Volume 34 • No. 1 • Winter 2020

Empowering Students with Polar Science Through Real-World Data

BY KRISTIN HUNTER-THOMSON, JOSH KOHUT, AND GRACE SABA

ABSTRACT
Since 2011 we have been exploring different ways to advance Polar Science and broader science education. Through various broader impact and education projects, primarily funded by the National Science Foundation, we developed a sequence of educational experiences for teachers and students grounded in partnerships that connect teacher/student audiences to the Polar Regions, and allow them to explore real-world phenomenon. We provide a description of the different projects, discuss how our approach evolved to leverage our successes, and share our lessons learned.

INTRODUCTION
- *How do we move students beyond penguins and polar bears?*
- *How do we engage kids in the United States with science happening at the Poles?*
- *We immerse them in Antarctic science missions!*

Over the past eight years we integrated students, in real time, into various science missions at the Poles. Our process and approaches have evolved, but the objective has stayed the same: connecting students, teachers, and scientists together as partners in science.

A key ingredient creating connections is the utilization of authentic, real-world data to empower students to be scientists alongside the Polar Science teams in the field. Using data in the classroom is an important component of STEM (science, technology, engineering, and mathematics) education for philosophical, pedagogical, and practical reasons (Manduca and Mogk 2002; Adams and Matsumoto 2009; Kastens 2010) and also integral to the Next Generation Science Standards (NGSS) in K-12 STEM teaching nationwide. Research has shown that early exposure to hands-on science with data-rich activities can enhance learner motivation, investment, and achievement in science (NRC 2000; McGrath 2001; National Center for Education Statistics 2001; Parsons 2006; Hug and McNeill, 2008). Therefore, we wanted to create innovative learning experiences that brought real-world datasets, models, and simulations into the classroom as a means to that end. Utilizing ever expanding polar data streams and observations provides unprecedented opportunities to expand teaching and learning innovations in STEM classrooms that could potentially be the bridge for classrooms to engage and understand how Polar Regions influence their lives.

Here we outline the development path of four previous projects and discuss plans for our next iteration of closing the large geographic, and often conceptual, gap between students and important research conducted in the Polar Regions as a way to connect students with the vital polar ecosystems and empower them to conduct authentic science.

ROSS SEA CONNECTION PROJECT
The Ross Sea Connection (http://coseenow.net/ross-sea/) engaged teachers and students as virtual members of a scientific field team aboard the *RVIB Nathaniel B. Palmer* in the Ross Sea, Antarctic during the austral summer season (Dec 2010-Feb 2011; NSF ANT-0839039). It was a ship-based expedition to explore the sources of nutrients and trace metals and their role in the Ross Sea food web. We partnered with Chris Linder, a professional science photographer; and Hugh Powell, professional science writer; and three educators at the Liberty Science Center to develop and implement the Broader Impacts, connecting Polar Science with non-scientist audiences. In addition, the project participants included an outreach team of 4 educators, 18 scientists, teachers from 16 schools, and 400+ students.

During the summer, prior to the Antarctic field season, we convened 6-9th grade teachers from across New Jersey to join our science team and bring our polar research into their classrooms. For a week, we explored the concepts driving our hypotheses and participated in a range of classroom-ready activities. As we were packing up our science equipment to send it south, students all over New Jersey were diving deep into learning about Antarctica. Teachers used a provided bank of lesson plans relating to Antarctica, or developed their own to introduce participating students to the Ross Sea region

Volume 34 • No. 1 • Winter 2020

and the research area and topics. During January, while the science team was aboard the *R/V Palmer*, Chris and Hugh produced Daily Journal entries on a blog for students to follow along during the research mission. Additionally, each participating school joined in a conference call with multiple members of the research team as well as ship crew to learn about what was happening in real-time and ask their own questions about the science, and what life was like aboard an Antarctic research vessel.

Exit surveys with participating teachers indicated that throughout the project the teachers and students grew attached to and invested in the science mission and science team. Many teachers even reached out to the education team to inquire about the safety of the scientists following the 2011 Christchurch earthquake as the students were worried knowing "their scientists" were flying home through New Zealand. The project ended with students energized about "their" polar scientists; and the science professionals excited to participate in more outreach efforts, according to our evaluation surveys and follow-up conversations. The teachers also communicated through exit surveys, suggesting things to consider doing differently in future projects. For example, participating teachers reported that the general Antarctic lesson plans bank, which were not specifically related to the research project, did not fully help students make sense of the ins-and-outs of the research mission. Instead, teachers were interested in using lesson plans specifically aligned with the hypotheses and approach of the research mission. Additionally, teachers reported that they felt the end of the field season brought an abrupt end to the partnership as there were no connection points between the research team and the schools following the end of the intensely, interconnected field season.

PROJECT PARKA (PLANTING ANTARCTICA IN KANSAS)

Building off of the momentum from the Ross Sea Connection and the suggestions of those participating teachers, we developed another year-long immersion experience for Kansas high school students during the 2013-14 academic year in conjunction with a research mission to study the impacts of ocean acidification on organisms instrumental to the Antarctic food web: Project PARKA (http://coseenow.net/project-parka/; NSF #1246293). The project participants included an outreach coordinator, 6 scientists, teachers from 19 high schools, and 500+ students. Here, our goals were to connect students to the complex multi-disciplinary scientific research and to demonstrate a broader sense that as students in a landlocked state their actions had impacts on organisms and the ecosystems thousands of miles away in Antarctica. We addressed these aims through a teacher training workshop, unique lesson plans, student group research projects, video conferencing between scientists and the participating schools, and a spring student research symposium.

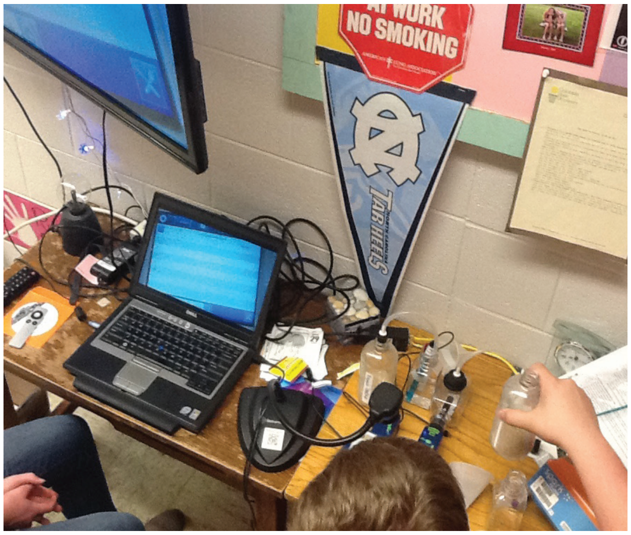

Figure 1. Students collecting data in a hands-on demonstration of the process of ocean acidification. Courtesy of Ruth Hutson

We first developed the connection between the participating teachers and scientists through a kick-off three-day training workshop in July 2013. First the lead scientist (Saba) presented the background information about the Antarctic research that would be happening in the field. Then Saba and the outreach coordinator (Hunter-Thomson) facilitated the teachers to participate in each of the provided lesson plans as learners themselves and then discuss strategies for teaching each. Rather than a suite of general Antarctic related lessons, we developed unique lessons that specifically addressed aspects of the hypotheses of the science team or mimicked the work the scientists would be doing. Teachers integrated these four provided lesson plans into their curriculum in the fall and early winter of 2013 to better provide all participating students with a sense of what was happening during the research field season (Figure 1).

Each lesson plan included the scientific background information needed to prepare the students and all necessary materials. To compliment the lessons, the students worked in small groups (3-4) to conduct an independent research project, on a topic of their choosing, that they worked on during the school year. These projects were designed with limited and shared resources, but the teachers, outreach coordinator, and scientists worked together to ensure each project was logistically feasible.

Similar to the Ross Sea Project, we connected all participating students with the scientists through video conferences while the scientists were in the field in January 2014. This allowed students to meet the scientists, experience their laboratory set-up in Antarctica, and focus some of their questions on the activities surrounding the scientific team in real-time. However, we built upon this connection between students and scientists by adding a culminating experience for all to connect in person. At the end of the project year following the research field season, we hosted a symposium that was attended by most of the participating high school students and teachers at the Washburn University campus in Topeka, Kansas on April 15, 2014. We modeled this symposium after a scientific conference with three components: 1.) oral presentations by the scientists describing preliminary research findings during their field season; 2.) poster presentations used by high school students to communicate outcomes from their group research projects to several participating scientists and each other for feedback; and 3.) a career panel with five scientists who briefly described their path to science followed by an open-discussion forum for student questions.

Again, participating teachers and students developed a strong bond with the science team and their work as indicated on post-project surveys. According to teacher and student survey responses, students gained a broader understanding of Antarctica as well as a thorough understanding of the scientists' research and how they were going about it via the developed lesson plans. The culminating experience was a highlight for many participating students as they got to present their original research to "real" scientists. The event also served as a celebration of the teachers, students, and scientists working together for the year. This project was a success, and the participating teachers offered suggestions to consider in designing future programs. For example, while many enjoyed the diversity of the student research projects, others communicated the research projects did not relate to Antarctica and; thus, felt disjointed from the project overall, creating a bit of a mismatch at the culminating event. These teachers expressed an interest in supporting their students to conduct polar research in the future, similar to the research team their students had connected with during the project.

PROJECT CONVERGE

We were able to roll our lessons learned from and build on suggestions from those teachers in Project PARKA straight into another opportunity to implement a year-long Polar Science Broader Impacts project during the 2015-16 academic year. We were fortunate to be awarded a grant for an interdisciplinary project looking at the connections between the physical oceanography and top predators (Adélie penguins) off the Western Antarctic Peninsula (WAP). This research required a diverse team of scientists and engineers from across the Western Hemisphere to review the data and communicate in real-time to make decisions about the project. This provided an opportunity to invite the students to be contributing members of our science and engineering team. The access to our real-time datastreams allowed the students to get a first look at the data, even before the teams deployed in Antarctica had a chance to analyze it! The project participants in this project included 7+ scientists, Chris Linder, Hugh Powell, 3 educators from the Liberty Science Center, an outreach coordinator and team, 22 teachers, and 1100+ students.

We ran Project CONVERGE (http://coseenow.net/converge/) with 6-9th grade classrooms from throughout New Jersey and New York. Prior to the summer workshop, we developed data-based lessons that taught students about the concepts driving the research mission's hypotheses. Three of the lessons explored the physical oceanography, ecology and food web dynamics, and engineering aspects of the project to help students understand the research mission (Figure 2).

Through the fourth lesson we transitioned the students from spectators of the science to contributing participants in the science. The students had to make sense of data similar to what the scientists would be looking at in the field and work in teams to determine which scientific instruments they would use, and propose how they would deploy the

Figure 2. Teachers participating in the hands-on activity regarding convergence zones before looking at wave data from around the Palmer Research Station in Antarctica.

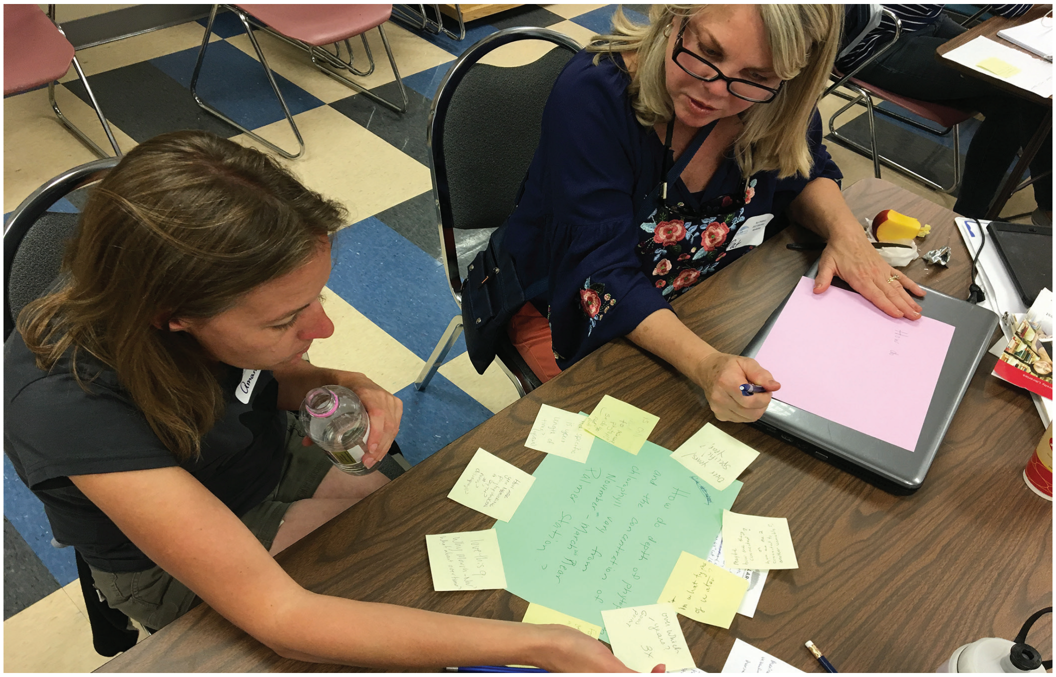

Figure 3. Teachers at the 2017 Summer Institute working to refine their testable question to explore during their investigation based on feedback from their peers in a gallery walk.

instruments in the field (directly modeling what the scientists would be doing during their field season). Additionally, we were fortunate to be able to work with Chris and Hugh again, so while the science team was in Antarctica there was a daily blog posted by professional science communicators. The students also participated in video conference calls with the science team when they were in Antarctica. Building off of the success of the culminating event for Project PARKA, the students were asked to develop their own ocean- and/or polar-theme investigations using data to present at the Student Research Symposium at the Liberty Science Center.

The students' projects were sophisticated in their use of data to answer their investigation questions. Teachers commented that two aspects of the project that most supported their students use of data were the data-based lessons and the data primer. The unique lessons developed for this project each contained data and asked the students to make sense of the data as they were learning the concepts. Additionally, we developed a Data Primer to explain all of the different datastreams being produced by the project, and how to access and use the data (as anyone could access the research mission's data in real-time with the scientists). In fact, more than half of the participating students in the project elected to use data collected by the science team for their own projects. The students and teachers were not only connected to the science team, but also became connected to the WAP ecosystem as they explored the data to answer their own science questions. Through post-project surveys and a focus group, participating teachers communicated with us that they were surprised with how much their students had struggled to develop testable questions and make sense of the large professionally collected datasets through the project. Many asked us for additional resources to better support their students develop these skills.

SCIENCE INVESTIGATIONS (SCI-I) PROJECT

An opportunity to put more focus on building process of science and data skills through polar data materialized through the Polar-ICE (Polar Interdisciplinary Coordinated Education) project (NSF #1525635). We wanted to leverage our lessons learned from the past three projects of year-long immersion experiences that joined teachers, students, and scientists in Polar Science while also providing more targeted support around data skills as requested by previous teachers. Therefore, we wanted to test a model that put a larger emphasis on building out students' data skills when working with professionally collected data than on the content of any one particular research project. As a result, the Sci-I (Science Investigations) Project (https://polar-ice.org/educator-resources/sci-i-workshops/) was developed. During the 2016-17 and 2017-18 academic years, we worked with students in grades 6-9 from New Jersey, Ohio, Missouri, Colorado, Utah, and California (see Hunter-Thomson within the journal [*Current*, Volume 34, Number 1, Winter 2020] for for a more complete description of the project).

Students developed and conducted authentic science investigations using freely available, online, professionally collected data from the Polar Regions, many looking at data from the Palmer Long Term Ecological Research (https://pal.lternet.edu/) project. The students conducted an observational investigation by developing their own questions, looking for patterns within existing data (a new experience for many students), and communicating their findings to their peers, teachers, and scientists. While the Sci-I Project did not include any specific lesson plans for the students, we did cover a wide range of activities with the teachers at a week-long summer institute prior to each implementation year. During the institute, the teachers conducted investigations using polar data as well as discussed implementation strategies (Figure 3).

During the year, the students were required to submit mini-proposals of their project ideas so that we could provide suggestions and feedback. Each year we hosted a student research symposium within each state at a central university for the students with the top projects from each participating school to attend, present their work, and meet polar scientists. According to student and teacher surveys, the students were empowered by their ability to ask and answer questions that no one else had asked previously from the real-world data. Additionally, the teachers and students reported using data and process of science skills developed through the Sci-I Project in other aspects of the curriculum.

NEXT STEPS

Through these four projects, we have learned invaluable lessons about connecting students with scientists in the Polar Regions as they undertake their field work and; afterwards, enhancing students understanding of the process of science, and increasing students' ability to and confidence in working with data to answer their own scientific questions. More specifically, we have learned that the following components of programs driven to connect students, teachers, and scientists together as partners in science should include:

- Inviting researchers to participate in summer trainings so that the teachers have a chance to ask their own questions about the science and meet the scientists.

- Conducting teacher professional development workshops that are centered around supporting teachers completing for themselves what they are asking their students to do, fostering a sense of a professional learning community among participants, and providing ample time to discuss and plan how to implement the program into their classrooms.

- Developing lesson plans that align with grade-level standards and utilize data from, or at least similar to, the research project to help students understand the specific components of and hypotheses in the research mission.

- Providing suggested online data portals and support resources for how to access and download the data to teachers and students, so they feel successful in searching freely available, professionally collected data to use.

- Utilizing online video conferencing technology to connect scientists in the field with students in their classrooms, so the students can meet the scientists, see where and how the research is happening, and ask the scientists questions.

- Encouraging students to develop mini-proposals of their research projects to receive feedback from scientists prior to completing their research projects, so that they can learn about the iterative process of science and adjust while working on the project.

- Host a culminating experience for teachers, students, and scientists to attend that facilitates one-on-one communication between the stakeholder groups and highlights the successes of the students in their science research.

While these projects led to communicated and measurable impact on the scientists, teachers, and students who participated in each project, we found that the impact of the project largely stayed within the classroom of individual participating teachers. In other words, through these four projects we were able to identify components that resulted in change for the particular teachers and students participating. But, we were not able to identify ways to share or scale the model so that more teachers and students could benefit from our lessons learned.

We received the news that a follow-up research mission to CONVERGE was funded in the fall of 2018 and; thus, began to think about how we could build on the momentum to date and develop a broader impact approach that scaled our successes to more teachers and students. We kicked off Project SWARM (https://polar-ice.org/swarm-workshop-2019/) in the summer of 2019. The emphasis of this project is similar to previous projects of connecting teachers, students, and scientists as well as enhancing students' awareness and understanding of Polar Regions, the process of science, and how to make sense of lots of data. However, we are building this effort as a train-the-trainer model so that the approach can reach more teachers and students. Teachers who have participated in these past projects were invited to apply to be Teacher Leaders in their local areas. As a community, we are working to develop a way to lead professional development trainings within our local communities to encourage and support more teachers to integrate data and Polar Science into their classrooms.

Through this latest project and others yet to come, we look forward to seeing how these efforts sustain and scale over time so that more students feel confident in using data, feel connected to the Polar Regions, and identify as scientists.

ACKNOWLEDGEMENTS

None of this work would have been possible without the work of Kate Florio, Katie Gardner, Harold Clark, Sage Lichtenwalner, Carrie Ferraro, Janice McDonnell, Bridget Clarkston, Kristen Hart, and Jacoby Baker. Also, we thank the other participating scientists and professionals that contributed to these activities: Kim Bernard, Abigail Bockus, Filipa Carvalho, Megan Cimino, Hugh Ducklow, Ryan Fantasia, Donna Fraser, Bill Fraser, Chris Linder, Schuyler Nardelli, Matt Oliver, Logan Pallin, Hugh Powell, Shenandoah Raycroft, Vincent Saba, Brad Seibel, Amy Shields, and Peter Winsor. Finally, we want to express a deep gratitude to all of the teachers and students who have participated in these projects over the years, it has been a great pleasure getting to know and work with all of you.

REFERENCES

Adams, L.G., and G. Matsumoto. (2009). Commentary: Enhancing ocean literacy using real-time data. *Oceanography*, 22(2):12-13. http://dx.doi.org/10.5670/oceanog.2009.55.

Hug, B., and K. McNeill. (2008). First and second-hand experiences in science: Does data type influence classroom conversations? *International Journal of Science Education*, 30(13):1725-1751.

Kastens, K. A. (2010). Commentary: Object and spatial visualization in geosciences. *Journal of Geoscience Education*, 58(2):52-57.

Manduca, C. A., and D. Mogk. (2002). *Using Data in Undergraduate Science Classrooms: Final Report on an Interdisciplinary Workshop at Carleton College*. April 2002. Natl. Sci. Digital Libr.

McGrath, E. (2001September/October). Is It Unique & Compelling? *Momentum*. National Catholic Educational Association. Retrieved from: http://www.ciese.org/papers/_vti_cnf/McGrathreprint1.pdf.

National Center for Education Statistics. (2001). *Digest of Educational Statistics 2001*. Office of Educational Research and Improvement, U.S. Department of Education, Washington, D.C.

National Research Council. (2000). *How People Learn: Brain, Mind, Experience, and School: Expanded Edition.* Washington, DC: The National Academies Press.

Parsons, C. (2006). *SWMP/IOOS Real-Time Data in K-12 Classrooms: A Front-end Evaluation Final Report–Executive Summary*. Retrieved from: http://coseenow.net/blog/2008/12/teacher-rtd-use-report.

KRISTIN HUNTER-THOMSON runs Dataspire Education & Evaluation LLC and is a Visiting Assistant Research Professor at Rutgers University in New Brunswick, NJ.

JOSH KOHUT is a Professor in the Department of Marine & Coastal Sciences at Rutgers University in New Brunswick, NJ, the Vice President of Education for the Marine Technology Society, and the New Jersey State Oceanographer.

GRACE SABA is an Assistant Professor in the Department of Marine & Coastal Sciences at Rutgers University in New Brunswick, NJ.