Satellite Images	Landsat Images	ImageJ
Exploring Regional Differences in Climate Change	Climate Model Simulations of Fuure Climate	EOS-Webster and Spreadsheet Application
Investigating the Streamflow-Precipitation Relationship	Streamflow Data, Precipitation Data	Spreadsheet Application
Analyzing Populations with Maps	Census Data	United States-Mexico Demographic Data Viewer
Measuring Distance and Area in Satellite Images	MODIS Images	ImageJ
Analyzing Wetlands	Wetlands Descriptors	Ramsar International Wetlands Data Gateway
Looking into Earth with GIS	Seismic Wave Model Output	Arc Voyager GIS
When is Dinner Served? Predicting Ocean Phytoplankton Blooms	Ocean Buoy and MODIS Images	GoMOOS (Gulf of Maine Ocean Observing System) Online Graphing Tool, WebCOAST
Visualizing Carbon Pathways	Satellite-Based Global Data Sets from NASA	NASA Earth Observatory Animation Generator, Carbon Visualator
Mapping Environmental Quality Around the World	Environmental Sustainability Index	MyWorld GIS
Analyzing the Antarctic Ozone Hole	TOMS Images (ozone levels)	ImageJ and Spreadsheet Application

Table 1. Earth Exploration Toolbook chapters currently available online and the Earth science dataset and data analysis tool featured. Each chapter has undergone a rigorous internal and external review process.

changes in streamflow rate using the spreadsheet application Excel. However, middle school teachers can simplify the activity by creating graphs that only have one variable, such as precipitation, to enrich their study of the weather. Undergraduate faculty can use the activity as an introduction to an advanced area of study, or make the investigation more complex by adding variables to the graph and comparing the relationship between the variables at different locations.

We test and refine individual EET chapters through an iterative process of review and revision. This includes an internal review to assure EET chapter consistency, a review by two external teachers for pedagogy and a scientist for scientific accuracy, and finally a field test of the chapter. Chapter authors make revisions in response to each of these reviews which are then approved by the reviewers. This process ensures that the chapters are easy to use, scientifically accurate, and the supporting resources are of the highest quality.

EET Chapters - The chapters of the Earth Exploration Toolbook comprise a collection within the National Science Digital Library (NSDL) and the Digital Library for Earth System Education (DLESE). Table 1 lists available EET chapters (in 2005) and the Earth science datasets and data analysis tools they feature. The diversity of topics increases the possibility that teachers will find a chapter that either relates to content their students must study or has a natural appeal to their students. The consistent theme that connects the diverse chapter topics is the Earth system; every chapter highlights some aspect of the Earth system and its interacting components.

EET chapters can play a major role in keeping science current in educational settings. Several of the existing chapters are the result of collaborations between scientists, tools developers, and curriculum developers at DLESE Data Services Workshops (http://www.dlese.org/cms/dataservices/). At these workshops, teams plan how the data from current scientific investigations can be made accessible to students via EET chapters. The possibilities for the future are rich. For example, teachers and students can follow new scientific initiatives such as the Ocean Research Interactive Observatory Networks (ORION), the International Polar Year (IPY), the International Heliophysical Year (IHY), and others through future EET chapters related to those projects.

EET Chapter Structure - We have created a common structure for chapters in the EET. The structure is indicated by the standard navigation bar that appears on each chapter's homepage (see Figure 2). This consistency provides teachers and students with an interface that becomes familiar, and helps them to communicate using a common language. The menu identifies the six basic elements of every EET chapter: the Chapter Title, Teaching Notes, Case Study, Step-by-Step Instructions, Tools and Data, and Going Further.

- The *Chapter Title* section of the menu provides a brief overview of the chapter content.
- The *Teaching Notes* section provides extensive curricular details about the chapter, including the target grade level, learning goals, links to appropriate national science, math, and geography standards, teaching suggestions, background information, and links to additional resources
- The *Case Study* section presents a relevant and interesting context that draws users in via a question

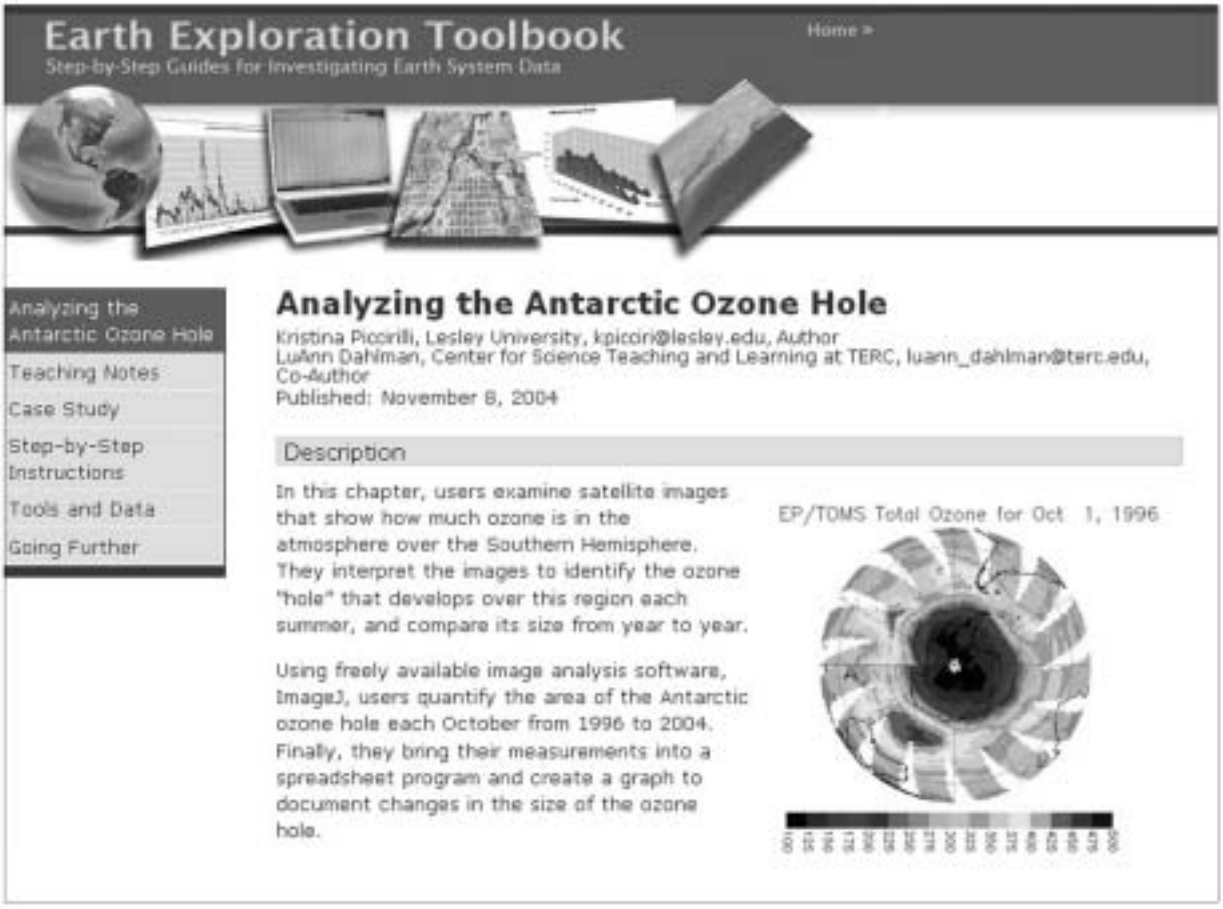

Figure 2. Typical EET chapter homepage with standard left menu bar.

or problem, and provides a reason for collecting and analyzing the data.

- The *Step-by-Step Instructions* guide users through the entire process of navigating to the pertinent Web sites, downloading the required data and analysis tools, formatting the data, and studying the results. The instructions are separated into three distinct levels. The highest level is "Parts" which indicates the broad steps that will be taken during the activity. Within each part are the "Steps" that give the user all the information needed to accomplish the activity. If the user has done the activity before or is computer savvy the entire activity can be accomplished from this level. For additional help, users can view detailed screen shots, generally labeled "Show me how." These are embedded in the "Steps" as drop down boxes that can be viewed or hidden at the user's discretion. The screen shots provide visual guidance on how to accomplish the detailed and sometimes complex "Steps" (see Figure 3).
- The *Tools and Data* section provides full details about each tool and dataset used in the chapter, including information about the individuals or institutions responsible for building the tools or making the data available.
- The *Going Further* section includes suggestions for users who want to extend the investigation or apply their experience to new situations.

The EET Chapter Template - Following the independent development of the first five EET chapters by curriculum developers on the EET team, we collaborated to develop a template of what an EET chapter should contain that would be broad enough to encompass the breath of potential EET chapters, drawing on our experience as both as classroom teachers and curriculum developers . This template was then built within the password protected Content Management System (CMS) at the Science Education Resource Center (SERC) at Carleton College (http://serc.carleton.edu) which also serves to display of all the EET chapters.

Chapter authors' use the CMS based EET chapter template, in collaboration with a member of the EET team, to insert text and images into predefined fields to build chapter pages. To ensure consistency across chapters, each template field has a prescriptive description of the type of content that the author should present. These descriptions are useful in facilitating chapter development by those who lack experience in curriculum development. For instance, data providers or scientists who know of an interesting demonstration or analysis technique use the template to contribute the steps necessary to accomplish the analysis. EET team members who are experienced teachers and curriculum developers then work collaboratively with these data providers and scientists to flesh out the steps to provide appropriate context for educators and students. The consistency of EET chapters is also aided by two support documents, the EET Chapter Author's Guide and the

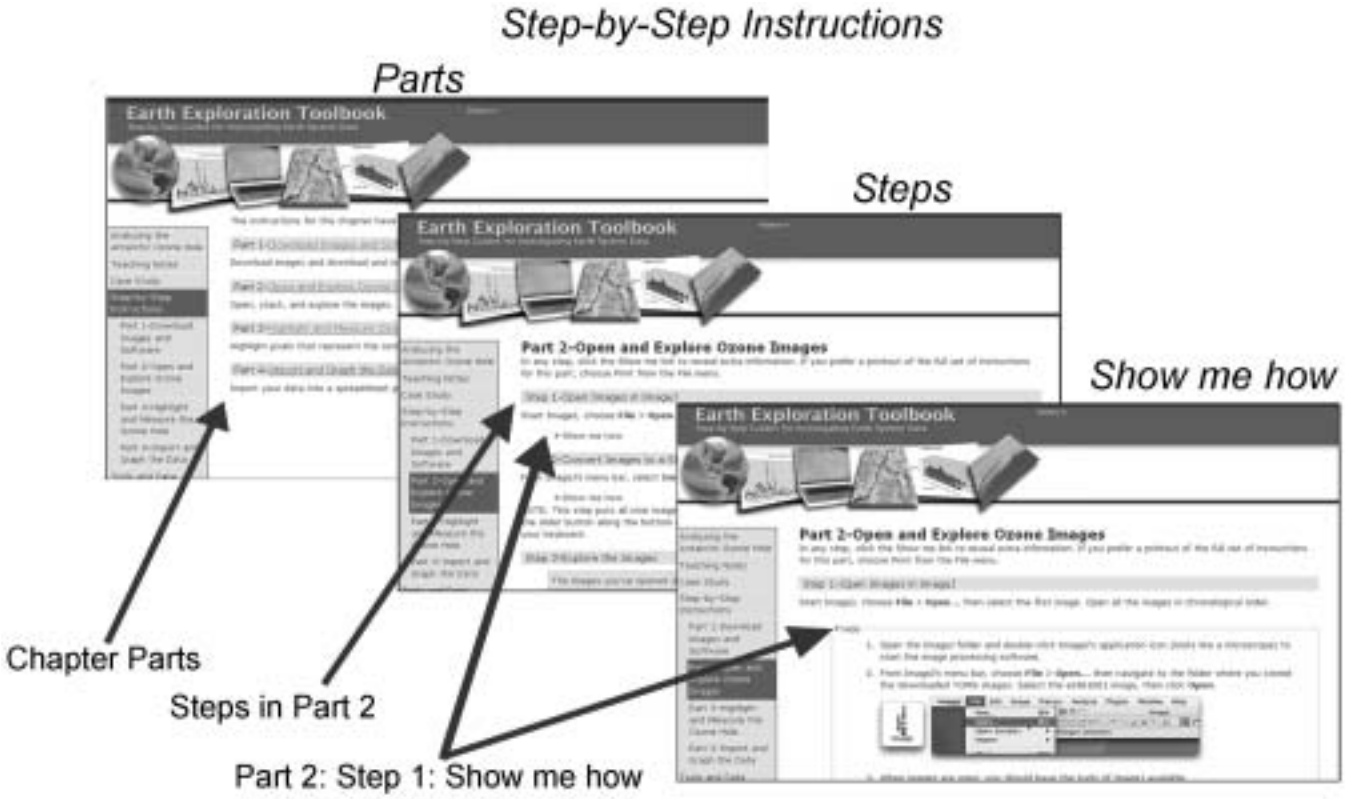

Figure 3. The three levels of the Step-by-Step Instructions: Parts, Steps, and Show Details

EET Chapter Field Descriptions (Dahlman, 2003a; 2003b).

We have used the template successfully in a variety of situations. In addition to using it for ongoing development, we worked with a pre-service teacher to develop a chapter, and teams of workshop attendees used the template to organize their approach to an activity. The EET template is available for creating new chapters, and we are actively seeking new partnerships to help us deliver timely data-rich experiences to educators and ultimately to students.

FACILITATING THE USE OF EET CHAPTERS BY TEACHERS

The EET project has piloted a unique form of professional development. Using a toll-free teleconference, we bring together teachers from across the nation to participate in a two-hour professional development workshop. Using their own computers, teachers work through a chapter by connecting to the EET Web site and simultaneously receiving support via the teleconference. An experienced facilitator guides them as they complete the EET chapter's data analysis techniques. In addition to completing the technological tasks, participants engage in discussion with other attendees, sharing ideas about how they might use the tool or dataset in their own setting.

These workshops are held during after-school hours or on weekends. Attendees receive a stipend for their participation. We recruit teachers by posting notices on the EET Web site, on TERC's Web site, and to the K12 DLESE listserve. The postings indicate that participants must have simultaneous access to a phone line and an Internet-connected computer in a relatively quiet place. Some teachers arrange to call in together from a common location at their school. Others prefer to call from their homes. Some teachers have participated in multiple seminars. In all cases, teachers are learning to use new software on a computer with which they are familiar.

From November 2003 through May 2005, we held 17 telecon-online workshops featuring EET chapters. At first, we piloted the seminars with small numbers of teachers, increasing the size as the demand increased. The number of participants at any given seminar has ranged from a low of seven to a high of twenty-four. We have found fifteen participants to be the optimal number to allow for useful group discussion while working through a chapter's techniques.

We surveyed teachers before and after their participation in the EET telecon-online workshops to learn about their use of digital libraries and data in their teaching. Since we began offering these workshops, almost 200 different people from 41 states have participated. 79% (N=172) of the participants identified themselves as classroom teachers. The remaining 21% offer professional development to teachers and include district technology coordinators, curriculum specialists, staff development specialists, and college faculty. 88% of the participants teach science, while 12% teach social studies and 3% teach technology.

One of the goals of the EET professional development workshops was to increase teacher and student awareness of digital libraries, and in particular, the National Science Digital Library (NSDL) and the Digital Library for Earth System Education (DLESE) within which the EET is a recognized collection. We wanted to make teachers aware of and able to use these

digital libraries to increase their ability to take advantage of the expanded access to educational resources that they offer them and their students.

The majority of EET workshop participants had not heard of either NSDL or DLESE before participating in a telecon-online workshop. 71% had not heard of DLESE, 26% had, and 3% did not respond. The results are similar for NSDL. 70% had not heard of NSDL before participating in the seminar, 28% had, and 2% did not respond. Although these results are similar, they are not perfectly linked. In other words, some who had not heard of DLESE had heard of NSDL and vice versa.

Despite the fact that most participants had not heard of NSDL or DLESE before attending an EET seminar, many did feel that they were likely to use the digital libraries in the future. After attending an EET seminar, 45% of the participants felt they would use DLESE or NSDL to find a teaching resource on a weekly or daily basis. Another third (34%) predicted that they would visit the digital libraries at least monthly.

More than half of our participants (57%) reported that their students use the Internet at school as a regular part of class assignments on a weekly or daily basis. However, this usage likely happens at home as teachers also reported in a later survey question that access to computers during class time is one of the greatest challenges they face when trying to incorporate technology-based instructional methods.

In addition, half of the workshop participants indicated that they had never downloaded an Earth science dataset or tool and used it with their students. This survey result indicates that teachers need help locating these resources as well, and are in need of adequate directions if they are to easily utilize the data and tools to teach concepts in their curricular area.

Participants in the workshop reported a high level of satisfaction with this uniquely facilitated learning environment, as well as with the content of the EET chapters. They felt that the seminar experience increased their confidence in their ability to work with data and data analysis tools and that it was very motivating. Most participants felt that they learned useful information during the workshop, would look for resources online to use with their students at least monthly, would be interested in participating in future workshops, and would likely use the featured chapter in their classrooms. In addition, they especially liked the opportunity to converse with teachers across the nation about issues related to using data in their curriculum. While our effort in running the pilot telecon-online workshops did not include extensive follow-up, a follow-up survey with teachers who participated in an EET telecon-online workshops 64% (N = 28) reported that they had tried using the chapter with their students.

CONCLUSIONS

In order to effectively make Earth science data accessible, usable, and useful by the educational community it is clear that there needs to be a spectrum of services and resources that address the obstacles and support the effort starting from the research scientist and ending with the student. We have described resources and services that address a number of components of this spectrum. The EET is an online resource that contains chapters, each of which provides step-by-step instructions to walk users through an example of using data and tools in a way that is relevant and interesting to the teachers and students. We developed a mechanism to support the development of new EET chapters, offering scientists with an effective way to provide their data, analysis tools, and scientific knowledge to the educational community. In addition, we piloted a professional development workshop series to facilitate the use of EET chapters by teachers.

We have found that providing scientists with a partnership and mechanisms that help them facilitate the use of their data, analysis tools, and scientific knowledge by the educational community is very effective. When scientists are asked to simply make their information available, it is often in a form that is not accessible or useful to teachers and students. The EET and the EET template are a viable mechanism that can make scientific data and analysis tools useable and useful to the educational community. In addition, the partnerships between scientists, educators and curriculum developers that we have facilitated either one-on-one or thorough larger research project collaborations to create EET chapters has made those data and tools accessible to the educational community.

We have also found that providing professional development for the use of EET chapters is very important for facilitating the use of scientific data and analysis tools in education. Prior to the telecon-online workshops most participating teachers had never used data in their teaching, although they realized that their students were accessing and downloading information from the Internet regularly. Following the workshops teachers had an increased confidence in working with data, and many indicated they would likely integrate the use the data and analysis tools with their students.

Overall, we found that our effort to provide some of the components in the spectrum of support to facilitate the use of data and data analysis tools in education was very successful. However, it is an ongoing process that needs to be extended and expanded. In addition, we feel that additional efforts are needed to address the other components of this spectrum - ie the integration of the use of scientific data and data analysis tools into the learning process for students, and a study of the effectiveness of that effort in deepening students understanding of scientific concepts.

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