4 | EDUCATION AND OUTREACH

HISTORICAL CONTEXT AND CURRENT OPERATIONS

IRIS, with strong NSF encouragement, initiated the Education and Outreach (E&O) program during the 1996–2001 Cooperative Agreement, with the goal of increasing public understanding of Earth science in general and seismology in particular. To set the program in motion, IRIS formed an E&O Standing Committee in 1997. In 1998, the committee convened a conference that included people from diverse science and science education disciplines, funding agencies, and other Earth science E&O programs. Participants were asked to develop a broad vision of how IRIS could uniquely contribute to science education and outreach, and the results formed the basis for a program plan published in 2002. The E&O program has slowly grown from a single IRIS staff member in 1998 to approximately 4.5 IRIS staff members managing a number of subcontract and consultant awards, with significant contributions from members of the IRIS community.

During the past decade, the mission of the E&O program has been refined to focus on advancing awareness and understanding of seismology and geophysics while inspiring careers in Earth sciences. The program draws upon the rich seismological expertise of the IRIS Consortium members and combines it with the educational and outreach expertise of the program staff to create educational and outreach products and activities. Although relatively young when compared to the other IRIS programs, IRIS E&O has already established itself as a model educational initiative among NSF-funded activities and has made significant impacts in a variety of arenas. The guiding principles of IRIS E&O are to deliver programs, products, and services that:

- Target a range of audiences, including grades 6–12 students and teachers, college students and faculty, researchers, and the public
- Emphasize seismology and the use of seismic data
- Benefit the Consortium through broader impacts to students and society or through services supporting members needs
- Undergo continuous improvement, leveraging both internal and external evaluations of our products and programs
- Promote the increased participation of underrepresented groups in our activities
- Maintain high levels of scientific accuracy while employing best educational practices

In 2009, the E&O program underwent a successful external evaluation by SRI, followed by an external panel review. Until now, the program has closely followed the original 2002 program plan as commended in the 2009 review panel report: *It is impressive how well the program has remained focused upon the objectives identified in this plan.* The program review has provided valuable input into the formulation of a new strategic plan that is the basis for our proposed new initiatives. This new plan includes a refined set of broad goals that underpin the new initiatives. These goals are to:

- *Improve Seismology Education.* Increase the quantity and enhance the quality of seismology education
- *Expand Earth Science Awareness.* Expand opportunities for the public to understand and appreciate seismology
- *Enhance IRIS Visibility.* Increase the visibility and recognition of IRIS through effective branding and communication of IRIS E&O products and services
- *Support IRIS Consortium Members.* Provide education and outreach products and services for members of the IRIS community
- *Expand the Earth Sciences Workforce.* Support development of a larger and more diverse Earth science workforce
- *Strengthen the E&O Program.* Seek collaborations and funding to sustain and grow the E&O program

The original strategic plan included a focus on K–12 and informal education within the E&O program. The new strategic plan maintains successful programs in these areas while emphasizing new development efforts aimed at undergraduate instruction, and workshops and training for the IRIS

Figure A4.1. Refraction/reflection experiment during the intern orientation week at New Mexico Tech.

community. This change in emphasis will also help to serve the needs of early-career seismologists who will be training the next generation.

As the E&O program implements this new strategic plan, the resulting activities and products will be subject to a process of continuous evaluation and improvement via a combination of both internal and external assessments. Results from these assessments will inform the program's decision-making process, allowing IRIS to significantly enhance its E&O activities over time. The SRI external evaluation of the program in 2009 concluded that: *When viewed against the practices of other Earth science and science outreach agencies, IRIS stands out as putting into place the best practices in the field in evaluation.*

DEVELOPMENTS UNDER CURRENT FIVE-YEAR AGREEMENT

SUMMER INTERNSHIPS FOR UNDERGRADUATES IN SEISMOLOGY

Highlights
- 99 undergraduates have participated
- 49 faculty, representing 39 Consortium institutions, have hosted interns
- 85% of alumni have attained or are pursuing a graduate degree in a field of geoscience
- 46% of interns have been female

Since its inception in 1998, the IRIS Undergraduate Internship Program has provided undergraduates with the opportunity to work with leaders in seismological research, to travel to sites around the world for fieldwork, and to produce research products worthy of presentation at large professional conferences. These activities are designed to encourage students, who represent a diverse population, to choose careers in Earth science. Since 2006, this program has been jointly funded through two NSF Research Experience for Undergraduates (REU) site awards as well as through the IRIS core award. REU funding supports student costs, while the IRIS core funding supports infrastructure such as salaries and other oversight costs.

Figure A4.2. Intern orientation field trip, 2009.

To capitalize on its dispersed human resources and research facilities, IRIS has developed a model for a distributed REU site that blends telecommunications technology and recent research on distance learning to achieve the spirit of a traditional REU. The intern experience begins with a one-week orientation designed to introduce the interns to some of the most exciting aspects of modern seismology as well as to foster a strong sense of community among the interns. Visiting scientists from across the IRIS community donate their expertise to lead in-depth laboratory exercises and lectures/discussion sessions. Additional sessions provide training in distance collaboration, an overview of graduate student life, strategies and opportunities to fund graduate education, and insights into industry, academia, and government lab careers.

Following the orientation, interns spend 8 to 12 weeks working on a seismological research project with scientists at an IRIS member institution (Figure A4.2). Each project provides interns with ample opportunities to develop an understanding of scientific inquiry and geophysical data. In addition to regular mentoring by research faculty, an alumni mentor (a student advanced in a PhD program) assists during the orientation week, and also monitors and mentors the interns using the cyberinfrastructure. The IRIS intern program has also developed a set of strategies to enable interns to self-monitor their progress by encouraging them to blog their projects in their own words, identify and structure their goals, monitor and evaluate their progress, and discuss the broader reaches of their work.

The culmination of each student's REU internship experience is the opportunity to present the results of their summer research at the fall meeting of the American Geophysical Union (AGU). Not only does attendance at AGU bring closure to the research project, it is an important opportunity for students to gain meaningful exposure to Earth science research as a viable career option. The longevity of the IRIS internship program allows much of this exposure to occur

through networking with numerous internship alumni and potential graduate advisors present at AGU, facilitated via an annual alumni mixer held at the meeting.

Personal encouragement from faculty is an extremely important factor in recruiting interns, and this is especially pronounced for minority applicants. In an effort to increase the diversity of the program, a special lecture series has been developed in collaboration with the North Carolina A&T State Department of Physics to personally invite physics majors at Historically Black Colleges and Universities (HBCUs) to apply to the program. Through this lecture series, dynamic, early-career alumni of the IRIS REU program deliver lectures focused on cutting-edge seismological research with explicit connections to core physics content. The lectures conclude with information on geophysics careers and the role the IRIS Internship Program can play in developing this career path.

PROFESSIONAL DEVELOPMENT FOR TEACHERS AND COLLEGE FACULTY

HIGHLIGHTS

- Over 1150 teachers and college faculty have attended one-day or longer IRIS workshops
- These instructors have the potential to reach over 80,000 students annually
- Tens of thousands of teachers are reached regularly by E&O staff participation on regional and national Earth science and physics listservs

Most middle and high school Earth science teachers have minimal science background in plate tectonics and seismology, and as a result, many of these teachers are poorly equipped to engage their students in geophysics and seismology content or to teach about recent advances in earthquake science and engineering. As a result, many such teachers rely on out-dated textbooks to enhance their own content knowledge and often avoid student inquiry in their instruction.

To support the need for better resources, IRIS E&O and faculty at IRIS member institutions have developed a suite of classroom activities that enable teachers to use seismic data. These data-rich resources provide hands-on and minds-on opportunities for students to explore, for example, Earth's structure, the size of earthquakes, why earthquakes occur, and principles of seismic wave propagation through Earth.

While IRIS-developed resources have been well received by teachers, educational research as well as IRIS formative assessments indicate that training is essential to increase teachers instructional confidence, which in turn allows them to teach in a more inquiry-oriented manner, and deliver more sophisticated content to students. Consequently, IRIS offers a variety of professional development opportunities to supplement its curricular resource effort. These experiences develop deeper content knowledge and understanding, and enhance the use of appropriate curricular materials to enable student learning. These opportunities range from one-hour sessions at regional and national science teacher or informal educator conferences, to multiday workshops offered in partnership with other organizations.

Figure A4.3. Teacher workshop at NC A&T, conducted in collaboration with AfricaArray.

In addition to serving a middle and high school audience, IRIS has recently begun to employ a similar approach to undergraduate instruction at community colleges and small liberal arts colleges, where faculty generally have a strong geoscience background, but rarely with a focus on seismology or geophysics (Figure A4.3). IRIS's involvement at venues such as the National Association of Geoscience Teachers, the Geological Society of America, and the Cutting Edge Workshop series have been highly successful and are an opportunity for IRIS E&O to further enhance geoscience instruction.

PUBLIC DISPLAYS FOR MUSEUMS AND OTHER VENUES

HIGHLIGHTS

Specialized Displays

- Annually, 13 million people visit the three museums where there are major IRIS/USGS displays
- 1.7 million people per year visit the Franklin Institute where a new IRIS E&O display was installed in 2010

Active Earth Display

- Over 105 groups have applied for accounts, 61 of which are schools, colleges, or community colleges, and this number is rapidly increasing
- 37 displays were in operation in June 2010
- Users estimate over 75,000 people per year will visit the existing displays

Museums are an important mechanism for scientific outreach to the general public, and the display of real-time seismic data offers the opportunity to capitalize on visitors' enthusiasm for current information. Thus, IRIS works with individual museums to help them create custom displays as well as to explore new opportunities such as the projection of near-real-time seismicity on three-dimensional globes. As an outgrowth of our experience creating large museum displays, including surveys of audience response (Smith et al., 2006, *Eos*, 87(8):85), IRIS has developed a more-versatile, and less-costly Active Earth Display that is aimed at smaller formal and informal learning institutions. These displays have been installed in locations ranging from visitor centers in national parks to small museums, NSF headquarters, departmental lobbies in universities, and at South Pole Station.

Although the content is delivered via a web browser, the system has many features that distinguish it from a simple web site. The Active Earth Display content pages are designed for interactive use with a touch screen, but the display can also be cycled in a non-interactive mode. The availability of content pages can be individually tailored for each site by the end user. Placeholder pages can be used to permit insertion of new material, such as teachable moment pages after significant earthquakes. Packages of content pages, such as the seismic and tectonic settings of Cascadia and the Basin and Range have been developed in collaboration with UNAVCO and the EarthScope National Office, and there are now more than 65 pages of content to choose from.

Figure A4.4. Active Earth Display kiosk and sample screens.

SEISMOGRAPHS IN SCHOOLS

HIGHLIGHTS

- Over 170 schools are currently operating seismographs provided by IRIS
- Over 375 users of educational seismographs from 42 states and 16 countries have registered their station in the Seismographs in Schools database
- Over 58 of these stations have displayed real-time views of their data on the web.
- Since 2004, 140 teachers have attended an AS1 users training workshop.

One of the best ways to engage students in scientific content is to give them opportunities to work with real scientific instruments and data and enable them to experience the discovery of scientific information. The Seismographs in Schools program is now doing this for thousands of students in physics and Earth science classes around the country. The foundational activity has been the dissemination of educational seismographs (the AS1) and software to classroom teachers and the development of a training workshop and curricular materials for teachers. More recently, a cyberinfrastructure has been developed to network teachers, both within the United States and internationally, to enable them to assist each other with technical issues as well as extending the value of the program by encouraging conversation on scientific content and instructional approaches. The seismometer also becomes a community resource, as local media commonly feature the school and their seismograph after a major earthquake (Figure A4.5).

However, the SIS program is based on more than the placement and support of AS1 seismographs in schools, as IRIS E&O has a pyramid goal of engagement:

- Hundreds of high-sensitivity sensors in classrooms to record global earthquakes
- Thousands of USB and other motion sensors to teach the basics of ground motion
- Hundreds of thousands of students using IRIS data via the web in classroom activities

Figure A4.5. Example of local TV news coverage of school seismographs.

Figure A4.6. AS1 training workshop for teachers.

As part of this strategy, IRIS encourages, collaborates, and supports both national and international educational seismology networks. For example, within the United States there are groups in over nine states that provide regional support for teachers. Internationally, IRIS has provided seed equipment and shared expertise with school seismograph networks at various stages of development in countries such as New Zealand, Great Britain, Ireland, France, Italy, Kazakhstan and Costa Rica. This work includes the development of an online database system that allows other educational networks (e.g., Great Britain) to share their data with schools using our site.

TEACHABLE MOMENT SLIDE SETS

HIGHLIGHTS

- Rapid creation of slide sets after 7 major earthquakes in the first 7 months production
- 100,000 visits to the Teachable Moments web page during February-March 2010

A major new addition to the set of IRIS E&O products in the past year is the production of Teachable Moment (TM) presentations following major earthquakes. Newsworthy earthquakes can capture the attention and imagination of students, however, many instructors lack the time and/or background knowledge to synthesize available web materials into a coherent package that tells an educational story. By delivering timely, easy-to-use resources, the TM presentations enhance Earth science education by expanding classroom discussion of seismology concepts and tectonic processes.

TM presentations, produced in collaboration with the University of Portland, are generally posted to the IRIS web site within 24 hours of the event. Each presentation is formatted in a way that allows an educator to tailor the materials to their particular audience and time frame. Common elements include USGS earthquake and volcano information, plate tectonic and regional tectonic maps and summaries, custom-generated computer animations, seismograms, AP photos, speaker notes, and other event-specific information, some of which is contributed by IRIS Consortium members. Full TM presentations were created for seven earthquakes from October 2009 through April 2010, and shorter TM presentations were made for seven less-newsworthy earthquakes in the same time period. The Haiti and Chile earthquakes were by far the most significant in terms of visibility, and in both cases, additional information, animations, lesson plans, activities, and other educational materials were added to the site.

Revisions to the IRIS web site have enhanced the visibility of and the traffic to the TM page. In addition to being prominently featured on the home page of the IRIS web site, notification of new TM presentations are distributed via a mailing list, on the IRIS E&O Facebook page, and on two Twitter accounts (one in English and one in Spanish). The custom animations that accompany the presentations are posted to YouTube to reach an even wider audience, resulting in nearly 25,000 views from January–May 2010. Perhaps even more important is the viral nature of the TM announcements as these are frequently reposted to teacher listservs, reposted on Facebook, and retweeted.

To expand the impact of the Teachable Moments, a number of improvements are proposed. More seismogram interpretation and fault mechanism information will be added that could be used in undergraduate classes, and TMs will be tied more closely to new automated DMS data products such as the Ground Motion Visualizations. An Active Earth Display page will be created for each event, which will automatically appear on displays that subscribe to TMs. As done for the Haiti and Chile earthquakes, additional educational products will be provided along with Microsoft PowerPoint sets. Options are being explored with the USGS to make more use of their automated event information system. Such collaboration would combine the USGS's scientific and public information expertise with IRIS E&O's educational experience.

WEB RESOURCES AND ANIMATIONS

HIGHLIGHTS

- In the first five months of 2010 there were over 2,500,000 visitors to the IRIS web site with the majority viewing the Seismic Monitor
- Over 80 animations on seismology topics are available in the animation library

The IRIS web site is the face of the Consortium to the general public. A key way to increase the impact of the E&O program is to drive more traffic to the web site and provide content that

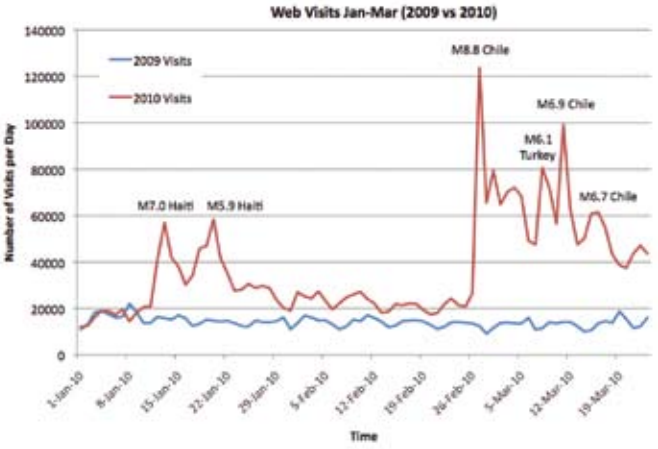

Figure A4.7. Daily web page visits, Jan-Mar, 2010.

brings users back to the site. Content includes timely information about recent seismological events as well as longer-lasting information such as classroom activities and animations.

Figure A4.7 shows the value of recent changes to the web site, where the increase in traffic after an earthquake results in both a short-term peak, and a long-term increase in users. This long-term upswing in users has been achieved by examining all of the delivery venues for educational content, followed by revisions and reorganizations across the web site, increased use of social networking sites, addition of new educational resources, and encouraging other groups to link to our materials.

Earth science teachers with limited geologic knowledge, as well as seasoned professors, are eager to supplement existing teaching resources with computer animations of geologic processes. Unfamiliar scientific concepts can be more accessible when learning is supported by animations, and the dynamic nature of animations may better engage the current generation of students. IRIS E&O offers cartoon and interactive Flash animations covering a variety of seismology and Earth science topics. Accompanying video lectures both promote Earth-science teachers' grasp of new science content and support their classroom presentation of earthquake science. To complement these, most of the animation and video lecture sets also have links to classroom activities that promote active learning of key seismological topics.

Another example of the increased use of the IRIS web pages is the IRIS Image Gallery, a diverse collection of photographs and visuals that encompass the range and breadth of seismology and the seismological community. It includes educational images from E&O posters, and research figures submitted by the IRIS community, as well as photographs of IRIS community activities worldwide, from workshops to field deployments.

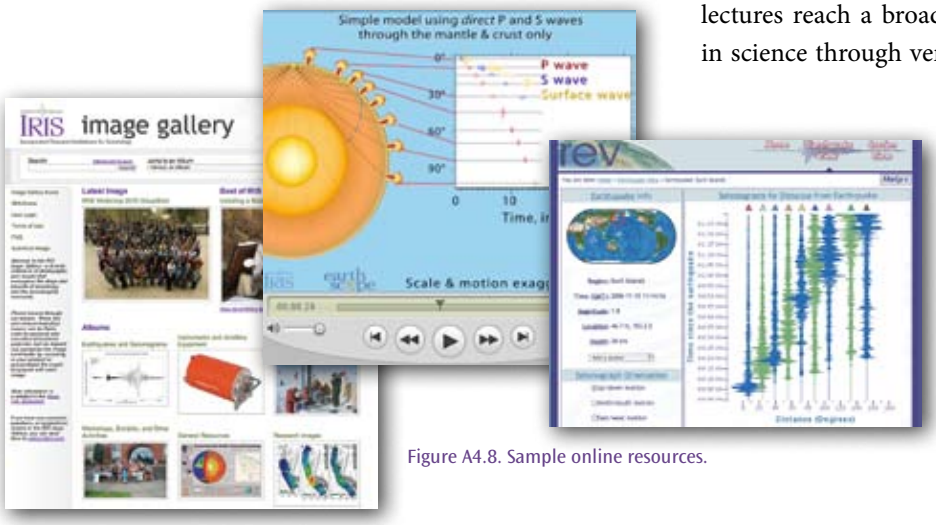

Figure A4.8. Sample online resources.

IRIS/SSA LECTURESHIP

HIGHLIGHTS

- 17 IRIS/SSA Distinguished Lecturers have given over 99 presentations to public audiences of up to 400 people per lecture at major museums and universities throughout the country
- Average attendance is 165 per venue
- All venues surveyed in 2009 described the lecture as a success and 100% were interested in having a lecturer for the coming season

There is a strong demand at informal learning institutions like science museums to provide local communities with direct contact with distinguished scientists. In 2003, IRIS and the Seismological Society of America (SSA) initiated the IRIS/SSA Distinguished Lecture Series to help meet this need. Two or three speakers are selected each year for the lectureship from a pool of nominees generated from the IRIS community. Selections are based on scientists' ability to convey both the excitement and the complexities of seismology to a general audience in a form that is engaging and enlightening. These lectures reach a broad sector of the public with an interest in science through venues that often have a well-established lecture series.

To address the requests from educators for electronic versions of these lectures so that they may incorporate the information into their own classroom lectures, lecturers are asked to ensure that their presentations are suitable for distribution via the web or CD-ROM, and videos of some lectures are placed online. The impact of the lectureship program is also increased by having many

venues arrange additional events in conjunction with the lectures, such as webcasts, radio interviews, teacher workshops, and IMAX films. In addition, the speakers frequently give a separate technical talk on their research at local university geoscience departments.

PUBLICATIONS AND GENERAL OUTREACH

HIGHLIGHTS

- Five educational posters and seven "one-pagers" have been developed
- Over 100,000 IRIS educational posters have been distributed to schools, colleges, and universities, including institutions in 22 different countries
- Several of the posters and all of the one-pagers are available in Spanish

IRIS produced its first educational poster (Exploring the Earth Using Seismology) in 1998 and continues to give out thousands of copies of that poster each year. IRIS has continued to develop new posters since then, on topics such as the 2004 Sumatra earthquake and the commemoration of the 1906 San Francisco earthquake (Century of Great Earthquakes). Recent posters have been aimed at high school and college students, and the full range of posters can be found at schools and universities throughout the world. To maximize the effectiveness of future posters, research was recently concluded on the use of posters in classrooms. The intention of this project was to identify a set of design features that increased their instructional usefulness, and new posters are being designed based on those results (e.g., Figure A4.9).

While IRIS E&O will continue to supply paper materials because of the important role they play in education and outreach venues, particularly school classrooms, the program is moving toward greater electronic distribution of materials such as videos, animations, and podcasts. Materials are now also distributed via DVD, as with IRIS's "Earthquakes" DVD, developed in collaboration with EarthScope. This DVD is an organized collection of electronic earthquake education resources, including both IRIS material (text, images, video, and animations) and high-quality activities from other sources.

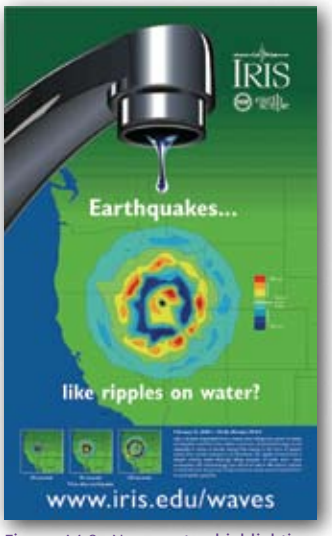

Figure A4.9. New poster highlighting Transportable Array data.

ENGAGEMENT OF DIVERSE AUDIENCES

An IRIS E&O priority is reaching and enfranchising a diversity of audiences with all of our activities, using three complementary approaches: (1) establishing and strengthening partnerships with programs and organizations specifically designed to serve underrepresented groups, (2) expanding individual IRIS E&O activities to engage these same groups, and (3) targeting underrepresented groups to include them in greater numbers in existing activities.

A successful approach is to build partnerships with groups that are already engaged in successful activities. An example is partnering with the Society for Advancement of Chicanos and Native Americans in Science (SACNAS). SACNAS has increased its emphasis on Earth science in the past several years through the efforts of Aaron Velasco, a former IRIS E&O Standing Committee member, and past president of SACNAS. IRIS has shared a booth at the SACNAS annual meeting for the past four years as well as cosponsoring an Earth sciences field trip at the meeting.

Interactions with SACNAS complement IRIS E&O's collaboration in UNAVCO's RESESS program (Research Experience in Solid Earth Science for Students), which provides a supportive summer research environment for underrepresented minorities. RESESS allows students to transition from research within a small student community to involvement with scientists throughout the United States. IRIS has shared student applications and research mentors between the programs so that the best match is found for students and hosts, and IRIS is now a co-PI with UNAVCO on the recently awarded five-year Opportunities for Enhancing Diversity in the Geosciences grant that supports the RESESS program. Through this collaboration, IRIS will be working intensively to increase opportunities for minority participation in IRIS activities as well as integrating the RESESS program into other opportunities that IRIS offers students.

E&O program staff members are also working with Penn State University and North Carolina A&T (an HBCU) on the AfricaArray project. This project is designed to increase educational capacity in Africa and increase the engagement of African American students in Earth science. As part of that process, IRIS E&O provides multiday professional development to teachers in North Carolina working in the highly diverse Greensboro region.

Wherever possible, underrepresented groups are targeted in existing programs. Diné College, a Native American college, was one of the first IRIS Educational Affiliate members, and

HBCUs will be approached as potential Educational Affiliate members. The USArray siting outreach program has made special efforts to engage minority groups, such as the multi-year project with Navajo Nation associated with the deployment of USArray stations in Arizona. Minority-serving institutions are targeted in advertisements for hosting a Distinguished Lecturer as are schools with a large percentage of students from underrepresented groups when selecting schools for AS1 seismographs. As part of the increased emphasis on use of online resources, the Spanish translations of web materials will be increased. The Spanish Teachable Moment presentations have been very popular, particularly after the 2010 Chile earthquake, and greater use is expected as part of IRIS's international development activities in Central and South America.

INTEGRATION WITH USARRAY

Considerable integration has already occurred between E&O and USArray Siting Outreach. All E&O products are already available for use by USArray, and USArray products are used and promoted by IRIS E&O. This integration will increase even further within the new IRIS management structure. Other examples include:

- Selection of new AS1 schools is focused on current or near future Transportable Array footprint
- Active Earth Display can be used to highlight USArray activities
- Professional development for either program depends on exercises and/or data from the other program
- Production of a new poster

NEW OPPORTUNITIES AND DIRECTIONS

Engaging undergraduates in real data analysis and providing them with current research examples can greatly improve their appreciation of science and increase the likelihood that they will continue on to a scientific career. To pursue this goal, a key E&O program focus during the next 27 months will be to develop new materials and programs for undergraduate education. This focus will allow IRIS to leverage the talent and resources that are available within the Consortium membership, and to make those resources available to a wider audience. The need to reach a wider audience is even more pronounced in the current environment where over 40% of undergraduates attend community colleges (see American Association of Community Colleges Fact Sheet at http://www.aacc.nche.edu/AboutCC/Documents/factsheet2010.pdf). Historically, the E&O program has emphasized middle school and high school audiences because of the great need for resources at those levels and the importance of capturing the imagination of students before they lose interest in science. However, the IRIS E&O program is mindful of the strengths and foundations of its program and the responsibility to serve the IRIS community. Here, IRIS E&O has the opportunity to use its university linkages to engage an extensive educational community, including expanding IRIS Educational Affiliates membership, to impact future practitioners in both research and education.

The other major focus during the next 27 months will be to greatly expand the impact of existing activities and resources. For example, to reach larger audiences for professional development, and accommodate the limited time of instructors, will require developing more short video segments and podcasts to deliver online training in support of pre-existing classroom activities, and fewer in-person workshops. It will be important to evaluate and, if appropriate, adapt efficiently to new methods of information dissemination as they continue to become available, whether it be mobile devices or new social networking sites. IRIS E&O is also aware of the need to reach a diversity of audiences, and is constantly working to find additional mechanisms for reaching minority and international audiences. The following sections outline new and modified E&O activities that are proposed over the next 27 months.

CREATE AND CURATE UNDERGRADUATE SEISMOLOGY RESOURCES

An important initiative by IRIS E&O to place more emphasis on undergraduate education will be to create, collect, and curate classroom and lab exercises that can be used throughout undergraduate geoscience curricula. There is a great need for these materials as recent scholarship has shown that undergraduates hold significant misconceptions about earthquakes and plate tectonics despite instruction using existing resources, and only 5% of undergraduate respondents recognized that scientists knew about Earth's layers based on information from earthquakes (Delaughter et al., 1998, *Eos*, 79(36):429–436; Libarkin et al., 2005, *Journal of Geoscience Education*, 52:17–26).

Instructors compiling their own set of classroom exercises often use activities posted on science teaching web sites such as the SERC (Science Education Resource Center at Carleton

College), DLESE (Digital Library for Earth System Education), USGS, SCEC (Southern California Earthquake Center), and IRIS. On the SERC web site, over 50 seismology-related activities are available, including those submitted by participants of the 2007 "Teaching Geophysics in the 21st Century" workshop in which IRIS staff participated and IRIS community members helped organize. Over three-fourths of these activities, however, are designed for upper-division students in advanced geophysics courses. Although the workshop helped increase the number of available geophysics activities, it also highlighted the great need for high-quality activities that use current data for introductory and intermediate-level geoscience courses. IRIS E&O will concentrate development efforts on materials that address these audiences.

Though the questions in the *Seismological Grand Challenges in Understanding Earth's Dynamic Systems* have been posed to help guide fundamental seismological and geophysical research for the next several decades, they also offer fresh content for developing new resources for the college classroom. Most of the 10 Grand Challenges address how seismology illuminates our understanding of Earth structure and address issues related to plate tectonics and related phenomena such as convection and volcanism. A few of the questions naturally allow for the use of active-source seismology in a classroom exercise, a topic that is largely absent from introductory classes despite its connection to societal issues. Furthermore, each of these questions represents course content that is already being covered in lower-division physical geology courses and aligns well with the newly developed *Earth Science Literacy Principles* (http://www.earthscienceliteracy.org).

Perhaps the greatest strength of using the 10 Grand Challenges as the content guide for course materials is that it permits integration of cutting-edge research into the classroom while allowing instructors to cover the same core content. Additionally, using the Grand Challenges as the content guide will extend the reach of the document to many undergraduate faculty who might otherwise be unaware of these important research questions.

The creation of new classroom materials has begun under a recently funded CCLI grant in collaboration with the College of New Jersey (TCNJ). The objectives of that project are to:

- Create undergraduate instructional materials and a detailed instructor's guide that correspond to each of the Grand Challenges, as well as at least six inquiry-based laboratory activities
- Disseminate developed resources through the IRIS web site and digital libraries such as SERC and DLESE, via workshops for undergraduate instructors, and through special sessions at national geoscience and seismological meetings

Achieving these objectives will provide first steps toward increasing the level of inquiry in seismology-related instruction in introductory geoscience courses and in courses such as structural geology and tectonics. As initial materials are developed, seismology faculty will be invited to share their rough exercises via a "faculty only" area on the IRIS web site (as requested by an IRIS early career faculty group). IRIS will assist in editing the submitted materials to make them more easily usable by other faculty. IRIS E&O will also conduct workshops with undergraduate faculty to vet, improve, and disseminate these new materials.

INVOLVE MORE UNDERGRADUATES IN FIELD RESEARCH

Each summer, numerous efforts to collect seismological data are underway within the IRIS community and most such experiments have a need for field assistants. As a result, the IRIS community has asked the IRIS E&O program to leverage the existing internship program infrastructure to develop a clearinghouse for recruiting undergraduate field assistants. This clearinghouse will also provide opportunities for students not currently part of the IRIS community, including math or physics students who might have an interest in seismology but have never taken a course or participated in fieldwork before, foreign students who are not eligible for REU programs, or community college students who might not yet have the prerequisites for an IRIS internship.

While this partnership with community members will provide needed students, it will also allow IRIS E&O to ensure that the field assistantship is more than just manual labor. The PI application process will be structured to ensure that PIs provide related learning experiences for the field assistants, rather than just handing them a shovel. Activities might include providing reading lists that will help the intern under-

Figure A4.10. Students installing seismographs as part of the Sierra Nevada Earthscope Project.

stand the scientific context for their fieldwork, pre- or post-fieldwork seminars on local and regional tectonics, and/or sessions providing instruction on data processing techniques.

Under this initiative, the robustness of the application and review system will be improved. Students seeking field assistantships will be able to enter and update their information online and provide details about available dates, potential locations, and topics of interest. The system will generate email notifications for projects that match their criteria. Similarly, when a PI lists a field opportunity, they will define their project according to parameters that will help ensure a good match between projects and students.

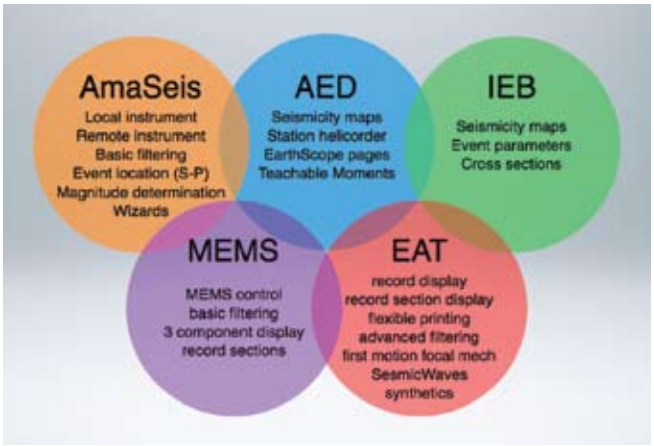

Figure A4.11. Software vision.

NEW DATA ACCESS AND ANALYSIS SOFTWARE

Software Strategy

A coherent set of software applications supporting IRIS E&O goals in seismological education and the E&O pyramid plan of engagement will be delivered. Most of these applications already exist and will be improved while one is an entirely new product. These applications will have the following properties:

- A well-defined scope (i.e., it will be easy to describe to users what a particular application does or to point users to the appropriate application for their needs)
- Contain a wide enough set of features so that most educational activities require using only one application, which implies some overlap in functionality but not so much as to obfuscate differences in the applications

The applications support the increased emphasis on the undergraduate audience, and all will be of use in the undergraduate classroom.

Figure A4.11 shows the software vision. The applications are:

- *Amaseis.* The primary function of Amaseis is to view and locally store data from seismographs such as the AS1 currently used in the Seismographs in Schools program. Enhancements to Amaseis will allow the data to be shared in near- real time among classrooms within a school or schools within a school district. Amaseis will also contain the analysis tools needed for K–12 exercises, including epicentral location and magnitude determination. The current overhaul of Amaseis has the following goals:
  - Rewrite in Java for a maintainable and platform independent code base
  - Add the ability to share data in real time via IP port 80 to avoid firewall issues
  - Display near-real-time data feeds from the DMS
  - Include help and prompting features to lower the use barrier for teachers
- *IRIS Earthquake Browser.* The primary function of IEB, developed by the IRIS DMS, is to allow users to explore seismicity data via a Google map-based interface. Although not initially developed for an educational audience, the ease of use and intuitive interface lends itself to exploration by the educational community and the general public. Results of customized searches are displayed on the map for analysis, but can also be downloaded in a variety of formats for analysis. We propose to add three-dimensional viewing capability to the tool to allow even more exploration.
- *Active Earth Display.* The primary function of Active Earth Display is to deliver interactive seismological and tectonic content to both formal and informal learning settings. The Active Earth Display will evolve into a more flexible delivery platform as described below.
- *QCN/MEMS.* The software developed in collaboration with the Quake Catcher Network (described below) will support the use of micro-electro-mechanical system (MEMS) accelerometers in classroom activities. This application will support the display, recording, and storage of single and multiple component waveform data, simple filtering, and perhaps the ability to record and display record sections from daisy-chained MEMS accelerometers.
- *Event Analysis Tool.* This new application will be aimed primarily at undergraduate instruction. The goal is to allow easy use of DMS datasets in classroom and lab exercises. The application will include the ability to display multi-component waveform data, plot record sections, filter and window data, convert waveform data to multiple formats, display and manipulate focal mechanism data, perform magnitude calculations, generate synthetic seismograms, and display seismic wave propagation paths. This application will leverage the new web services developed by the DMS.

EXPAND ACTIVE EARTH DISPLAY USAGE

The Active Earth Display, as described previously, is poised to become a vehicle for the delivery of IRIS educational materials on a much larger scale, including enabling this system to be deployed in K–12 classrooms and schools, undergraduate geoscience departments, and local museums and parks. To achieve this much larger scale of deployment, we propose to make several improvements and modifications to the Active Earth Display system and then to greatly increase the marketing of the displays. Although the model has been to primarily provide the content of the display with each venue providing their own hardware, the hardware costs can sometimes be a barrier. Thus, partnership with hardware manufacturers will be pursued to support this effort through donated or subsidized hardware.

Adapt the System to Arbitrary-Resolution Displays

Integrated computers with widescreen touch displays from several manufacturers are now available for under $1000, whereas the current Active Earth Display pages are designed for a fixed-resolution square screen. Existing pages will be adapted to scale gracefully to widescreen displays. In addition to allowing the use of low-cost, all-in-one touchscreen computers, this will also facilitate the deployment of non-interactive displays on flat-panel televisions. Over the funding period, the design of new pages will take advantage of widescreen aspect ratios, and work will begin on using resolution-independent technologies to replace fixed-size raster graphics. Resolution independence will also allow elements of the Active Earth Display to be deployed on new types and sizes of touchscreen devices such as touchscreen phones and media players, and tablet and pad-type computing devices. These "personal" touchscreen devices are rapidly becoming major platforms for media consumption and it is anticipated that they will become widely used as tools to deliver educational materials.

Develop New Content Modules and Content Creation Tools

One of the features that distinguishes the Active Earth Display from a passive web site system is the ability of end users to both configure which pages are displayed from IRIS, but also to add pages of their own. This feature allows, for example, users to develop pages that deal with local seismic or tectonic issues. Currently, users need to code pages directly in HTML and SWF formats. We propose to develop a toolkit that will allow end users to generate content by simply mixing their custom text and graphic images with preconfigured widgets and templates. IRIS E&O will subsequently host user-created content that is of high quality and broad appeal.

To facilitate nationwide dispersal of Active Earth Display systems, and to complement the progress of USArray's Transportable Array, new content modules will continue to be developed, including one on the seismicity and tectonics of the New Madrid region and one on seismicity and tectonics of the eastern margin of North America.

INCREASE IMPACT AND EFFICIENCY FOR SEISMOGRAPHS IN SCHOOLS

The experience gained during the development of the Seismographs in Schools program provides the basis for creating a much greater impact without increasing staff involvement. The revised approach will focus on developing resources to support regional centers, lead by local seismologists, and less national emphasis on interactions with individual teachers. For example, Kaz Fujita from the University of Michigan is developing a regional group based around the Michigan Earth Science Teachers Association. To ensure the effectiveness of this approach, sufficient teacher training will still be vital. However, it will be achieved through the regional networks rather than IRIS E&O in two ways. First, IRIS E&O staff will develop "train the trainer" resources to leverage the program's considerable experience developing individual teachers' skills and content expertise. Second, additional web-based training for teachers will be developed. This development has already begun with clips demonstrating how to assemble the instrument, and it will be expanded to videos covering more advanced processes and techniques (Figure A4.12). Web-based training will also include a curriculum sequence developed and tested by the Boston College Educational Seismology Project with partial funding through IRIS E&O. Additional leveraging will be achieved through the capabilities of improved software (Amaseis), with more classroom impact per sensor, and access to live research-quality

Figure A4.12. AS1 instructional video.

MEMS TECHNOLOGY IN THE CLASSROOM

The use of MEMS technology in the classroom integrates research and education and addresses the Grand Challenges recommendation to explore MEMS technologies to develop low-cost seismic sensors that can be deployed in great numbers and can supplement or replace current seismometers. The reduction in price and improvement in quality of the sensors is being driven by the computer gaming industry. The resulting sensors have already shown their usefulness as aftershock sensors for the 2010 M 8.8 Chile earthquake (Cochrane, 2010, personal communication).

data via the DMS. IRIS will also work with manufacturers to improve the hardware to make it more robust and easier for teachers to set up and maintain.

PORTABLE DEVICES AND INCREASED USE OF SOCIAL MEDIA VIA THE WEB

Mobile phones are becoming primary web information tools, while "the iPod, the most ubiquitous student tool, is enabling college students to tap into lectures on their own time, and in the K–12 space, podcasting is opening up the classroom to parents and to the community" (from http://www.techlearning.com/article/8328). To exploit these trends, IRIS E&O plans to begin developing resources for mobile devices. These resources will include simplified near-real-time information pages for mobile phones, new animations and videos, and educational materials that involve the motion sensors in most new devices. Audio podcasts will be created on topics including general seismology, IRIS Consortium research, and recent earthquakes. Initially, the podcasts will be produced for a general public audience, with a later focus on undergraduate-level topics. The podcasts will be designed to complement existing USGS podcasts.

The use of social media (e.g., Facebook, YouTube, Twitter) is an important new strategy, and its use will be expanded to both attract audiences already using those venues as well as draw them to the main IRIS web site for more detailed content. For example, the IRIS YouTube accounts have been a very popular venue for visitors to locate and use IRIS multimedia resources. As part of the move to more online professional development, animation and short video clip offerings will continue to be expanded.

Targeted input will also be provided to articles on Wikipedia, adding links to IRIS-related material. While changes to the IRIS web site have significantly raised IRIS's standing on Google searches in the past year, Wikipedia still is higher than IRIS for most seismology-related topics, so a larger audience can be reached by adding information and images to those pages.

IRIS's experience with collaborative development of SeisMac, which allows every Mac laptop to act as a seismograph, has led to collaboration with the Quake-Catcher Network (QCN), led by Stanford and UC Riverside. QCN uses low-cost MEMS accelerometers within, or external to, a laptop or desktop computer, and distributed computing to record earthquakes. QCN provides the cyberinfrastructure for individuals to actively collect scientific data and share in scientific discovery, while participants provide the physical infrastructure for the QCN sensors (e.g., computer, Internet, power). Currently, QCN has over 1,000 participants worldwide (Cochran et al., 2010, *Seismological Research Letters*, doi:10.1785/gssrl.80.1.26). QCN developed kinesthetic learning software similar to SeisMac that uses MEMS sensors for education. However, to become an effective educational tool, engaging modules are needed to target specific learning outcomes. Further, to fully utilize the sensors and software in formal educational settings, user interfaces and functionality need to be improved in a way that serves an educational audience, and both of these needs will be pursued under the current proposal through a subaward to Stanford/QCN.

Simple seismograph-like applications also exist for iPhones and other smart phones, but none has been designed specifically for educational purposes. IRIS E&O will work with the

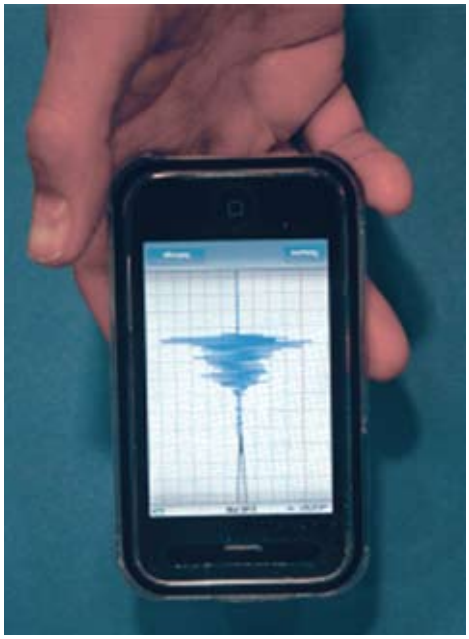

Figure A4.13. Sample iPhone seismograph app.

developers of these applications, as we did with SeisMac, to improve their educational value and integrate their use into IRIS educational modules. In addition, IRIS E&O will develop educational resources that can either be embedded in or linked to these applications to deliver supporting content once users have been hooked through experimentation with these devices. These tools will allow educators to use a wide range of devices to engage students in kinesthetic learning.

INTEGRATED ONLINE MIDDLE AND HIGH SCHOOL CURRICULUM

IRIS E&O has extensive experience with face-to-face professional development and the creation of new online educational modules that target gaps in available materials relating to seismology. However, a missing aspect of the web-based materials is that they do not communicate an approach to delivering content in the classroom, or promote instructor learning of subject matter, pedagogy, and pedagogical content knowledge, which are all elements identified as key components of effective curricula (Davis and Krajcik, 2005, *Educational Researcher*, 34(3):3–14). Further, these web-based resources lack an instructional sequence linking one activity to another. While existing sequences do exist, they are either dated (FEMA's Tremor Troops is 25 years old) or have been watered down to the "traditional staples" by textbook companies.

To address these needs and to greatly expand the impact and value of the existing IRIS educational resources, we propose to develop an online *Middle-School Teachers' Guide to Earthquakes and Seismology* in partnership with the University of Portland. This guide would feature learning sequences for: (1) basic plate tectonics, (2) an introduction to seismology and Earth structure, (3) fundamentals of earthquake seismology and earthquake hazards, and (4) regional plate tectonics and earthquake and tsunami hazards. Each learning sequence would feature a coordinated set of slide presentations, video lectures, computer animations, and classroom activities. Underpinning each learning sequence would be a novel web-based "instructor guide," promoting instructor learning of subject matter, including how to teach the material. The principal elements of this sequence are already available via the IRIS web site, the *Middle-School Teachers' Guide to Earthquakes and Seismology* DVD, and the TOTLE eBinder CD created by Robert Butler, or have been refined through IRIS's many years of delivering professional development. The next steps toward the development of this guide will occur through publication of a special issue of the journal *The Earth Scientist*, focused on seismology, in which the National Earth Science Teachers Association has invited IRIS to take the lead.

WORKSHOPS AND TRAINING FOR THE IRIS AND INTERNATIONAL COMMUNITY

IRIS E&O has extensive experience planning and implementing high-quality professional development experiences for teachers and non-IRIS Consortium college faculty. As part of the new strategic plan to support IRIS Consortium members, IRIS E&O proposes to combine that experience with IRIS community research and education expertise to provide workshops designed for Consortium graduate students and early-career faculty that are more data intensive. The presenters would be leading seismologists, and they would share cutting-edge analysis tools and techniques. An example of such a workshop is the USArray data processing short course held in 2009 and scheduled again for 2010. It is also proposed to develop a workshop targeted at Educational Affiliates that will focus on data use for undergraduates. The workshop will highlight the new analysis software and activities proposed in earlier sections. Another workshop for IRIS researchers and students will focus on shallow active-source seismology supporting the acquisition of new equipment by PASSCAL. In addition, IRIS E&O will work with the IRIS international development group to provide educational materials and help to provide support for capacity-building workshops.