The Integrated Ocean Drilling Program "School of Rock": Lessons learned from an ocean-going research expedition for earth and ocean science educators

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ABSTRACT

The “School of Rock” (SOR) expedition was carried out onboard the JOIDES Resolution during a 2 wk transit from Victoria, British Columbia, Canada, to Acapulco, Mexico, in 2005 as a pilot field program to make scientific ocean drilling research practices and results accessible to precollege educators. Through focused inquiry, the program engaged and exposed 10 teachers and three informal educators to the nature of scientific investigation at sea and to the data collected and discoveries made over nearly four decades of scientific ocean drilling. Success stemmed from intense planning, institutional support, and a program design built on diverse experiences of the instructional team and tailored to educator needs, including an integrated C3 (connections, communications, and curriculum) instructional approach. The C3 approach

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BACKGROUND

The Integrated Ocean Drilling Program (IODP) is an international (United States, Japan, 17 European countries, People’s Republic of China, and the Republic of Korea) scientific ocean drilling program that explores Earth history and structure recorded in seafloor sediments and rocks, and monitors sub-seafloor environments (Fig. 1; IODP Planning Sub-Committee, 2001). The IODP builds upon the earlier successes of the Deep Sea Drilling Project (DSDP) and the Ocean Drilling Program (ODP), which revolutionized our view of earth system history and global processes through ocean basin exploration. IODP is a multiplatform program involving a riserless drilling vessel, a riser drilling vessel, and mission-specific platforms operated by three implementing organizations in the United States, Japan, and Europe, respectively. Over 40 yr, DSDP-ODP-IODP has recovered sediment and rock cores from more than 300 sites in the world’s oceans (Fig. 2). Recovered cores are stored at repositories at the University of Bremen in Bremen, Germany, Kochi University in Kochi, Japan, and Texas A&M University in College Station, Texas, USA. Deep-sea cores and scientific ocean drilling data are available to scientists and educators around the world (http://sedis.iodp.org/front_content.php).

Scientific ocean drilling has proven that much of the ground truth data for foundational concepts in the geosciences and investigations into the working of the earth system lie in sediment and rock recovered from the subseafloor (Fig. 3; Warme et al., 1981; Kappel and Farrell, 1997; White and Urquhart, 2003). Marine sediment core records, in particular, tap the highest resolution, most continuous, and thus most complete sections for the Cenozoic Era (i.e., past 65 Ma; Ruddiman, 2001). Such cores are therefore windows into a detailed and varied tectonic and climate change history (e.g., Zachos et al., 2001). Investigations of marine core records employ the same scientific skills and interpretative principles that are used to “read” and interpret traditional land-based outcrops. Thus, marine cores, like outcrops, are a geologic archive that can be drawn upon for student learning in the geosciences at all educational levels.

The DSDP-ODP-IODP legacy program is arguably a cornerstone research program for earth system science. This program’s basic scientific practices and accomplishments also have many parallels to national content standards for middle and high school earth science education (Fig. 3), including, for example, scientific inquiry, the nature of science, and the development of an understanding of the earth system and fluctuating climates (National Resource Council, 1996). However, for the first 36 yr of the program, the bridge between scientific ocean drilling research and education was only loosely constructed. During this time, only individual efforts and funding for part-time staff enabled the Joint Oceanographic Institutions (JOI; now the
Consortium for Ocean Leadership) to support the development of a limited number of educational materials for use in the classroom. These included “The Blast from the Past” poster, which depicted marine stratigraphic and paleobiologic evidence for the Cretaceous-Tertiary (K-T) impact (JOI, 2000), the Cenozoic Glaciation workbook (Domack and Domack, 1993), and the expedition-focused interactive CDs “Mountains to Monsoons” (JOI, 2001a) and “Gateways to Glaciations” (JOI, 2001b).

A programmatic shift for scientific ocean drilling education came in 2004 when IODP’s U.S. Implementing Organization (USIO) and U.S. Science Support Program provided full-time funds to support a small education staff for scientific ocean drilling. The ramp-up for the “School of Rock” (SOR) expedition program began soon thereafter. As an introduction to her new position, Education Director Peart sailed on the JOIDES Resolution during a short transit between expedition port calls in 2004. It was during this experience that she conceived the idea of transforming a usually quiet and low-staffed ship on transit between expeditions to a vibrant school at sea populated by highly motivated formal and informal educators as the students, and a diverse instructional team of research scientists, education specialists, and media-resource specialists. The goal of this floating field school was to make ocean drilling science accessible to educators in a high-impact way.
PLANNING LOGISTICS

The SOR expedition was a teacher research field experience blended with an inquiry-based workshop. As such, planning for logistics varied little from any field-based learning experience and borrowed heavily from logistical planning for IODP expeditions, especially in the use or adaptation of policies, forms, and documentation. Logistical planning began in late 2004, when the draft 2005 expedition schedule was first published, and the Expedition 312 transit was identified as suitable for an “all-education” expedition. The USIO’s education and outreach team outlined and submitted an education plan based upon the science objectives of Expedition 312, thinking that cores drilled from the same site during earlier expeditions and scientific staff would likely to be onboard during the transit.

Once the concept was approved and, in late October to November 2005, the transit schedule was confirmed, the opportunity was broadly promoted to educators at all grade levels and informal educators through seven IODP-related and partner Web sites and listserves. With only 3 mo remaining, a small subset of the instructional team reviewed and ranked nearly 60 applications and conducted phone interviews over a fast-paced 2 wk period, leaving just enough time for selected teachers to make arrangements for being away from their classrooms, completing paperwork, and securing physicals and passports. Ten grade 5–12 teachers with progressive, inquiry-focused philosophies and demonstrated track records of curriculum development and/or peer teaching were selected from a national pool. Three berths were assigned to informal education partners from the Smithsonian’s National Museum of Natural History, the Science Museum of Minnesota, and a K–12 textbook publishing representative.

In early summer 2005, research scientists with experience in scientific ocean drilling on the JOIDES Resolution were chosen...
as lead instructors, and the content theme of paleoceanography was finalized, a theme that matched the expertise of the scientists who volunteered and were chosen to direct the pilot SOR.

**PROGRAM DESIGN TENETS**

The program design for SOR evolved out of the collective experience of the USIO’s education and outreach team and the SOR instructional team. Peart and Klaus, USIO deputy director for data services, and facilitator for the USIO’s education planning group, served as the administrative branch of the SOR team and shared responsibilities for program planning logistics within JOI and USIO. Content instruction was designed and implemented by Leckie and St. John, both of whom had sailed numerous times on the *JOIDES Resolution* as a paleontologist and sedimentologist, respectively. In addition, Leckie and St. John each had interest and experience in the pedagogy of geoscience education for adult learners, including undergraduate and graduate students and in-service teachers, and had served sequential terms on a scientific ocean drilling advisory committee (U.S. Advisory Committee on Scientific Ocean Drilling, USAC) as education and outreach advocates. Niemitz, a JOI program associate at the time and a geoscientist by training, was experienced in Web design and real-time multimedia communications, and was responsible for SOR ship-to-shore communications and support of onshore interactive learning. Slough, science education specialist, provided pedagogical guidance, along with Peart, and was responsible for program evaluation. Peart also facilitated the adaptation and development of SOR curriculum by the teacher participants during and after the expedition.

Instructional team planning began 3 mo before the SOR expedition and included three face-to-face meetings, one at Texas A&M University in College Station, Texas, one at the JOI office in Washington, DC, and a final 2 d meeting prior to the participants’ arrival at the ship in Victoria, British Columbia. Through the USIO education and outreach team discussions and these face-to-face SOR discussions, as well as conference calls and e-mails, the instructional team outlined the following SOR program design tenets:

1. K–12 teachers and informal educators need a program leadership team that includes research scientists and professional educators to help fulfill their scientific content, skill set, and pedagogical needs.

2. The transit of the *JOIDES Resolution* offers a unique, authentic, and technology-rich field setting for educators to experience ocean drilling science. The SOR experience should model how ocean drilling science is done at sea through inquiry, technology, and teamwork. The educators need to experience the breadth of the scientific ocean drilling experience, from core flow to analytical databases, and from the atmosphere of the “science party” to interactions with the science support team and ship’s crew.

3. The SOR curriculum should be data-rich, integrating authentic ocean drilling practices that are fundamental to all IODP science, as well as content topics that draw on the expertise of the research scientists on the instructional team. Thus, the topics of core description, age determination, and the marine sedimentary record of past climate change (paleoceanography) would be the primary content focus.

4. The program could not be taught as would an undergraduate field course for geology majors. The SOR field program would neither be a capstone experience in which geology students work independently and show what they learned after a multiyear degree program, nor would it be a show-and-tell, as may be more typical for a novice audience. The SOR audience would be professional educators, all with college degrees, but not necessarily in the earth sciences; most, in fact, had education or biology bachelor degrees. SOR curriculum would be taught at the undergraduate to graduate level for adult learners.

5. The teachers need access to curriculum that is based on actual scientific data and discoveries for use in their classrooms. These curricular materials need to be linked to local and state standards so that they are matched to high-stakes accountability exams that dominate the teaching and learning expectations in public schools today. The participating educators themselves would be responsible for adapting and developing SOR curriculum for their classrooms during and after the SOR expedition. The premise is that as each content topic is completed, the educators should then have the knowledge and skills to translate ocean drilling science from the undergraduate/graduate level at which they were taught in SOR to the grades 5–12 level (or general audience level) at which they teach.

6. The educators need time in the field to communicate with their schools, students, and museum audiences. Most participants would be taking leave from their classrooms (and their families) to participate in SOR. We recognize that during professional development programs, educators are constantly thinking “how can I use this in my own teaching?” Since the SOR program was during the school year when classes were in session, translating their experience in near real time for use with the students in their classes became more important. Thus, online communication would be an essential factor in the SOR field program.

7. The educators need time to make connections between and among the new things they are learning and experiencing in the field and their classroom and museums, as well as their prior experiences and knowledge. They need time to reflect and write about what they are doing and learning, and time to process and capture their experience. This is especially true given the expectation that the educators would begin adapting and developing teacher resources during SOR based on their SOR field experience.

8. The educators need flexibility in the field program agenda. They are teaching professionals who bring a different angle to the whole field-based science learning community. Teachers may want time to investigate some aspect of the field experience that was not originally emphasized on the curriculum agenda. This could be very fruitful, albeit not in the original field plan.
EVALUATION DESIGN

The SOR ocean-going research experience was implemented as a pilot program, and its evaluation was informed by the “design-based research” approach (or design studies), which emphasizes both qualitative and quantitative data collected in cooperation between researcher and practitioners (Bell et al., 2004). Design-based research is a systematic but flexible approach to studying educational innovations in authentic teaching and learning contexts (i.e., during SOR), enabling researchers and instructional team members to design, implement, and improve instructional materials and programs as they are being implemented. As such, the design-based research approach was able to provide “just-in-time” feedback to the instructional design team.

Because SOR was a pilot study, the design-based research approach matched the inductive reasoning phase of a research cycle, which emphasizes the movement from facts, observations, and evidence through inductive logic to general inferences (Krathwohl, 1993; Tashakkori and Teddlie, 2003). The primary data source (i.e., facts) for this critical feedback was through teacher “connections.” In the teachers’ daily “connections” journals, they were prompted to record connections of all kinds (e.g., past experience and knowledge, people, memorable events, instructional ideas) encountered during laboratory, classroom activities, curriculum development, classroom communications, and throughout the day. The teachers were also asked to record frustrations, or missed connections. A more summative evaluation included focused interviews and observations after the expedition by the field program evaluator. Questions and observations focused on teacher involvement in a variety of required and elective activities sponsored by the SOR program, including reflection on the efficacy of these activities and implementation of the developed curricula in their respective classrooms. Additionally, long-term impact of the SOR experience was collected through systematic and continuous communication and data collection with all SOR participants. A monthly e-mail that details the current state of the education and outreach components of Deep Earth Academy (formerly JOI Learning) routinely includes the celebration of professional successes (e.g., a new job, a new exhibit, or a presentation at a conference that includes/involves SOR) of the SOR participants and instructors. The e-mail includes prompts to continue to provide examples of the ways in which the participants and instructors continue to use SOR curricula, develop new curricula, present at conferences, teach workshops, publish papers, or anything else they want to celebrate related to SOR. There also have been two annual follow-up questionnaires that have provided additional documentation of SOR activities by participants.

IMPLEMENTATION

The SOR field expedition for educators took place during the IODP pre–Expedition 312 transit from Victoria, British Columbia, Canada, to Acapulco, Mexico, from 31 October to 12 November 2005 (Fig. 4). The SOR continued for two additional days in port in Acapulco. From the time the educators arrived on the JOIDES Resolution (Fig. 5) until they departed for their flights home, the cohort of educators, as well as the SOR instructional team, were immersed in a learning community of scientific ocean drilling. The days were long for the teachers (12–14 h) and even longer for the instructional team, since about half of the curriculum used in the SOR was developed while at sea, and instructors were continuously adjusting to address teacher questions and needs. A summary of the daily schedule is provided in Table 1.

Field instruction modeled and supported open inquiry using exercises based on authentic shipboard research activities and data. The educators worked with previously drilled sediment and basement cores that were sent to the ship from the IODP Gulf...
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<thead>
<tr>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
<th>Day 6</th>
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<tbody>
<tr>
<td>In Port—Victoria, British Columbia, Canada</td>
<td>Under way to Acapulco, Mexico</td>
<td>Warm up and debrief, depart Victoria, view Juan de Fuca Strait, introduction to water and meteorological data collection</td>
<td>Warm up and debrief, core flow introduction, tour of the core laboratory, core description activity: visual core description smear slides, creation of barrel sheets</td>
<td>Warm up and debrief, teachers share core descriptions and sample cores</td>
<td>Warm up and debrief, biostratigraphy continued (Group B) and C3 time (Group A)</td>
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<tr>
<td>Morning</td>
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<td>C3 time Ship tour</td>
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<td>Transport participants to JOIDES Resolution</td>
<td>Cabin assignments, paperwork</td>
<td>Orientation: life on board, communications</td>
<td>Plate tectonics discussion and activities</td>
<td>Marine sediments lecture</td>
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<tr>
<td>Afternoon</td>
<td>Lifeboat drill</td>
<td>Core description activity continued</td>
<td>Introduction to biostratigraphy: construction of age-depth plots and sedimentation rates (Group A) and C3 time (Group B)</td>
<td>Biostratigraphy continued: sample processing in paleo laboratory, photomicroscopy of smear slides</td>
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<tr>
<td>Orientation: safety</td>
<td>Plate tectonic activities continued</td>
<td>C3 Time = connections, curriculum, and communications</td>
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<td>JOIDES Resolution tour and introductions</td>
<td>Ocean drilling legacy lecture</td>
<td>&quot;History of Our Planet Revealed: Stories Only Rocks Can Tell&quot; by Dr. Jeff Fox, Director, IODP</td>
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<td>Evening</td>
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<td>Open</td>
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<td>Core description continued</td>
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<td>Table 1. &quot;SCHOOL OF ROCK&quot; DAILY SCHEDULE (Continued)</td>
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<th>Day 7</th>
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<th>Day 11</th>
<th>Day 12</th>
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<tr>
<td>Under way to Acapulco, Mexico</td>
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<td>Under way to Acapulco, Mexico, and in Acapulco</td>
<td>In Acapulco</td>
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<td>Morning</td>
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<td>Introduction to geochemistry Geochemistry activity on percent carbonate analysis C3 time</td>
<td>Warm up and debrief “CORK 101” lecture (via ship-to-shore videoconference)</td>
<td>Warm up and debrief C3 time</td>
<td>Warm up and debrief Abrupt events in Earth history</td>
<td>Warm up and debrief Climate cyclicity discussion Activities on Milankovitch cyclicity and suborbital oscillations</td>
<td>Activity on sediment point-count analysis and interpretation Observe arrival in port Customs and immigration</td>
<td>Climate change discussion</td>
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<td></td>
<td>Presentation on viewing the Expedition 301 CORK sites via submersible</td>
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<td>Abrupt events in Earth history discussion Activities on K-P extinction, PETM, E-O boundary and Oi1 event</td>
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<tr>
<td>Afternoon</td>
<td>Paleomagnetism laboratory tour and activity: polarity reversal, stratigraphy, correlation to GPTS, construction of age-depth plots Geochemistry cont’d</td>
<td>Geophysics lecture and tour of underway geophysics laboratory Geophysics activities: seismic stratigraphy in site selection and sea-level curves</td>
<td>Ocean crust lecture, core description, thin section microscopy</td>
<td>C3 time</td>
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Key: E-O—Eocene-Oligocene; GPTS—geomagnetic polarity time scale; K-P—Cretaceous-Paleocene; Oi—initial Oligocene glaciation event; PETM—Paleocene-Eocene thermal maximum.
Coast Repository, and they worked with published data from 56 drill sites and 26 scientific ocean drilling expeditions to investigate fundamental scientific practices and discoveries of the DSDP-ODP-IODP legacy (Leckie et al., 2006). Complementing this, activities were carried out in which the educators learned how to handle and process core and core samples in the same laboratories that scientists use on research expeditions. The educators were introduced to the processes of drilling at sea and core recovery by the drilling crew, and core flow through the many shipboard laboratories and laboratory equipment by the science technical staff. In addition, the exercises and activities required the educators to learn how to access published data through the scientific ocean drilling program legacy Web sites.

Many of the special needs of teachers were met by incorporating an almost daily instructional piece entitled “Connections, Communications, and Curriculum (C3)” (Table 1). C3 time was woven into the SOR field schedule to allow teachers time to work on curricula for their classrooms, to communicate with their students, and to make a variety of connections—from curricula to people to “the science.” C3 time was packaged in conjunction with natural breaks in the schedule and at different times each day to allow for free-form time and teachers’ communication with students in several different time zones. It was essential to integrate communication time to the classrooms with curriculum development and connection time in order to gently push participants away from their personal learning and education and bring them back into the realm of the average student. This helped the participants be in the right “frame of mind” for applying the new concepts they were learning to their own individual classrooms (Niemitz et al., 2006, 2008). Teachers reported “frequent contact outside the conference room [the shipboard classroom].” One teacher noted C3 time “allowed me to process, catch-up, or just take a break. To me, the schedule was both accommodating and full.”

Because the SOR took place during the school year, it presented a unique opportunity to engage teacher-to-student interaction via ship-to-shore communication in near real time. The expedition Web site (http://www.joilearning.org/schoolofrock/) included daily blog posts, an expedition location tracking exercise, a video question-and-answer section, participant biographies, and a library of background resources. Through these varied means of connection, onshore students were able to immerse themselves in the experience of an oceanographic expedition as well as discover what the participants were doing on a daily basis. Beyond simply providing an interactive way to connect with the participants onshore, the Web site extended the School of Rock learning community to nonparticipant educators and the general public, before, during, and after the expedition (Niemitz et al., 2006, 2008, 2009). A special ship-to-shore video conference was also set up so a scientific expert on shore could teach a unit on marine hydrothermal circulation and answer SOR educators’ questions about IODP in situ monitoring of such a circulation system on the nearby Juan de Fuca Ridge.

Unscheduled times typically were filled with more C3 time by teacher choice. Teachers also used this open time to interview a cross section of the ship’s manifest, as well as develop instructional laboratory demonstration videos. The career interview format was developed through group discussion between the SOR instructional team and educators. Instructional laboratory videos were not part of the instructional design, but they were incorporated and supported when this exciting idea emerged through teacher-instructor discussions. Educators also interacted with the captain and crew on the ship’s bridge regularly; meteorological and oceanographic data, which were normally collected and recorded twice daily by the bridge deck crew, became a shared-task of rotating paired educators and the bridge deck crew.

**DISCUSSION**

**What Did We Accomplish?**

Logistics of ocean-based research are well understood by IODP scientists and managers; however, the logistics and value of an “all-education” expedition for a cohort of teachers were untested aboard the JOIDES Resolution until the SOR. This was due to two primary factors: (1) the scientific ocean drilling IODP legacy program rarely has times when science programs are not scheduled on the vessel, and (2) berth space is prioritized to maximize scientific outcome. With SOR, we demonstrated that a research vessel can be populated by a group of teachers and scientists brought together for the single purpose of education. While the ship’s crew and technicians traveled onboard the vessel between scientific expeditions from Victoria to Acapulco, the ship was “repurposed” for education by placing the SOR instructional team and the teacher cohort aboard with a wealth of cores and data at their disposal.

The National Research Council publication titled *How People Learn* (Bransford et al., 2000) recognizes that people construct a view of the natural world through their experiences and observations. To explain phenomena and make predictions, people need to draw from their own authentic experiences and observations—they need to engage in deliberate practice, to promote a conceptual change of prior knowledge (Chinn and Malhotra, 2002). By bringing teachers into the field setting of marine geoscientists, the teachers develop their own skills of observation, data interpretation, and synthesis that exemplify theoretical and empirical (Bransford et al., 2000; Bransford and Donovan, 2005) best practices for learning. In addition, the SOR program for teachers and informal educators modeled key aspects of the nature of science: (1) discoveries and scientific connections are rarely made in isolation, but they are the fruits of collaboration, and (2) scientific advancements often rely on technological advancement, especially in marine geoscience.

**What Did We Learn?**

Borrowing from the old African proverb, “it takes a whole ship to raise a SOR teacher.” As a world-class research vessel, the JOIDES Resolution and her crew were the perfect host for the
Inaugural SOR. Four major themes have emerged that highlight the teachers' enthusiasm for the quantity and quality of the field program. The first three major themes are largely connected to research and are described as: (1) the importance of scientific ocean drilling, (2) the JOIDES Resolution's role in that process, and (3) the historical role of cores as the primary data source. The excitement of ocean floor observatories, which was a new scientific area for most of the educators, and their future relevance were also noted. These themes could be largely predicted from the subheading for the expedition title: “An Ocean-Going Research Expedition for Earth and Ocean Science Educators” and were clearly the result of focused inquiry-based instruction. The final theme came from the C3 instructional component and was characterized by (4) overwhelming enthusiasm and productivity during the expedition, in spite of 12–14 h workdays plus “homework” for eleven straight days in a shipboard environment.

The first three themes were explicitly related to scientific ocean drilling research but were different enough to be singled out. The first theme represents the overall importance of scientific ocean drilling as it was expressed repeatedly, to paraphrase a number of teachers, “to use real...easily accessible...data to prove how we know what we know.” This was very powerful compared to their previous descriptions of “scientists have researched this.” Scientific ocean drilling’s contribution to powerful frameworks in earth science such as plate tectonics, seafloor spreading, and global climate change were mentioned by almost every teacher as “take-home messages.”

The second theme revolved around the use of technology in marine geoscience research. Simply put, the JOIDES Resolution made an impression on every participant. Predictably, every educator truly appreciated the technical sophistication and gained professional enrichment by experiencing this workshop in the shipboard environment. One 30 yr teaching veteran described the ship as a “technological and social marvel” and proceeded to photo and/or video every inch of the ship that he could receive permission to document and every employee from “cook to captain.” The majority of this information was edited and sent back to his school in almost real-time with the help of JOIDES Resolution and SOR staff and an enthusiastic computer technician at his home school. A teacher noted, “The JOIDES Resolution represents a micro-version of how the scientific community works. Usually, the general public does not recognize the collaboration involved in substantial findings.” The teachers consistently noted the general and technological problem-solving skills demonstrated by drillers, staff, and technicians on a daily basis.

The third and final research-related theme that the educators universally noted was the importance of cores as a data source for the scientific ocean drilling program. One teacher noted, “When we were processing core, we were processing data...‘data’ is no longer an abstract concept.” Teachers consistently cited Web-based access to data as essential to scientists and teachers alike—“research at my fingertips.” One stated that “data was [sic] integral to future teaching plans...we have to make this easy...totally accessible.” Other teachers were so aware of the data potential that they started planning to order core material from the repository.

A representative statement by a teacher sums up the success of the pilot SOR field expedition for teacher education:

My previous experience with professional development was about 90% useless and 10% valuable. Most professional development for teachers (at least in my experience) is designed and conducted by people who maybe don’t quite understand teaching or students. As a result, it is often irrelevant to what actually goes on in the classroom. ... The School of Rock was clearly designed around a need… The key to the success of the School of Rock is that it was a responsive program—instead of creating something in a void, and then cramming it down our throats, the organizers sought to respond to an existing need; and during the program, they listened to our feedback and made adjustments as necessary.

In addition, as the expedition unfolded, it was hard to tell if the teachers were more impressed by the ship or by the crew. We expected the ship to be the most important component of the ocean-going portion of this experience, but clearly the entire crew, from cook to captain, complemented the experience. The crew of JOIDES Resolution is fairly consistent and as such carried out routines that had been established over time to support its scientific drilling mission. While the crew and the scientific party maintain a supportive and collegial relationship, there is often a separation that develops to maximize the science. One of the most successful curricular resources initiated on the ship were career profiles (e.g., http://www.oceanleadership.org/education/deep-earth-academy/students/careers/career-profiles/), which every participant helped develop and thus felt a sense of ownership. The participants were so enthusiastic about the career profiles because not many of their students will sail as ocean drilling scientists, but all of their students could see a career that they were capable of and possibly interested in. Thus, the participants scoured the ship to find crew to interview. Almost without exception, this resulted in a personal relationship between the participants and the crew. They began to eat meals together, they visited in the hallways, and they exchanged contact information. In the end, the captain was eating with the participants, and invited the entire SOR to “sail with him anytime!” Camaraderie and a spirit of unity and respect among the SOR group, technicians, IODP staff, Catamaran, and Transocean were apparent and welcomed. The scheduled trips to all areas of the ship, twice daily weather and ocean reports collected from the bridge, and the career profiles all likely contributed to this spirit, but perhaps more importantly, the teachers clearly respected everyone on the ship and thus earned the respect of the crew.

What Were the Long-Term Outcomes?

As we look at long-term impact, the observable indicators include a continuous engagement with the community, new professional opportunities and awards that were influenced and
supported by SOR participation, and continued development and implementation of SOR curricular resources. The SOR participants and instructors have remained a very close group.

One powerful indicator that SOR has had a long-term impact is the continuous engagement with, and expansion of, the community. The original instructional team is largely intact and has expanded since 2005. This expansion includes incorporation of new university-based collaborators and SOR participants into the instructional team. Instructors continue to teach in subsequent SOR or SOR-related courses. Instructors and participants continue to develop curricula together, as well as present at conferences and publish papers together. Participants invite instructors into their classroom and vice versa. Most importantly, there is a sense of community that is maintained by continuing to work together— instructor and participant.

A second area where the long-term impact of the SOR can be seen is through new professional opportunities that have been directly influenced by SOR participation. The most direct and powerful example is characterized by one of the SOR participants who was hired as a full-time member of the Ocean Leadership education and outreach team. While she was clearly an accomplished educator, her SOR experience and demonstrated ability to participate and thrive in the community was a deciding factor in her hiring. A second example is reflected by another well-accomplished SOR educator who worked in formal professional development for science educators on the east coast. In part because of her SOR experience and SOR professional connections, she switched jobs to informal science education on the west coast and is now working with a long-time collaborator of Ocean Leadership. The third example comes from a member of the instructional team who returned to graduate school after the SOR to develop and study the impact of emerging technology on learning, which closely mirrored his role with SOR. He continues to publish with the group, provides technology consulting for various curricular products, and used SOR technology examples in his portfolio to secure an educational technology job with a Fortune 500 company.

Following the SOR, all of the participants led informal presentations of SOR highlights, activities, and reflections to their students and fellow teachers. All but one participant has documented formal presentations beyond their students and fellow teachers to include: the local school boards; local interest groups (e.g., gem club, summer camp, retirement home); local and regional news sources; and local, regional, national, and international presentations at professional conferences, often in continued collaboration with instructors. One teacher taught a college-credit short course for science teachers based on SOR activities and samples requested through the Gulf Coast Repository. Another participant was able to help incorporate scientific ocean drilling into the new Ocean Hall exhibit at the Smithsonian (which opened in fall 2008). Four participants have returned to subsequent SOR workshops as instructors.

The long-term impact of SOR can also be seen through awards and recognitions supported by SOR participation. One SOR teacher with over 30 yr of teaching experience has received five teaching awards in the past year that all included a significant link to SOR participation and a collaboration that he developed with his local computer information technology support person to develop near real-time and asynchronous modules from his shipboard experience. A second teacher received the Outstanding Earth Science Teacher award for the Eastern section of the National Association of Geoscience Teachers, based in part on a strong recommendation and continued collaboration with a SOR instructor. A third example comes from a SOR informal educator; this participant’s museum team won two awards from the 2006 Museum and the Web Conference for their Science Buzz Web site, in which his work with SOR was cited.

The final area where the long-term impact of SOR can be seen is in the continued development and implementation of SOR curricular resources. The lead instructors developed over a dozen undergraduate- to graduate-level exercises for the SOR, and SOR participants translated their learning into useful teaching resources by developing 25 new discovery-based activities, posters, videos, and computer interactive modules related to ocean drilling research. Table 2 identifies some of curriculum resources stemming from the pilot SOR; all of the exercises listed in Table 2 (among many others) are accessible at the Deep Earth Academy Web site (http://www.oceanleadership.org/education/deep-earth-academy/). Several of the teachers and almost all of the instructors continue to create and modify curricular resources that are shared through this Web site and are patterned after SOR activities and/or are based on the wealth of data and legacy of scientific ocean drilling. These materials are constantly evolving through testing in schools and at various SOR outreach activities. Since the expedition, the educators have helped disseminate the new activities through 50 talks, workshops, presentations, and publications for local to national audiences. Other tangible outcomes are the subsequent SOR shore-based programs for educators, including programs held at Western Michigan University, Grand Valley State University, the national Geological Society of American (GSA) meeting in Philadelphia, the Denver Museum of Nature and Science, Manchester Community College, University of Massachusetts, Lamont Doherty Earth Observatory, the Gulf Coast Repository at Texas A&M, as well as extensions into graduate education via inclusion of SOR-adapted materials at Ben Gurion University in Israel and the international Urbino Summer School for Paleoclimatology in Italy, and funding of an extension project to develop SOR-type curriculum for the introductory undergraduate geology classroom (Jones et al., 2008; Leckie et al., 2008; Pound et al., 2008; St. John et al., 2008).

While we clearly recruited participants and instructors who were accomplished, initial SOR participation and continued engagement directly impacted their interests and ability to take the next steps in their careers, opened up many new professional opportunities, stimulated some impressive educational awards, and provided outlets for developing significant curricular resources. These participants still have opportunities to attend other professional development programs. Instead, their
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<td>Nannofossils Reveal Seafloor Spreading Truth!</td>
<td>Seafloor spreading</td>
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<td>SOR participant</td>
<td>Grades 5–8 Grades 9–12</td>
</tr>
</tbody>
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*SOR—School of Rock
†These (and others) can be found at http://www.oceanleadership.org/learning.
§S.E.A.—Science & Engineering Academy
almost unanimous continuous participation in SOR outreach signals a transition from receiver of professional development to provider, which is perhaps the best indicator of the long-term impact of SOR.

CONCLUSIONS

The SOR was a pilot seagoing educator workshop aboard the JOIDES Resolution during a transit of the drill ship from Victoria, British Columbia, Canada, to Acapulco, Mexico. During the 12 day expedition, 13 formal and informal educators from across the United States were mentored and taught by scientists engaged in ocean drilling research, the USIO education director and staff, and shipboard technical staff. This pilot program provided the educators with an opportunity to experiment on ocean-floor core samples and participate in hands-on learning in a number of the shipboard laboratories. They were exposed to the rich history of scientific ocean drilling and its foundational impact on our understanding of earth system processes and history. They learned that legacy scientific ocean drilling data are valuable educational resources and accessible on the Web.

By living, working, and learning aboard the JOIDES Resolution, the educators discovered the conditions of life at sea, the highly collaborative nature of scientific investigation, the workings of a research vessel, and the many scientific, technical, and maritime careers that serve the operation. C3 time (connections, communications, and curriculum) provided the educators with the opportunity to reflect on what they were learning, make connections with people, previous knowledge, and experiences, create original age- or audience-appropriate activities, and share their new experiences with their classrooms, museums, colleagues, and families.

The teachers were intensely engaged in the scientific endeavor and were highly motivated to translate what they learned at sea to classroom experiences for their students. They were involved in the excitement of discovery that comes on every expedition of scientific ocean drilling. SOR exemplifies the possibilities for bridging partnerships between science research and education. It strengthens and supports excellence in science education. It strengthens and supports excellence in science education. It strengthens and supports excellence in science education. It strengthens and supports excellence in science education. It strengthens and supports excellence in science education.

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REFERENCES CITED


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