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ANDRILL's Education and Outreach Programme 2005-2008: MIS and SMS Project Activities during the 4th IPY

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Abstract - A key goal of the ANDRILL programme's education and outreach (E&O) activities was to engage the public in, and inform it about, our scientific endeavour to uncover the behavior of Antarctica's ice sheets over the past 20 million years. We recognized that a critical component of ANDRILL's research effort was to ensure that our motivation, methods, and results were conveyed to non-experts in a clear and understandable manner. This effort benefited from several factors: a synergy between scientists and educators generated by the 4th International Polar Year (IPY); the allure of the Antarctic region as one of Earth's few remaining frontiers; a desire to understand and respond accurately to climate change discussions; and the interest of many nations and institutions to enhance science and environmental literacy in schools and across broad public audiences. In order to achieve ANDRILL's E&O objectives, we developed a diverse range of education and outreach projects, established key partnerships with a range of informal science education outlets, implemented a communication network of educators and scientists, and sparked the curiosity and interest of students while promoting understanding and a prospect of continuing engagement. A central component of ANDRILL's E&O activity, the on-ice ANDRILL Research Immersion for Science Educators (ARISE) programme enabled 16 science educators to participate in ANDRILL's scientific activities and gain first-hand experience in a multi-national scientific drilling programme. ARISE participants then used knowledge gained from this experience to develop innovative and exciting learning approaches for the public. Partnerships with established teaching and learning institutions and programmes provided excellent opportunities to broadcast content to a broad audience. Interest in ANDRILL from the popular media was high and resulted in the production of several film documentaries involving ANDRILL science, audio programmes, and print articles in newspapers and journals. ANDRILL's education and outreach materials and programmes are available at http://www.andrill.org/education.

INTRODUCTION AND OVERVIEW

The ANtarctic geological DRILLing programme (ANDRILL) developed an extensive and innovative education and outreach (E&O) programme as a key component of its overall scientific programme for the McMurdo Sound Portfolio (Harwood et al., 2006). This inaugural effort led to the successful recovery of the two longest drillcores in Antarctica, the complementary McMurdo Ice Shelf (MIS) and Southern McMurdo Sound (SMS) Projects (Naish et al., 2007; Harwood et al., 2009), that record a history of climate, ice sheet and geological changes. A primary goal of the integrated E&O effort was to engage the public in both the scientific and technical aspects of the drilling programme through the use of effective and innovative materials and approaches. In addition, we wanted to provide members of the

public with a view of the Antarctic continent from the perspective of an Antarctic geoscientist, and to also highlight the important role that Antarctica plays in the global system today, how that role has evolved through time, and the complex system of interrelated feedbacks that influence the Antarctic region into the future.

The ANDRILL programme developed and implemented the following five-component strategy to achieve its educational and outreach goals:

1. Network with the education and outreach 'community' to share ideas and learn about innovative and effective approaches to teaching and learning Earth science;
2. Create new 'stand-alone' E&O programmes within the ANDRILL structure (*e.g. ANDRILL Research Immersion for Science Educators* [ARISE] programme);
3. Establish partnerships to develop new projects with experts outside ANDRILL (*i.e.* ANDRILL personnel would act as advisors for new E&O projects, providing access to ANDRILL science and methods, but would not maintain primary responsibility for these projects);
4. Provide ANDRILL content and materials to enhance and expand existing E&O projects and programmes;
5. Communicate directly with news media and develop press kits and related materials to provide the media with key information about the science mission, methods, and outcomes of this major project of the 4th IPY.

As a result of this strategy we were able to establish a variety of E&O materials, projects, and news products including: an on-ice research experience for teachers (ARISE); a multi-lingual flexible exhibit and Media Guide; high-profile web-sites with videos and pod-casts; school curricula; numerous newspaper and popular news articles; and two major video documentaries. Details of these approaches and outcomes are described in this paper.

WORKSHOPS AND NETWORKS

Community involvement was a key strategy in developing the ANDRILL E&O plan. ANDRILL's science leaders and science management staff participated in several E&O workshops (*e.g.* US-IODP Meeting, University of Rhode Island, May 2003; TEA regional workshop, Illinois, 2003; and *Bridging the Poles: Education Linked With Research*, Washington, D.C., June 2004) and in education sessions at major geoscience meetings (*e.g.* American Geophysical Union, European Geosciences Union, and the Scientific Committee on Antarctic Research Open Science Conference, 2008). In addition, ANDRILL hosted E&O workshops in April 2005 (in conjunction with the US-ANDRILL Science Workshop), and in September 2006 (at the University of Nebraska-Lincoln), which brought together members of the MIS Project ARISE cohort and representatives from a variety of education and media projects focused on Antarctica. These workshops provided opportunities for parties interested in polar education to learn more about ANDRILL and to establish partnerships. We were also able to seek guidance from the E&O community regarding the types of media and materials that would be useful to other E&O programmes (*e.g.* video, photographs, and activities involving scientific data), providing us with a list of things to obtain while we were in Antarctica, and various vehicles and venues for their effective distribution.

ANDRILL RESEARCH IMMERSION FOR SCIENCE EDUCATORS (ARISE) PROGRAMME

OVERVIEW

ARISE is a professional development programme for science educators that was developed as the flagship for ANDRILL's E&O programme and was a key component of the original international proposal for the ANDRILL programme. ARISE was designed in accord with previous teacher immersion programmes such as *Teachers Experiencing Antarctica and the Arctic* (TEA) (Amati, 1999; McComb et al., 2001; http://tea.armadaproject.org), the *ARMADA Project* (http://www.armadaproject.org), and smaller institutional teacher research experience projects (e.g. Gosselin et al., 2003). The TEA programme brought classroom teachers to Antarctica (and the Arctic) to work within field and lab-based research teams, and ARMADA placed educators within science teams on US research vessels. These experiences usually inserted a single teacher within a research group. A network of educators was established to support participants following their field-based research experience. In contrast to the single-educator per research team approach used by TEA, the ARISE programme established teams of six to eight science educators and integrated these larger groups within the ANDRILL research team working in Antarctica. The main objectives for this 'team approach' was to (a) provide science educators the opportunity to learn science through an authentic research experience, and (b) provide an environment in which the education experts could regularly interact, discuss their common research experience, and develop innovative educational activities, projects, materials, and curricula.

A total of sixteen science educators, representing the four ANDRILL partner nations (Tab. 1), participated in five field-based research projects between 2005 and 2008, as part of ANDRILL's site survey and drilling efforts. In each of the two drilling seasons (2006 and 2007) the ANDRILL E&O Coordinator also participated on-ice to help manage the ARISE programme. In 2005 a teacher from the ARMADA Project became the first ARISE participant when she was matched with ANDRILL and spent five weeks as a member of

Tab. 1 – ARISE Participants and their affiliations.

SMS Site Survey - 2005 Michelle Brand-Buchanan, Teacher, Alexandria Middle Magnet in Alexandria, Louisiana, USA. **MIS Project - 2006** Matteo Cattadori, Teacher, I.T.I. Fontana Rovereto, Trento, Italy; LuAnn Dahlman, Curriculum Developer, TERC, USA; Vanessa Miller, Teacher, Central Park East 2, New York, NY, USA; Alexander Seigmund, Professor, University of Education, Heidleberg, Germany; Julian Thomson, Teacher, Lower Hutt, New Zealand; Betty Trummel, Teacher, Husmann Elementary School, Crystal Lake, IL, USA.	**SMS Project and Mackay Sea Valley Site Survey - 2007** Julia Dooley, Teacher, Downes Elementary School, Newark, DE, USA; Robin Frisch-Gleason, Teacher, Bach Elementary School, Ann Arbor, MI, USA ; Joanna Hubbard, Science Curriculum Specialist, Anchorage School District, Anchorage, AK, USA; Rainer Lehmann, Teacher, Waldorf-school Hannover Bothfeld, Hannover, Germany; Ken Mankoff, Programmer/Educator, NASA GISS, New York, NY, USA; Kate Pound, Professor, St. Cloud State University, St. Cloud, MN, USA; Graziano Scotto di Clemente, Teacher, Scuola Media Luigi Stefanini, Treviso, Italy; Bob Williams, Teacher, Wairarapa College, Masterton, New Zealand. **ONH Project Site Survey - 2008** Shakira Brown-Petit, Teacher East Harlem, New York, NY, USA

the SMS Project seismic/site survey team (Betterly et al., 2007) working on the sea-ice in McMurdo Sound (Fig. 1). In the following year, six science educators (Fig. 2) joined the MIS Project's Science Team based at the Crary Science and Engineering Center at McMurdo Station. In the final year of ANDRILL's current drilling operations (2007), eight science educators (Fig. 3) joined the science team and split their time and effort between processing and study of the SMS Project core at the CSEC and field work on a seismic survey team operating on sea ice in Granite Harbour. In 2008, one science educator joined a seismic survey team working to select future ANDRILL drilling targets in the New Harbor area.

Fig. 1 - Michelle Buchanan (ARISE 2005), supported by Laura Lacy of the ANDRILL SMO, lowers an airgun through a hole in the sea-ice during site survey activities for the Southern McMurdo Sound Project. Drilling sled with auger is visible in the distance over her shoulder, at the next shot-point, 100 m along the line.

SELECTION PROCESS

Each partner nation conducted its own selection procedure. US applicants submitted an application package to the ANDRILL Science Management Office. These packages were reviewed by a panel, which then made selection recommendations to ANDRILL-US Project Leaders. Other ANDRILL partner nations selected participants through a variety of mechanisms including committee review and direct appointment as part of the educator's role in a national programme (*e.g.*, Teaching Fellow for the Royal Society of New Zealand).

PRE-DRILLING/FIELD-DEPLOYMENT ACTIVITIES

Pre-Drilling Meeting

Once selected, ARISE participants were encouraged to attend a pre-deployment orientation meeting in order to meet members of the ANDRILL Science Team, foster collaborative relationships, and provide participants with a sense of ownership in the science.

Fig. 2 - The 2006 ARISE cohort (back row, left to right – Julian Thomson, Betty Trummel, Alexander Siegmund, LuAnn Dahlman; bottom row – Vanessa Miller, Matteo Cattadori).

Fig. 3 - The 2007 ARISE cohort (back row, left to right – Joanna Hubbard, Rainer Lehmann, Bob Williams, Ken Mankoff, Graziano Scotto di Clemente; bottom row – Kate Pound. Julia Dooley, Robin Frisch Gleason, Louise Huffman [E&O Coordinator]).

In 2006 ARISE team members from the USA and New Zealand met at the MIS Project Pre-Drilling Meeting, 3-5 September, at the University of Nebraska - Lincoln. The following year, ARISE team members from the USA and New Zealand met during the SMS Project Pre-Drilling Meeting, 15-17 August, also at the University of Nebraska-Lincoln. Participation in these meetings provided an opportunity for many members of each ARISE cohort to meet their education colleagues and members of the science team with whom they would be working in Antarctica. These meetings were the first major event involving the majority of the respective science teams. Integration of the ARISE participants at these events also provided the participants with an opportunity to get involved in logistics discussions and to directly observe how the science project evolved. In addition, ARISE members were able to begin to explore ways in which international collaborations could enhance the experience and improve their project plans. Expectations and responsibilities were defined, and participants were given time to interact with each other, as well as to plan and address any questions and concerns prior to deployment to Antarctica.

School Visits and Workshops

Many members of each ARISE cohort conducted workshops and gave presentations at schools and community events during the period leading up to deployment to Antarctica (Fig. 4). The goal of

Fig. 4 – Matteo Cattadori and Betty Trummel (ARISE 2006) visit classrooms prior to deployment to Antarctica.

these presentations was to generate excitement and engage school teachers and their students in ANDRILL's scientific objectives and technical ability and to encourage them to follow ANDRILL's progress through the two to three months on-ice drilling period. Over one thousand teachers and several thousand school students from the USA, Germany, Italy and New Zealand, were inspired to engage the students in Antarctic geoscience as a result of the outreach efforts conducted by many ARISE members prior to their departure to Antarctica.

In both 2006 and 2007 ARISE team members met in Christchurch several days before they were scheduled to head to Antarctica to conduct 'multi-national' outreach. In 2006 the ARISE cohort conducted school visits, and in 2007 the ARISE cohort led a four-hour workshop for gifted and talented students and gave two community presentations for adults. Many of the hands-on *Flexhibit* activities (see section below) were used during these presentations.

Classroom Networks

Prior to deployment to Antarctica, significant effort was directed towards establishing connections to schools in each of the participating nations. Students and teachers at these schools were encouraged to 'join the ANDRILL adventure' via ANDRILL's web-based education and outreach portals including *Project Iceberg* (http://www.andrill.org/iceberg) and *Project Circle* http://web.me.com/lhuffman/Project_Circle/Welcome_.html).

ON-ICE ACTIVITIES

Research Experience

At the outset of the ARISE programme the goal was to immerse each participating educator within a science discipline and allow them to become fully engaged in the scientific process and outcomes. This goal was difficult to achieve in 2005 as the ARISE participant worked on a seismic data collection expedition and most of the daily tasks were practical (drilling holes in the sea-ice and deploying an air gun) (Betterly et al., 2007). Collection of data and initial field processing is highly specialized and the educator was only able to observe this work rather than do it herself. However, the experience did provide authentic insight into the nature of geophysical fieldwork. Furthermore, daily interaction with the geophysicists both in the field and at camp provided plenty of time to learn some basic principles of geophysics.

Our goal to provide a more complete science experience became achievable once drilling operations began in 2006. The research immersion experience was designed to allow participation in all components of the on-ice science operation at the CSEC including: core description, sample selection, sample preparation/ processing, sample examination, data generation, and data interpretation. In order to achieve this goal each educator was placed within teams working on one of the following disciplines: paleomagnetism, sedimentology, paleontology, pore water geochemistry, petrology, and core sampling

Fig. 5 – ARISE participants engaged in a variety of scientific activities including: a. examining rock thin sections; b. studying microfossils; c. collecting physical properties data using a multi-sensor core logger; d. sampling the split core; e. helping the curatorial team; and f. collecting chemical data from pore water samples.

and curation (Fig. 5). Note that science operations at the drill site were not considered due to logistical restrictions, although the ARISE team members visited the drill site to gain an understanding of the coring process and drillsite science programme. Science disciplines listed above were selected because the methods used to conduct the on-ice science were relatively straightforward and allowed the educators to quickly get involved in the scientific process. Some disciplines did provide a more complete experience, *i.e.* involved sample processing, data collection, and data interpretation (sedimentology, paleontology). Other disciplines were more limited, in that much of the on-ice work involved sample collection and processing (*e.g.* paleomagnetism, curation, and geochemistry). To accommodate the differences between discipline-based tasks the ARISE participants rotated jobs every 3-4 weeks to provide a more rounded experience. In 2007 a training day was implemented to facilitate efficient transition between discipline tasks and reduce the pressure put on the scientists who had to focus on processing samples to keep up with continuous core flow. The training day also provided an opportunity for the educators to utilize their teaching skills in training their replacements, and to develop ideas and methods for effective knowledge transfer. ARISE members also participated in daily science team meetings where current results and some initial interpretations were presented and discussed, and where scientists taught other team members about their results and specific area of geological expertise.

The ANDRILL drilling rig operated twenty-four hours a day, seven days a week. Core was delivered to the CSEC at least once a day (weather permitting). Science operations were also conducted over a 24-hour period to keep up with core-flow and the CSEC science team was split into two twelve-hour shifts. In 2006 several members of the ARISE cohort wanted to work on the night shift. Relevant Science Discipline Team Leaders indicated that the educator's help was needed so ANDRILL Education coordinators agreed to allow the ARISE members to work at night. However, this split the cohort and removed some capability for effective collaboration. In 2007 all ARISE members worked on the day shift allowing them to participate as a team in other organized ARISE activities, such as those described below.

Geoscience Course

The initial concept of the ARISE programme included a geoscience course that would be offered to ARISE participants during the on-ice phase of the programme. We aimed to provide formal classes using the on-site research scientists as instructors and facilitators. Several field trips to locations away from McMurdo Station were included in the course. During the MIS Project, implementation of the course was hindered by several challenges. Scheduling was difficult, particularly for the ARISE participants and scientists who worked during the night-shift, and a lack of formal structure frustrated participants and instructors. We improved the course structure and organization for the SMS Project. A syllabus was prepared prior to deployment and text books were selected including *Antarctic Marine Geology* (Anderson, 1999) and *Geology: A Self-Teaching Guide* (Murck, 2001).

Teleconferences

Teleconferences were conducted during each of the two drilling seasons and typically involved ARISE participants and research scientists talking to off-ice audiences (Fig. 6). These events connected ANDRILL team members working at CSEC to a variety of distant educational settings including: individual classrooms, entire schools, museums, math and science conferences, 'girls in science' conferences, and professional development conferences for educators. Significant preparation was required to ensure effective communication between McMurdo Station and distant classrooms. The following provides an overview of procedures and technical requirements that we typically followed and used to achieve a successful conference:

- Prepare a powerpoint presentation to highlight the relevant teleconference theme and upload to a website where it can be retrieved by the receiving teacher;

Fig. 6 – An ANDRILL science team member at the Crary Science and Engineering Centre at McMurdo Station in Antarctica talking to six-year-old school students in the United States.

- Schedule the teleconference well in-advance to account for time/date differences between McMurdo Station and the receiving site(s);
- Provide a speakerphone at all sites (a microphone is recommended for classrooms;
- Ensure that classrooms have a large screen and projector to allow the audience to effectively view the powerpoint presentation.

As the teleconference progressed, each site advanced through the prepared presentation at the same time as the educator(s) and scientist(s) at McMurdo Station told their 'ANDRILL story'. Audience members were then invited to ask questions. Several teleconferences were conducted during the MIS Project including multiple connections between McMurdo Station and school classrooms in Italy. During the SMS Project a well-coordinated effort to conduct teleconferences resulted in over forty successful connections with off-ice audiences.

Video teleconferences (VTC's) between McMurdo Station and remote classrooms were also conducted during both drilling seasons although these required more technical preparation than standard teleconferences. A videoconference procedure and set of requirements has been established by the CSEC-IT group, Raytheon Polar Services Company, and can be obtained from the US Antarctic Programme. Technical set-up at the CSEC was generally simple and straightforward (required a hand-held video camera, Ethernet connection, and a telephone) but establishing connections through school firewall ports at the receiving end was often difficult. Preferably a test of the equipment needed to be run a week before the scheduled videoconference. Connections utilized low-bandwidth through Yahoo Messenger. Live images were sent off the ice to classrooms and allowed the audience to get a sense of the working environment in the CSEC and see a view of the landscape outside the laboratory window. While these videoconferences provided the audience with a 'real-time' sense of place image quality was limited (low resolution and jerky) due to required low bandwidth transmission. Over fifteen low-bandwidth VTC's were conducted during the two drilling seasons 2006-07.

Note that high-bandwidth, high-quality video-conferences were also conducted during the 2007 season (see *Ice Stories* section below). These events required permission from the National Science Foundation, which needed to be obtained at least 60 days before the conference was scheduled to take place.

Blogs

Blog entries were posted by each ARISE participant in each of ANDRILL's research seasons. These blogs were an important tool for communication and achieved broad impact. All blogs are archived at http://www.andrill.org/iceberg/blogs and demonstrate the process of science and the adventure of living and working in an extreme environment, through lively, engaging stories. Each blogger had his/her own style and aimed their writing and photographic documentation at different age groups. Some blogs posed questions for the readers; some set-up science activities for the students to try; some told personal stories; some reported the science; while all recorded the experience for history. The team approach provided a wide variety of stories, voices and subject matter. During the SMS Project, in an effort to help maintain cohesion and communication within the science team, the ARISE educators' blogs were sent as RSS feeds to the website.

In addition to the efforts of the ARISE team, several members of the MIS and SMS Project science teams also posted blogs to a variety of web sites including: Popular Mechanics, Columbia University, University of California-Davis, Blogspot, and International Polar Year.

Postcards

Several ARISE outreach projects utilized a postcard theme. Each ARISE educator penned at least one *Postcard from the Field* that were posted on the University Corporation for Atmospheric Research (UCAR) *Windows to the Universe* website (http://www.windows.ucar.edu). In addition, classrooms were invited to create postcards comprising original artwork and questions about Antarctic science and mail these to ARISE educators in Antarctica. Scientists, educators, and members of the McMurdo Station community answered these questions and the postcards were sent back to the students, postmarked from the ice. Enthusiastic feedback from participating classrooms and individual recipients was overwhelmingly positive. Finally, The ANDRILL SMO produced postcards that were made available to the SMS Project scientists and the McMurdo Station and Scott Base on-ice communities to send to friends, family, and colleagues around the world. This was an effort to reach a diverse audience and attract them to the ANDRILL web site, to learn about ANDRILL activities and results.

Laboratory Experiments and Lessons

A series of small lab experiments were conducted by ARISE members at CSEC and were recorded and published on the *Progettosmila.it* website (see below) (examples include a simple lab on the Coriolis force, and measurement of the declination of the Sun at noon). In addition, a video-lesson was created to explain how sedimentologists describe and illustrate rock and sediment core using PSICAT software.

On-line Competitions

Several on-line competitions were created by the ARISE participants to engage students in ANDRILL and polar science. These competitions included a short quiz published on *Progettosmila.it* that comprised a series of questions on polar science. Students responded online and were sent prizes including t-shirts, posters, books, and entry tickets

Fig. 7 – Examples of activities used during the Crary Science and Engineering Center 'open house' event hosted by ANDRILL in 2007. ANDRILL team members utilized *Flexhibit* materials to convey a range of climate science concepts and guided members of the McMurdo Station and Scott Base communities through an interactive tour of ANDRILL's technological capabilities and scientific activities.

for Antarctic museums if they responded correctly and in the quickest time.

Crary Science and Engineering Center Open House

During the MIS and SMS drilling seasons the ANDRILL team hosted an open-house event at the CSEC (Fig. 7) to share ANDRILL's scientific approach, research goals and technological capability with members of the McMurdo Station and Scott Base communities who supported the ANDRILL effort and other US and NZ research. Members of the ARISE programme were instrumental in developing activities for the event during the SMS Project (http://www.exhibitfiles.org/andrill) and used curriculum from the Antarctica's Climate Secrets project (Dahlman, 2008) to convey climate science concepts. This event helped establish a greater understanding of ANDRILL's science, and allowed for direct communication between station support staff and the ANDRILL team.

POST-ICE ACTIVITIES

The variety of projects and activities that were developed or conducted by the ARISE team after leaving Antarctica were as many and varied as the personalities and talents involved in the programme. Some of these projects and activities are outlined below.

Presentations and Workshops

Following their on-ice experience, most members of the ARISE cohort took their ANDRILL experience to a range of audiences in a variety of educational settings including kindergarten classrooms, adult Sunday school classes, packed auditoriums, museums, and small living room gatherings. Each of these visits has brought Antarctic geoscience concepts and ANDRILL activities to life.

The ARISE programme also established key relationships between educators and researchers and paved the way for ANDRILL scientists to visit classrooms, as well as to connect to schools through telephone calls and web based interviews. Many ANDRILL science team members maintain a connection with the ARISE participants and the learning environments at which they teach and work. These connections are significant as both web-based and personal connections between the public and practicing scientists have a positive impact on science interest and understanding (Koszalka, 2002).

Video Products

Several participants created short-films using material that they collected on-ice and include movies that highlight the nature of science from the perspective of an Antarctic geoscientist.

Workshops for Teachers

Summer workshops for teachers and camps for students were conducted by several ARISE participants at a variety of locations in Italy and the United States (*e.g.*, US National Science Teacher's Association (NSTA) short course *Hot Topics: Cool Science* in 2006, and the Golden Apple *Polar Science Workshop*, Starved Rock, IL, 2006). These meetings aimed to engage teachers in Antarctic science and show them how to bring the excitement of scientific research in Antarctica to children in an authentic way.

A series of professional development workshops for middle school teachers entitled *C2S2: Climate Change Student Summits* were run by staff at the ANDRILL Science Management Office in mid 2008 and again in 2010, and will continue at 4-5 sites per year across the US through 2012. Climate science research conducted within the ANDRILL programme was integrated within the summit content. These workshops were followed by the C2S2 student summits (http://web.me.com/lhuffman/C2S2/Welcome.html).

Fig. 8 – School students work with Kate Pound (ARISE 2007) to collect sediment cores from beneath a 'floating ice platform' on a lake in Minnesota in the United States, to model sediment core studies similar to the ANDRILL cores.

Curricula and Teaching Resources

Many ARISE participants developed teaching resources that aim to help educators integrate authentic science experiences and climate change concepts into many subject areas including science, math, English, and environmental studies. Training units using ANDRILL scientists' field notebooks, guides to inquiry through science notebooks in the classroom, traveling discovery kits and outreach modules that reach rural communities are being developed and tested in various places around the world. ARISE educators have developed clever, effective ways to help teachers connect their required curriculum to current, authentic science. Examples include:

- The *ANDRILL Lake Coring Outreach VEnture* (ALCOVE), which is a sediment coring project designed to bring the process of sediment coring, analysis, and interpretation to life for middle and high school students and their teachers (Fig. 8; Pound et al., 2008);
- A Google Earth layer that provides a virtual tour of the ANDRILL SMS project. This layer is connected to a global overview of climate through the *Education Global Climate Model* (EdGCM);
- Web-based education and outreach projects including *Progettosmilla.it* (http://www.progettosmilla.it/2/) and *Coole Klassen* (http://www.polarjahr.de/Expeditionen.451+M54a708de802.0.html);
- Curriculum developed using ANDRILL data in collaboration with the Integrated Ocean Drilling Programme (IODP) that integrates scientific ocean drilling data and research with education in a spectrum of introductory geoscience courses that serve general education students, pre-service teachers, and early geoscience majors (Leckie et al., 2009);
- A 'walking-guide' to the Geology of Hut Point Peninsula, an educational resource provided to the McMurdo Station and Scott Base community as a recreational exploration of the local volcanic geology;
- Curriculum developed for the US-NSF funded *Antarctica's Climate Secrets* project (Dahlman, 2008);
- New Zealand national curriculum educational achievement internal assessments addressing climate change themes;
- Audio materials that make science experiences accessible to blind students and other special needs populations.

Fig. 9 – Megan Berg films David Harwood at Nussbaum Riegel in the Taylor Valley to include in one of *Project Iceberg's* video journal series. *Project Iceberg's* web portal page to a variety of educational resources available at http://www/andrill.org/iceberg.

WEB-BASED EDUCATION PROJECTS

The internet was utilized extensively as part of ANDRILL's E&O efforts. In addition to its own website, ANDRILL's partners developed a variety of web-based outreach. A few are summarized below.

Project Iceberg

Project Iceberg was developed as ANDRILL's web-based Education and Outreach portal (Fig. 9) and was the primary link to ANDRILL's on-ice activities during drilling (http://www.andrill.org/iceberg). The website hosts several creative resources that engage people in ANDRILL's science. A set of video journals are available for download and includes two series. The first series, produced during the MIS Project (2006) and available in weekly installments, takes the viewer on a journey to Antarctica and follows the on-ice drilling and scientific operations. As the videos track the core as it is pulled from beneath the sea-floor and is passed through the suite of scientific analyses conducted at the drill site and CSEC, the viewer meets members of the science, drilling, education, and support teams. The sequence of titles in the 2006 video series includes: *Join the Journey; Getting to the Rock; Preparation for Departure; Southbound; Happy Camper School; Drilling Team; Physical Properties and Logging; Core Curation; Sedimentology Team; Paleontology Team; Petrology Team; Paleomagnetism; McMurdo Life*; and *Co-Chief Wrap-Up*. The second video series, produced during the 2007 SMS Project, focuses on the scientific drivers for ANDRILL, exploring the geology of the Antarctic continent, and explaining why ANDRILL aims to recover sediment and rock core from key locations around the Antarctic margin. Titles in the 2007 video series include: *Antarctica Today*; *Antarctic Geology*; *Historical Journey*; *Where to Drill*; *Telling Time*; and *Cenozoic Global Climate*. Companion texts have been produced to accompany each of the video journal series. In addition to video journals, *Project Iceberg* also includes links to blogs, ice sheet animations, the *Flexhibit* website, ARISE programme information, a photo library, and links to other educational websites with an Antarctic focus.

Project Circle

Project Circle is an online collaboration between science educators from around the world and connects students, teachers and interested participants with ANDRILL (Fig. 10). The original Project Circle community was established prior to deployment of the SMS Project Science Team in 2007. Each participating teacher received a set of teaching/learning materials that were developed as part of the *Antarctica's Climate Secrets* Project and include an activity guide, podcasts, videos and banners. Participating educators were connected through an online group-hub, which

Fig. 10 – Images from *Project Circle* activities including: a. the Pound Middle School banner 'flying' at the ANDRILL SMS Project drill site (Richard Levy for scale); b. middle school students and teachers engaged in a teleconference with ANDRILL team members in Antarctica; c. students using Flexhibit activities, and watching ice melt; d. students learning about microfossils during a visit from an ANDRILL scientist.

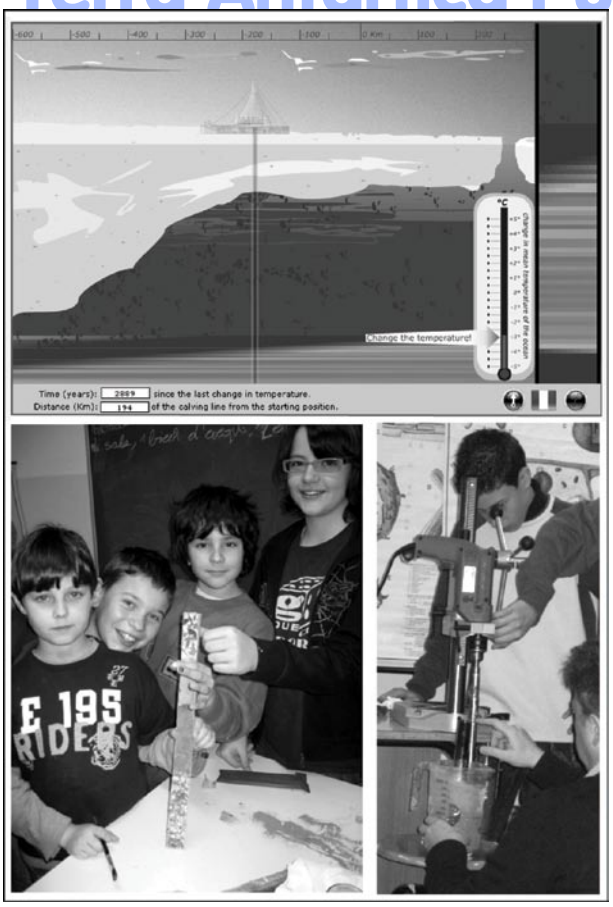

Fig. 11 – Progettosmilla.it provides online teaching resources including animations that describe how the West Antarctic Ice Sheet has advanced over and retreated from the ANDRILL MIS Project drill site as climate (temperature) has changed through time. The project also offers classroom programmes and professional development for teachers. Italian students construct and describe a 'mock' sediment core (left) and try to drill a system that simulates the ice shelf environment (right).

provided a virtual forum in which ideas were presented and discussed, activities and photos were shared, cultural exchanges could occur, and students were able to chat. Each participating classroom received a personalized postcard that was sent from Antarctica and engaged in a teleconference with ANDRILL scientists and ARISE educators. Each participating school agreed to lead a *Flexhibit* to reach out to their larger communities.

Many participating schools also sent banners and t-shirts to Antarctica. These banners were photographed in a variety of locations in Antarctica (Fig. 10a) and were sent back after being signed by the ANDRILL team and members of the McMurdo Station community. Many of these flags and banners are now proudly displayed in the school buildings.

Coole Klassen

Coole Klassen (www.polarjahr.de/Coole-Klassen.155.0.html) is an online polar science education project that involves more than 130 teachers from Germany. The project was developed during the SMS Project by the German ARISE participant. Engaging materials based on the science behind the IPY and ANDRILL were delivered to teachers via blogs and video journals. In addition, geography lessons showing the relationship between Antarctic geology, climate and ocean circulation were uploaded and made available to all participants. The ultimate goal of the project is to have an impact on German education. Connections with German newspapers were leveraged to broaden the impact of the website and articles have been submitted for publication in geographic journals. On-going collaboration between educators participating in *Coole Klassen* is encouraged and all educators are asked to present at conferences, to revise German curricula, and to publish articles in educational journals.

Progettosmilla.it

Progettosmilla.it is a web portal project that provides access to an expansive variety of educational materials about Antarctica, ANDRILL, and other Italian polar research activities. The project has been supported by the Italian National Museum of Antarctica (Museo Nazionale dell'Antartide), the Museum of Natural Science of Trento (Museo Tridentino di Scienze Naturali), and the School Administration of Trento (Dipartimento Istruzione della Provincia di Trento). The web site contains blogs, photograph libraries, interactive animations, and information about ANDRILL science (Fig. 11). *Progettosmilla* extends its reach beyond the website and provides online support to science teachers to help them link their Earth science curriculum to polar geoscience topics. The project has facilitated two science teacher training courses on ANDRILL and Antarctica reaching 60 participants. In addition, Progettosmilla has helped test the *Flexhibit* package and has translated the materials into Italian.

The project involved over 2000 students, 100 teachers and roughly 60 schools in 18 different italian's regions. The involvement of local institutions allowed more than 100 meetings to occur between the participant schools. The method of ARISE-progettosmilla.it has recently been replicated in a new E&O programme of scientific research like the ORTLES project and LARISSA (LARsen Ice Shelf System Antarctica).

PARTNERSHIPS WITH INFORMAL SCIENCE EDUCATION PROGRAMMES AND INSTITUTIONS

ANDRILL established partnerships with key informal education institutions (*e.g.* science museums) to develop new outreach programmes (*e.g. Antarctica's Climate Secrets*) and to provide content material and resources for existing programmes and new public exhibitions.

Antarctica's Climate Secrets

The *Antarctica's Climate Secrets* project (http://www.andrill.org/flexhibit/index.html) was developed

Fig. 12 – Flexible Exhibits (*Flexhibits*) have been conducted at a variety of locations around the world. The *Flexhibit* packages are part of the *Antarctica's Climate Secrets* Project and are designed to enable young learners to organize and run events for their local communities, and teach about ANDRILL and polar science to their peers, their parents, and the public.

through collaboration between ANDRILL scientists, the University of Nebraska State Museum, Nebraska Educational Telecommunications (NET), and NOVA (WGBH-Boston). The project comprised development and implementation of flexible exhibits and production of a science documentary. The Flexible Exhibit (*Flexhibit*) package includes hands-on activities, attractive and engaging banner graphics, and video podcasts that make it possible for groups of 10- to 15- year olds to have some fun learning, teaching and exploring. The activities (Dahlman, 2008; Dahlman 2009, Italian edition by M. Cattadori and C. Ossola) were designed to allow groups of young learners to host a public science event or develop their own exciting exhibit for peers, families, or the public (Fig. 12). Many of the ARISE programme participants have used the *Flexhibit* materials and curriculum as part of their ongoing education and outreach efforts.

The NET/NOVA role in the *Antarctica's Climate Secrets* project was to create a TV documentary that included ANDRILL's paleo-climate research in Antarctica. Filming for the documentary occurred in Antarctica during the SMS seismic survey season in 2005 and the SMS and MIS drilling seasons in 2006 and 2007, respectively. Additional filming has also occurred at a variety of locations in New Zealand and the United States.

The Exploratorium and Ice Stories

The Exploratorium museum of science, art and human perception in San Francisco developed the *Ice Stories Project* (http://icestories.exploratorium.edu/dispatches/index.php) as part of their IPY outreach programme. This ongoing project provides polar scientists with cameras and blogging tools and asks the scientists to document their field work. The material collected by the scientists is presented to the public via the Exploratorium's web site. ANDRILL established its collaboration with the Exploratorium during the MIS

Fig. 13 – The *Ice Stories* Studio at the Exporatorium in San Francisco. Inset shows ANDRILL scientist Tim Paulsen communicating via video-teleconference from the SMS Project drill site lab located on sea-ice on McMurdo Sound.

Project in 2006, prior to the formal beginning of *Ice Stories*. During the 2006 field season team members conducted a low-resolution VTC from the core lab at CSEC to the Exploratorium in San Francisco. During the SMS Project field season members of ANDRILL's science team participated in several high-resolution video conferences with Exploratorium staff at their studio in San Francisco. One of these conferences was broadcast from the SMS drill site floating on eight meter thick sea-ice in 380 meters of water (Fig. 13). These conferences utilized Polycom equipment and were broadcast live at the museum and sent out to a broader audience via the internet. In addition, one of the ANDRILL scientists participated directly in the *Ice Stories* project and was provided a video camera and training prior to deployment to Antarctica.

Museum Exhibitions

Several museums around the world have incorporated exhibits containing ANDRILL-related materials and information. Many of these exhibits have been facilitated by ARISE participants and several utilize the *Flexhibit* package developed in the *Antarctica's Climate Secrets* project (Fig. 14).

Virtual Field Trips

LEARNZ provides teachers with virtual field trip experiences to locations in New Zealand and Antarctica (http://www.learnz.org.nz/). During 2006 and 2007 the *LEARNZ* team worked with ANDRILL team members to collect video, audio, and photographic material from the drill sites, Scott Base, and at McMurdo Station and used these materials to construct virtual field trips that highlighted ANDRILL science. ANDRILL team members also participated in teleconferences hosted by *LEARNZ* that connected our scientists and educators working at CSEC to several schools in New Zealand.

Fig. 14 – Robin Frisch-Gleason (ARISE 2007) helped develop and stage an exhibition on Antarctic research and ANDRILL in a museum at the University of Michigan.

Polar-Palooza

POLAR-PALOOZA was a multimedia initiative - supported by both the US-NSF and NASA as part of the US International Polar Year activities. The project involved researchers, in-person presentations at science centers and natural history museums, video and audio podcasts, and more (http://passporttoknowledge.com/polar-palooza/). The project incorporated a traveling science road show, which included participation by ANDRILL Co-chief Scientists David Harwood and Ross Powell.

NEWS MEDIA

MEDIA GUIDE AND POLICY

A 'Media Guide' (ANDRILL Science Management Office, 2006) was produced to provide the news media with key information about the ANDRILL programme. This document was translated into Italian, and both the Italian and English versions were printed and made available to media, policy makers, educators and science team members, and is available at http://www.andrill.org/media. ANDRILL also developed a policy for media and guidelines for science team members (in Naish et al., 2006) which were designed to help manage interactions and information flow between ANDRILL team members and the cohort of on-ice media.

Fig. 15 – A film crew from Nebraska Educational Telecommunications collects footage of an ANDRILL scientist in the field (left), and radio reporters from *SoundPrint Media* capture audio material from Julia Dooley (2007 ARISE participant) during the Crary Science and Engineering Center open house event.

FILM, TELEVISION, AND PHOTOGRAPHY

Several filmmakers have worked with the ANDRILL team at various stages throughout the five-year period of the McMurdo Sound Portfolio. The projects and products proposed by these filmmakers ranged in scope from those that focused on full-scale science documentaries centered on the ANDRILL programme to those that wanted to include ANDRILL as a minor piece in a more general film about life in Antarctica. These film projects are summarized below.

A film crew from Nebraska Educational Telecommunications (NET) have collected hours of video footage recording ANDRILL's activities from 2005-2009. The NET team has captured the SMS Project seismic survey (in 2005), the ANDRILL drilling system in action, scientists working in the field in Antarctica (Fig. 15) and New Zealand, science discussion at both a variety of workshops, and research conducted at home institutions around the world. This video material will be used as part of a NOVA (WBGH-Boston) documentary being developed as a component of the US-NSF supported *Antarctica's Climate Secrets* Project. In 2006 Werner Herzog captured images and interviews with drillers and scientists at the ANDRILL MIS drill site and at the Crary Science and Engineering Center in McMurdo Station. During the SMS Project field season a film crew from DOX Productions collected footage for its project on climate change research in Antarctica. The project was a joint initiative between DOX, Victoria University and Oxford University to communicate the problems and science of climate change. The flagship of this initiative is the production of a feature film for cinema release, entitled *The Tipping Point.* Regarded as a sequel to Al Gore's *An Inconvenient Truth* – which documented environmental change and links such change to human activity. *The Tipping Point* will help the audience understand how the climate system works and what consequences we can expect through the eyes of working scientists. In addition to the feature film, DOX will produce DVDs of the film for wide distribution at schools and libraries, a website and other forms of literature, addressing both global and regional climate change issues.

Over the two years of drilling, television crews from New Zealand, the United States, and Germany visited CSEC and the drill site to capture footage for a variety of news broadcasts. In addition, several ANDRILL science team members were asked to capture film footage for television broadcasts in their home nations, and several radio stations broadcast live interviews with ANDRILL scientists in Antarctica during the drilling period.

During the SMS Project, Lucia Simion, a photographer from Italy was immersed within the SMS science team and photographed daily activities on-ice, while also interviewing Italian SMS women science team members for an article about women scientists (Simion, 2008). She has arranged several exhibitions of her ANDRILL photographs in France, is engaged with schools and has provided assistance to ANDRILL to translate the *Flexhibit* banners into French and Italian.

AUDIO PROGRAMMES

A US NSF-funded IPY project, *Pole to Pole* – A Collaborative Radio Series and Educational Clearinghouse created by Soundprint Media Centre, Inc. (SMCI) set out to produce a landmark multi-part radio series, and which aimed to capture documentaries, short radio features and oral histories on scientific research in the Polar Regions. International collaborators working with SMCI included the Australian Broadcasting Company, the BBC World Service, Radio Deustche-Welle and Radio New Zealand. SMCI and Radio New Zealand collaborated to produce a documentary specifically on ANDRILL science. In addition, several Radio New Zealand pieces were produced by an on-site journalist during the MIS Project. During the SMS field season, two radio journalists from the US deployed to Antarctica and was stationed at McMurdo (Fig. 15). The journalists joined the ANDRILL-SMS science team for two weeks to capture daily science activities and sounds of Antarctica, and to conduct interviews.

PRINT MEDIA

Many newspaper articles and popular science journal pieces have been written about the ANDRILL programme through the entire process of the programme (*i.e.*, before, during, and after drilling activities were completed in Antarctica). Access to several of the journalists who wrote these articles was

facilitated through the on-ice journalism programmes of the National Antarctic Programmes of New Zealand and the United States. However, most of ANDRILL's team members actively worked with their local media to highlight the importance of Antarctic climate change research and the key role that ANDRILL has played in developing the science. The *Antarctic Sun* an on-line newspaper for the US Antarctic Program (http://www.antarcticsun/usap.gov) carried several articles that covered ANDRILL's activities in the McMurdo region in 2005 to 2007.

SUMMARY

ANDRILL's Education and Outreach programme was comprehensive and ambitious. It included a spectrum of projects and programmes ranging from a full-immersion research experience for science educators to telephone interviews with local news media. The programme helped establish a high profile for ANDRILL and its scientific endeavor and produced a variety of quality education and outreach materials. Our E&O effort is ongoing and the relationships established between scientists, educators and the media will continue to produce innovative and effective mechanisms and materials that highlight the scientific and technological achievements of ANDRILL.The ANDRILL programme recognizes that a successful E&O programme is of critical importance and that we must take responsibility to effectively convey the outcomes of our research to members of the public, to students and to policymakers. Future efforts will build on the programme that we have established, and will aim to enhance, the mechanisms employed during the McMurdo Sound Portfolio based on lessons learned.

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