



ASPIRE: Teachers and researchers working together to enhance student learning

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Abstract

Science, Technology, Engineering, and Math (STEM) disciplines have become key focus areas in the education community of the United States. Newly adopted across the nation, Next Generation Science Standards require that educators embrace innovative approaches to teaching. Transforming classrooms to actively engage students through a combination of knowledge and practice develops conceptual understanding and application skills. The partnerships between researchers and educators during the Amundsen Sea Polynya International Research Expedition (ASPIRE) offer an example of how academic research can enhance K-12 student learning. In this commentary, we illustrate how ASPIRE teacher-scientist partnerships helped engage students with actual and virtual authentic scientific investigations. Crosscutting concepts of research in polar marine science can serve as intellectual tools to connect important ideas about ocean and climate science for the public good.

Introduction

Antarctica: just the name inspires all to wonder about a place where most will never venture themselves. Images of sculpted icebergs, tiny plankton, playful penguins, and predatory leopard seals bring the science of this unique polar world to the forefront for inquiring minds. Scientists have long been intrigued by the unique polar world, especially places like polynyas where the sea meets the ice and the wildlife is abundant. Exploring these extreme environments is not only captivating but also important for understanding the global climate system. With a rapidly changing climate, harnessing curiosity about polar ecosystems has never been more important.

Teaching about science has also changed. Today we know that students learn better when they experience scientific inquiry more personally. Exposure to research can therefore enhance learning about science. Antarctic research can be particularly effective because of its global importance and the added adventure. Historically in the United States, ocean science was not taught in pre-college classrooms due to its exclusion from state and national standards (Ocean Literacy, 2013). In 2005, a group of national organizations, scientists, and educators developed essential principals and fundamental concepts to define Ocean Science Literacy (Cava et al., 2005; Ocean Literacy, 2005; 2013). The scope and sequence of their work was to insure that ocean concepts were well represented in science education and in the national Next Generation Science Standards (NGSS; NGSS Lead States, 2013). Exposing more students to field research in coastal Antarctica can be an effective way to teach ocean science.

Current research on science education emphasizes the need for multiple ways to engage students with scientific inquiry by “participating in normative scientific practice akin to those that take place and govern scientific work” (NRC, 2009, p. 70). These ways of participating are sometimes called authentic science experiences, which aim to engage students in finding evidence-based answers to questions and problems

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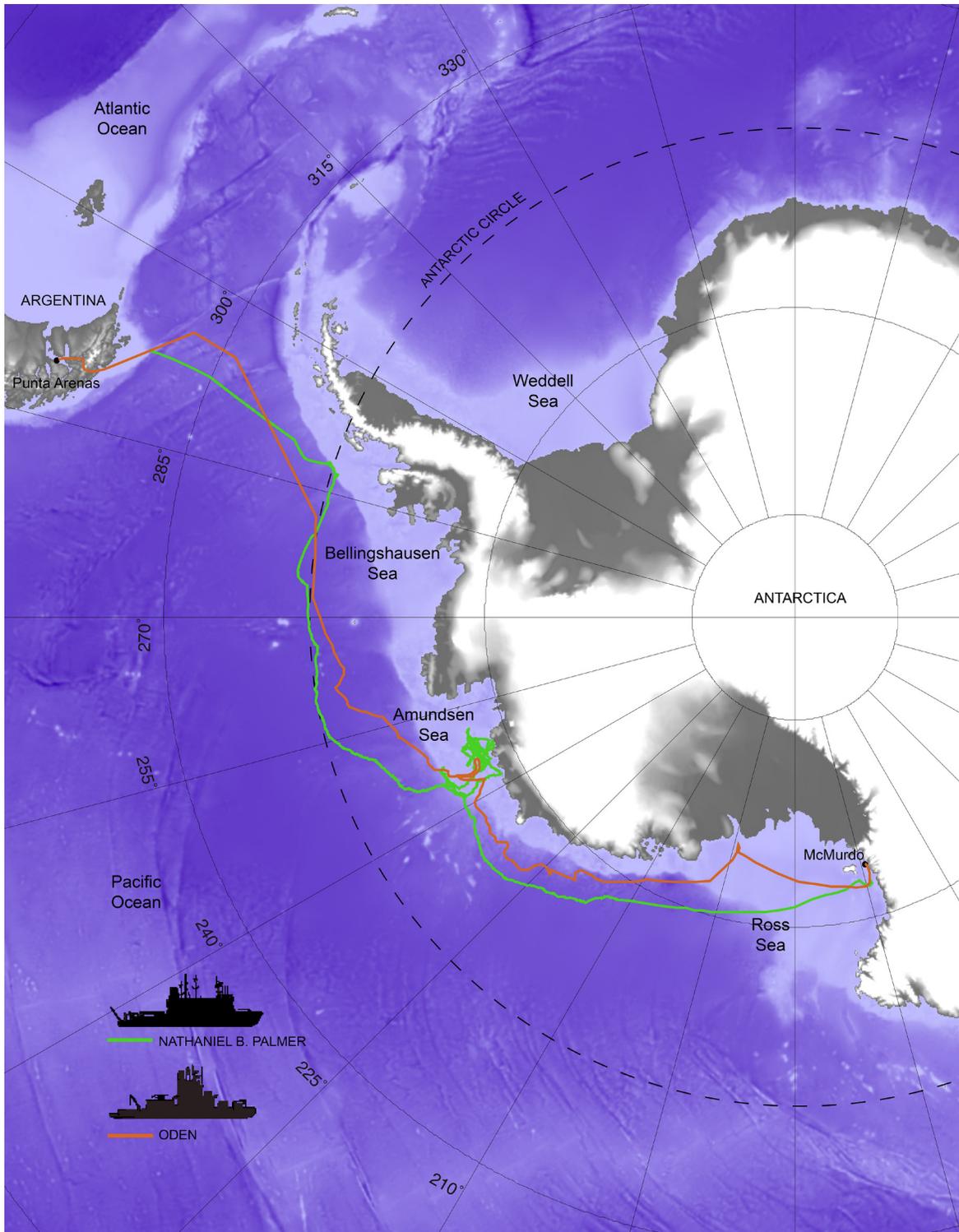


Figure 1

Map of Antarctica and Southern Ocean showing the two-ship operation for the ASPIRE project.

During December 2010 and January 2011, two research icebreakers, the US RVIB *Nathaniel B. Palmer* and the Swedish IB *Oden* traveled from Punta Arenas, Chile, to McMurdo Station, Antarctica. The *Palmer* focused on the open waters of the Amundsen Sea polynya, while the *Oden* worked in the sea-ice covered region further offshore. The base map comes from the ETOPO1 data set, available from NOAA's National Geophysical Data Center. The map was done with Generic Mapping Tools: <http://www.soest.hawaii.edu/gmt/>

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in natural contexts with no pre-determined solutions (McKay and McGrath, 2006). Field-oriented experiences transmitted through teacher-research partnerships can move student thinking towards evidence-based problem-solving and scientific argumentation (Trautman and MaKinster, 2005). Students should experience excitement, interest, and motivation to learn about phenomena in the natural and physical world and to think about themselves as science learners, developing identity as someone who knows about, uses, and sometimes contributes to science (NRC, 2009, p. 4). The most recent education reform document, *A Framework for K-12 Science Education* (NRC, 2012), laid a roadmap for future science curriculum development focused on student performance expectations that are tightly aligned with scientific and engineering practices, disciplinary core ideas, and crosscutting concepts (Krajcik et al., 2014). Engaging in scientific investigation requires not only skill but also knowledge specific to each practice. Drawing on this framework, the Next Generation Science Standards emphasize student engagement with scientific practices across the K-12 curriculum.

One way to effectively merge real-time oceanographic research and K-12 education is through collaborations between marine scientists and classroom teachers. Successful partnerships provide a powerful context for engaging teachers with scientific practices and field research with direct access to the scientific community (Cowie et al., 2010). Teacher-scientist partnerships have been described as vehicles for changing student attitudes towards an interest in science (Wormstead et al., 2002; Wurstner et al., 2005). Effective teachers help their students move past simply learning facts by focusing on applications and seeing inquiry as habits of mind integrating practice with content (Pruitt, 2014). Several programs have successfully teamed marine scientists with classroom teachers, including NOAA Teacher At Sea (teacheratsea.noaa.gov), JOIDES Resolution (joidesresolution.org), ARMADA (armadaproject.org), and PolarTREC – Teachers and Researchers Exploring and Collaborating (polar trec.com). The National Science Foundation's Research Experiences for Teachers (RET) Program (<http://www.nsf.gov>) also helps build and support long term collaborations.

PolarTREC, funded by the National Science Foundation and organized, supervised, and implemented by the Arctic Research Consortium of the United States (ARCUS), forms partnerships between classroom teachers and polar scientists traveling to remote places in the polar regions. Over the past eight years, over 100 U.S. educators have been placed with research teams throughout the Arctic and Antarctic, with nearly half participating in Antarctic research aboard ships, in remote camps, and at all three U.S. bases. Beyond bringing diverse educational professionals into the field, this program serves to improve the education and outreach efforts of researchers while exposing researchers to the methods and means by which science is shared in the classroom. These experiences are changing the face of polar and ocean science in classrooms by empowering teachers with first-hand knowledge that is then transformed into original activities and classroom lessons (Garay et al., 2010; Schwartz et al., 2004). Here we report on the efforts and outcomes of teacher-scientist collaborations that took place in one of the most remote corners of coastal Antarctica, the Amundsen Sea (Figure 1).

Implementation

In 2007, PolarTREC selected Redd Middle School teacher Lollie Garay (Figure 2a) from Houston, Texas, to join the US/Swedish oceanographic expedition to the Southern Ocean. The Swedish Icebreaker *Oden* explored the Amundsen Sea and Ross Sea on its way to McMurdo Sound from Punta Arenas, Chile. It was during this seven-week research cruise that she and Dr. Patricia Yager (UGA) began a collaborative educational partnership now in its seventh year.

During this Southern Ocean expedition, Garay assisted Swedish and US teams by monitoring the conductivity, temperature and depth (CTD) recorder as the attached Niskin bottle rosette collected seawater (Figure 2b). She also conducted hourly ice observations to ground-truth satellite imagery of sea ice conditions and assisted with plankton tows. In her 2007–2008 *Oden* expedition report, available on the PolarTREC website (Table 1), teacher Garay explained that the most important shipboard knowledge came from seeing how all of the different scientific research projects came together to give the big picture of what was happening in the ocean. Post-expedition, the teacher-researcher relationships were deepened and solidified by Garay participating with the science team in data synthesis workshops and international conferences. A classroom teacher for over 40 years, Garay has credited the overall opportunity for making her realize how much both polar and ocean science were missing from her school curriculum. It also motivated her to incorporate more real-time marine science research into her lessons, drawing from the scientific network established as a result of the 2007 expedition. Garay's experience produced several original classroom activities that helped develop the ongoing polar and ocean science curriculum that she has since implemented into her teaching (Table 2; Figure 3).

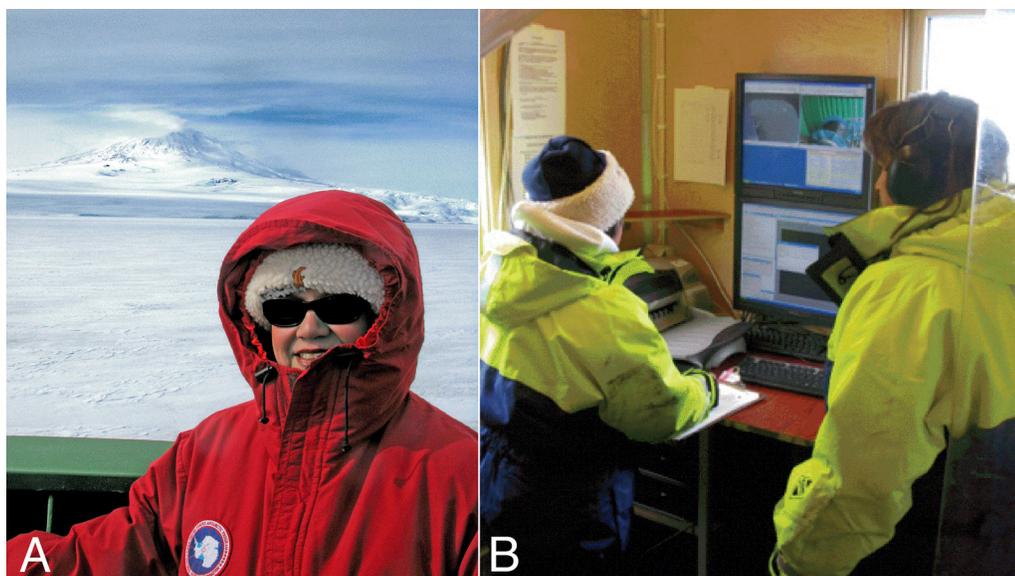


Figure 2

PolarTREC put teachers in the field with ASPIRE scientists.

Teacher Lollie Garay worked onboard the Icebreaker *Oden* in 2007–2008 (A), including operating the CTD recorder with researcher Yager as it descended 500 m into the deep Amundsen Sea (B). (Photo credits: L. Garay, courtesy of ARCUS)

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Table 1. ASPIRE Weblogs and newspaper blogs

Author	Location
Teacher Lollie Garay	http://www.polartrec.com/expeditions/oden-antarctic-expedition-07 and http://antarcticaspire.org
Teacher Anne Marie Wotkins	http://www.polartrec.com/expeditions/oden-antarctic-expedition-2010
Graduate student Kate Lowry	katelowry.wordpress.com (maintained for students at the Louisiana School for Math, Science, and the Arts: http://www.lsmsa.edu)
Graduate student Peng Yi	Daily blogs published in People's Newspaper, China

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Table 2. Classroom activities developed and available online

Activity	Online location
Pumping Carbon	www.polartrec.com/resources/activity/pumping-carbon
The Amazing Antarctic Trek	http://www.polartrec.com/resources/lesson/the-amazing-antarctic-trek
Identifying Ice	http://www.polartrec.com/resources/lesson/identifying-ice
Arctic SEAs	http://www.polartrec.com/resources/lesson/arctic-seasons

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The Amundsen Sea was a remote and challenging place to conduct research, but the scientific questions that emerged during the 2007 expedition were compelling enough that the team successfully proposed to return to the region in 2010. The resulting Amundsen Sea Polynya International Research Expedition (ASPIRE; Yager et al., 2012) was focused on understanding the mechanisms behind the very large algal blooms in this region (Arrigo et al., 2012), the controls on the fate of that algal production, and whether the ecosystem was climate-sensitive, especially considering that this area is adjacent to some of the fastest melting glaciers in Antarctica (Rignot, 2008).

Between November 2010 and January 2011, ASPIRE took place onboard the US research icebreaker, RVIB *Nathaniel B. Palmer* (Yager et al., 2012) and the Swedish Icebreaker *Oden*. Garay remained in her classroom in Houston during ASPIRE, but used her experience from 2007–2008 to help the project maintain a weblog (Table 1) that received over 16,300 hits during its first year.

Once the ASPIRE expedition was over, Garay and Yager recognized the continuing need to bring field experiences in scientific practices into the classroom. As Gulf Coast residents, Garay felt her students needed to understand more about the interconnectedness of the global ocean (Ocean Literacy, 2013) and human impact on Earth's systems (NGSS Lead States, 2013). Garay wanted not only to engage her own students, but also to develop a collaborative study with other classrooms following the synergistic model of science teams she witnessed on the *Oden*. To this end, Garay and Yager developed the Students Monitoring Ocean Response to Eutrophication (SMORE) Project, a tri-state coastal ocean monitoring collaboration that partners schools in Texas, Georgia, and Alaska, supported by a Toyota Tapestry grant (tapestry.nsta.org)

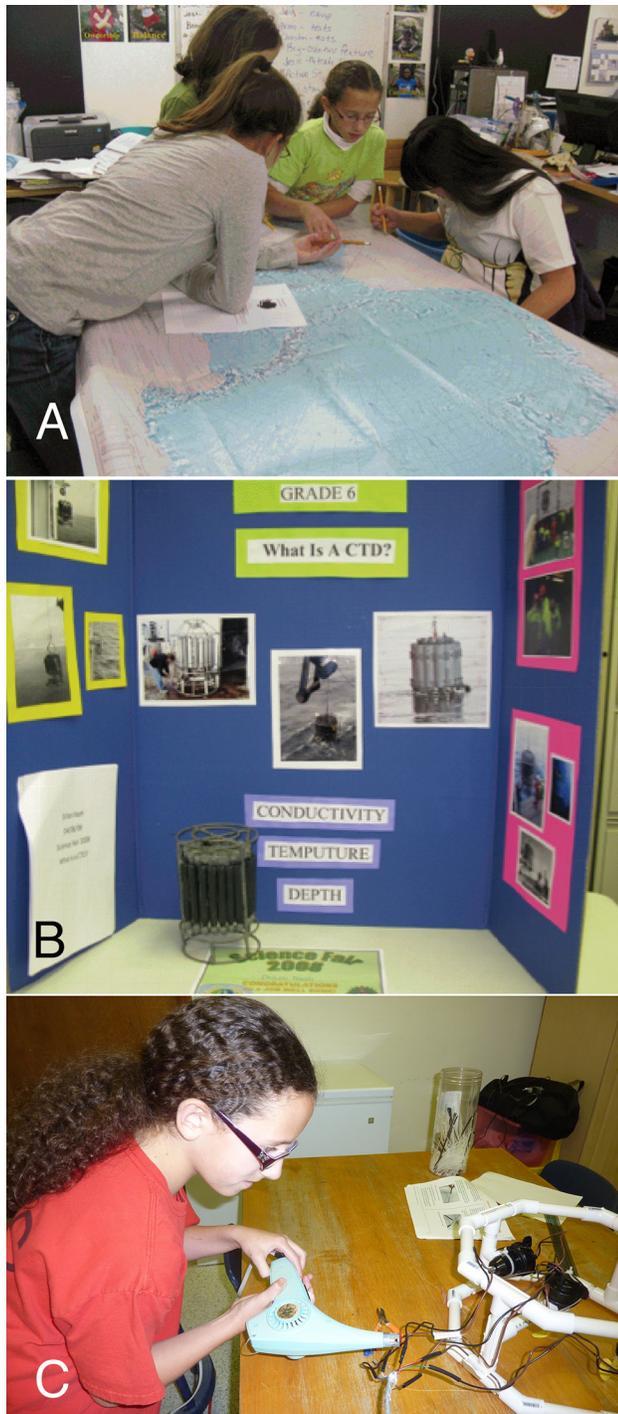


Figure 3

At sea technology inspired student participation and learning.

Students mapped the expedition cruise track (A); developed science fair posters, for example explaining the CTD recorder with a model (B); and built a robotic underwater sampler (C). (Photo credits: L. Garay)

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in 2011. Yager's three ongoing research projects included contrasting studies of the marine nitrogen cycle around the world, including research expeditions to the Amazon River plume and to Barrow, Alaska, which Garay joined through an NSF RET grant and additional PolarTREC support. The idea behind SMORE was to develop an analogous field study of the nitrogen cycle and human impacts on local waters, where students could conduct their own research focused on biogeochemical cycling (Figure 4). Using the global ocean as a platform, the project-based study immersed students in authentic research that developed both conceptual understanding *and* scientific thinking: posing questions, planning investigations, analyzing and evaluating data, and applying new knowledge (NRC, 2012; LaBoy-Rush, 2007). Such research highlights the importance of “the co-development of reasoning skills and conceptual knowledge” (Zimmerman, 2000).



Figure 4
Involving students with fieldwork in their own backyards.

SMORE Texas students sampled nutrients at Bolivar Peninsula, Houston, Texas USA. (Photo credit: L. Garay)

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Combining schools from distinct social environments, including a polar region, also gave SMORE students new perspectives on the implications of human impacts on the global ocean and climate change (Sadler et al., 2004). Engaging in dialogue and reflection through peer review allowed students to generate their own new questions about the nature and process of science (Schwartz et al., 2004; Minstrell and van Zee, 2000; Trautmann et al., 2000). Garay has observed that all students demonstrated achievement and growth in self-esteem using authentic student-driven science projects (Trautmann et al., 2000).

During ASPIRE, another PolarTREC teacher, Anne Marie Wotkyns from Kittridge Elementary School, Van Nuys, California (Figure 5a) was paired with researcher Stephen Ackley (UTSA) and his team onboard the *Oden*. Similar to Garay's experience on the *Oden*, Wotkyns worked with the science team, this time using an Electromagnetic Profiler that measures sea-ice thickness and records the data. The data were later compared

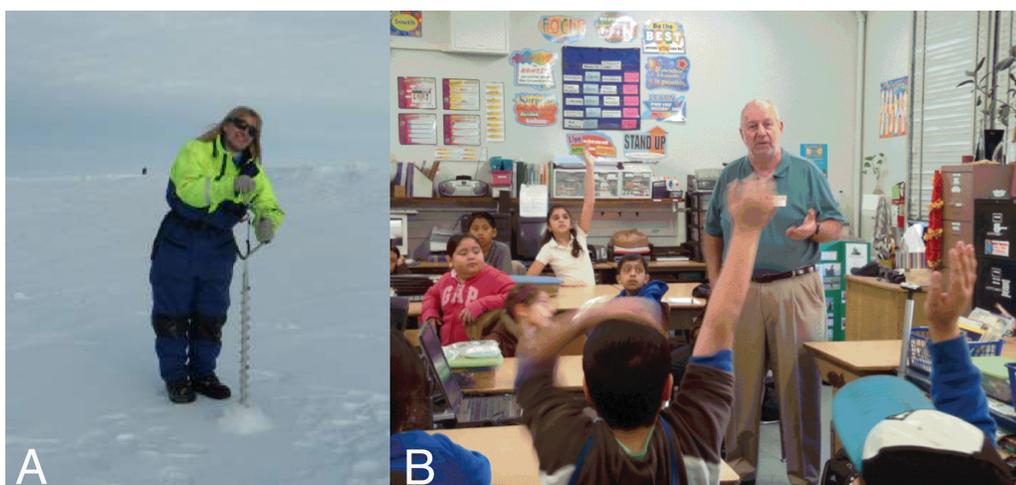


Figure 5
Teachers in the field and scientists in the classroom help bring the science home.

Teacher Anne Marie Wotkyns sampled the sea ice during the *Oden* Southern Ocean 2010–2011 expedition (A). Dr. Stephen Ackley answered questions from enthusiastic students in teacher Wotkyns's classroom (B). (Photo credits: A. Wotkyns, Courtesy of ARCUS)

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to physical measurements the team had made by drilling holes through the sea ice into the water below. Wotkyns also assisted in the deployment and monitoring of the Ice Mass Buoys that the team had installed on four ice floes during the expedition. After returning to school, Wotkyns' 4th grade students monitored the position of the ice floes from the classroom using the satellite tracking information posted online. Teacher Wotkyns also maintained a blog and conducted a live webinar from the ship (Table 1). Virtual fieldwork rich in images and videos provided students an experience as close as possible to being there.

As with Garay and Yager, an ongoing collaboration between the teacher and the researcher continued, with researcher Ackley visiting Wotkyns' 4th grade classrooms in March 2011 (Figure 5b). He interacted with the students as they did an ice observation activity that he and Wotkyns had written together. Wotkyns and Ackley also developed a Polar Science Day for Monlux Elementary School (May 2011) and co-presented at a teacher workshop at the University of Texas San Antonio (June 2011). Wotkyns then took a leave of absence for two years to continue her work in polar science in a charter school in Sweden. Like researcher Yager, researcher Ackley continues to be enthusiastic about working with teachers in the field.

Outcomes

How do you measure the impact of the experiences teachers gain from the direct partnership with researchers? The PolarTREC program has developed a qualitative and quantitative assessment to address these questions. Data collected on the teachers participating in the program show a significant increase in science content knowledge, in parallel with an increase in science interest among students whose teachers have participated in teacher research experiences (ARCUS, 2013). Teachers Garay and Wotkyns also have collected data on the impacts of their experiences, using grade-appropriate pre- and post-assessment as well as ongoing formative assessment to measure student success, identify misconceptions, and make adjustments to the instructional plan as needed (Hodgson and Pyle, 2010). Reflective journaling, coupled with explicit teaching, records progress in thinking and provided a safe way for students to express themselves through words, diagrams, and pictures (Khishfe and Abd-El-Khalick, 2002; Schwartz et al., 2004). Performance assessments focused on observed behaviors and skills that *demonstrated* what the students knew (content) and could do (skills). These demonstrations were rubric-based and required students to complete an activity, create a product, or write a response summarizing or analyzing a completed activity. Self-assessments throughout the learning process engaged students in checking their own progress (e.g. "thumbs up, thumbs down", journaling, or open-ended questions) and developing ownership in their learning (Hodgson and Pyle, 2010). Summative assessments (capstone projects) at the end of a study helped to evaluate how successful the instructional plan was in developing learning. Both Garay and Wotkyns observed that written assessments in the form of tests demonstrated increased content knowledge both in polar and ocean science. The national Stanford Achievement Test 10 used by Garay's school reflected that students were meeting or exceeding science standards in general.

Garay observed that her own instructional methods were also strengthened by a better understanding of science processes and application, empowering her to translate her experiences more explicitly into her teaching practices (Lederman, 1999; Lederman and Lederman, 2004; Silverstein et al., 2009). Garay has always embraced the idea of open-ended inquiry in her classroom, but working with Yager made her more confident in using this strategy for teaching science. Moreover, by having observed inquiry in action shipboard she became more comfortable taking risks in providing realistic and relevant science content to her students (Trautmann and MaKinster, 2005). Another significant outcome of the 2007 expedition is Garay and Yager's continuing collaboration that has included joint research and educational outreach in the Antarctic, Arctic, and Amazon River plume.

Scientists benefit from teacher/researcher collaborations as well (Caton et al., 2000; ARCUS, 2013). Receipt of US federal funding for science requires "broader impacts" beyond traditional intellectual merit (NSF, 2014). Researchers must effectively transmit their science to a larger audience. Partnerships between researchers and teachers provide a vehicle to engage with K-12 students and their families. Yager argues that scientists benefit by having their research explained in ways that the broader public can understand: collaborations with teachers produce classroom lessons and published work that generate interest in the scientists' research specifically and in marine science in general.

Researchers can also learn from their education partners about more effective teaching strategies that can be transferred to the college level (Caton et al., 2000; ARCUS 2013). Researchers who work with teachers in turn gain perspectives on the constraints that teachers and students face in the pre-college classroom (Cooper and Cowie, 2010; ARCUS 2013). Researcher Ackley (personal communication) observed that teachers not only contribute as field hands but bring an infectious degree of energy and enthusiasm to the research team. Many of the science team members were eager to interact with the teachers; other ASPIRE researchers were motivated to conduct additional educational outreach (Table 3).

Table 3. ASPIRE Education/Public Outreach (local, state, national, international)

Participant	Activity
Teacher Lollie Garay	43 school/public presentations to date
Teacher Anne Marie Wotkyns	17 school/public presentations to date, including in Sweden
Graduate Student Kate Lowry	4 school/public presentations to date, including at Girls' Middle School and the Stanford Educational Studies Program
Researcher Patricia Yager	8 school presentations, 3 public presentations, 6 university-level presentations (Continuing Education/invited seminars)
Researchers Stephen Ackley, Hongjie Xie, and Blake Weissling	> 20 school/public presentations to date, 3 summer (25-hour) teacher workshops, reaching a total of 60 teachers, and multiple university-level courses
Researcher Anne C Alderkamp	9 public presentations, including the TechTrek science and math summer camp for girls at Stanford (http://www.aauw-techtrek.org/index.php)

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Conclusions

Developing and sustaining effective and reciprocally beneficial teacher-researcher partnerships can be difficult yet transformational for both parties (ARCUS, 2013). Partnerships must include open and frequent communication between the partners; the most meaningful impact is achieved when scientists and teachers understand each other's goals and needs. Modest financial support from federal and private foundations makes such relationships and their positive outcomes possible. Currently, Garay and Yager are in their seventh year of collaboration. Our experience has made clear to us that long-term relationships must be actively cultivated with attention to sustainability. Future scientists grow from children who discover a love of science as students, often because they were inspired at some point by an amazing science teacher. These science teachers can find inspiration and support by working directly with researchers in the field. Researchers benefit as funding for scientific research depends on effective communication between scientists and the public. Everyone benefits from an increase in public scientific literacy. Given the climate sensitivity documented by ASPIRE in the rest of this special feature, involving teachers, students, and their families in scientific inquiry has never been more important.

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Contributions

- Contributed to conception and design: LG, AMW, PY
- Contributed to acquisition of data: LG, AMW, KL, ACA, JW, PY
- Drafted and/or revised the article: LG, KL, ACA, JW, PY
- Approved the submitted version for publication: LG, AMW, KL, ACA, JW, PY

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Teacher-Researcher partnerships

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Competing interests

Authors report no competing interests.

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