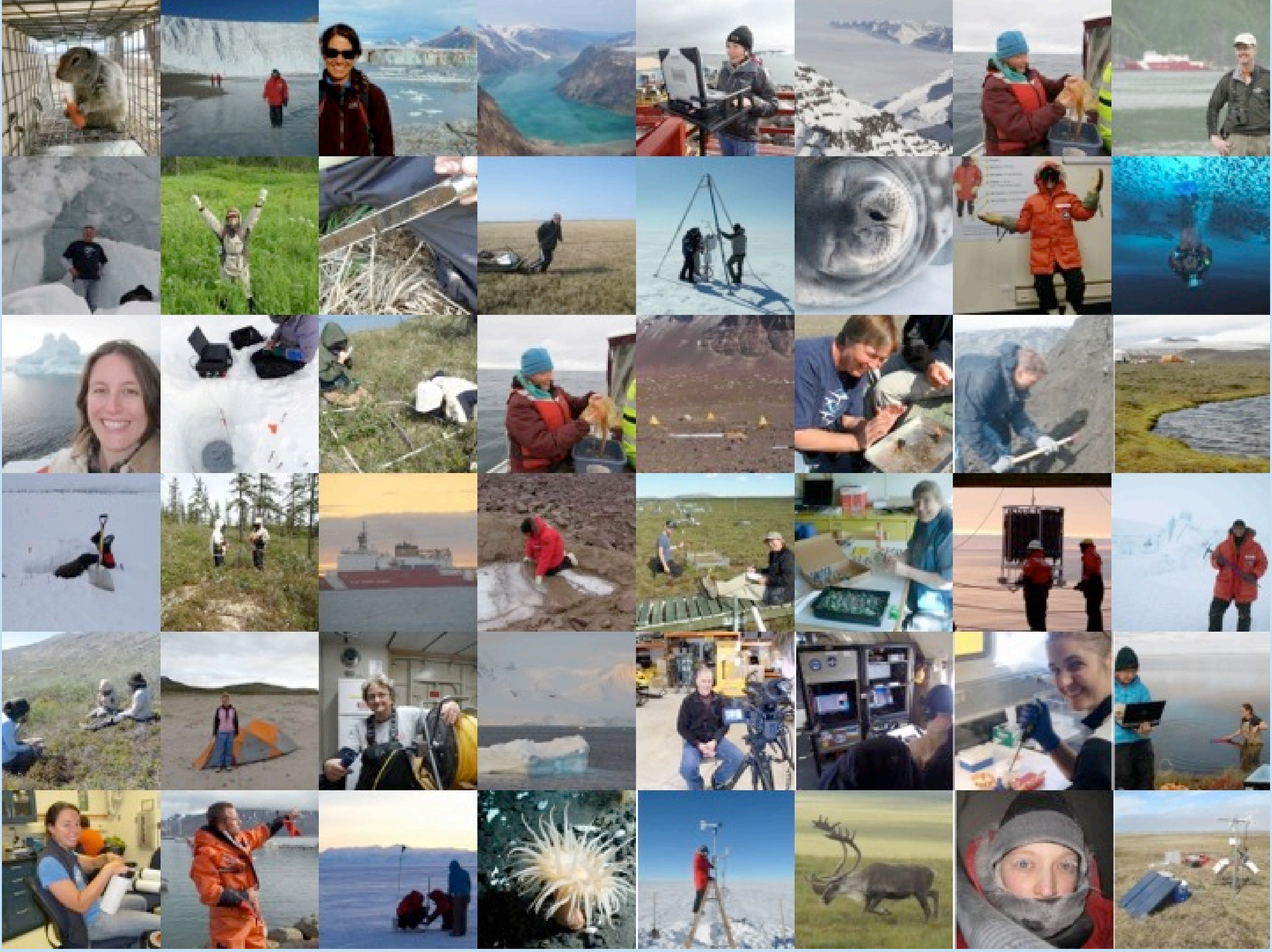

PolarTREC
Teachers and Researchers Exploring and Collaborating
(NSF PLR 0956825)
2010-2014 Final Evaluation Report

Presented to Arctic Research Consortium of the United States (ARCUS)
by Goldstream Group, Inc.

December 2015

PolarTREC: Teachers and Researchers Exploring and Collaborating (NSF PLR 0956825)

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Cover Photo Credit: Photos by *PolarTREC* alumni 2010-2014, courtesy of ARCUS.

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Executive Summary

For more than ten years, the Arctic Research Consortium of the United States (ARCUS) has developed and implemented *PolarTREC*–Teachers and Researchers Exploring and Collaborating (*PolarTREC*), a teacher professional development program that brings together K-12 and community college teachers and polar researchers together through an innovative teacher research experience (TRE) model. *PolarTREC* is one of the few national TRE programs in the United States and is unique in its use of field-based experiences in the polar regions. *PolarTREC* teachers spend three to six weeks in remote Arctic and Antarctic field camps from Toolik station in Alaska to Antarctica's McMurdo Station to Bering Sea ships. During their research experience, teachers become team members filling a variety of roles such as research technician, manual laborer, educator, data enterer, observer, and instrument operator. They also fulfill the distinctive role of public outreach officer, conducting live presentations from the research site to the public, keeping a web-based polar journal, answering the public's questions, and posting pictures of their daily experiences. Prior to their field season, teachers receive extensive training in logistics, outreach, and education planning. Upon their return, participants are expected to integrate their experiences into their classroom instruction and continue their public outreach, making the experience a part of their ongoing professional career development. Funding for *PolarTREC* has been provided through the National Science Foundation (NSF). In this final evaluation report, we will report the summative program impacts on participating teachers, their students, and the participating researchers from 2010 -2014(NSF Award PLR 0956825).

For this award (NSF Award PLR 0956825), *PolarTREC* had four primary goals: 1) to improve teacher content knowledge of the polar regions and the science conducted in these regions; 2) to increase teachers' use of authentic scientific research or inquiry with their students; 3) to increase students' understanding and interest in the polar regions; and 4) to increase researchers' understanding of K-12 education. An underlying assumption of these goals is that teachers will develop long-term professional relationships with researchers and among other *PolarTREC* teachers. In turn, these professional relationships will facilitate ongoing teacher growth and integration of polar science content into their classrooms long after their *PolarTREC* experience ends.

ARCUS contracted with the external evaluation team, Goldstream Group, to evaluate the *PolarTREC* program. The evaluation had two primary objectives: 1) to better understand the immediate impacts of the program on participating teachers, their students, and the researchers with whom they partnered; and 2) to explore the long-term impacts of the *PolarTREC* experiences on participating teachers' professional experiences, and in particular their use of authentic scientific research with their students and ongoing relationships with researcher team members and other *PolarTREC* teachers.

Summary of Evaluation/Methods

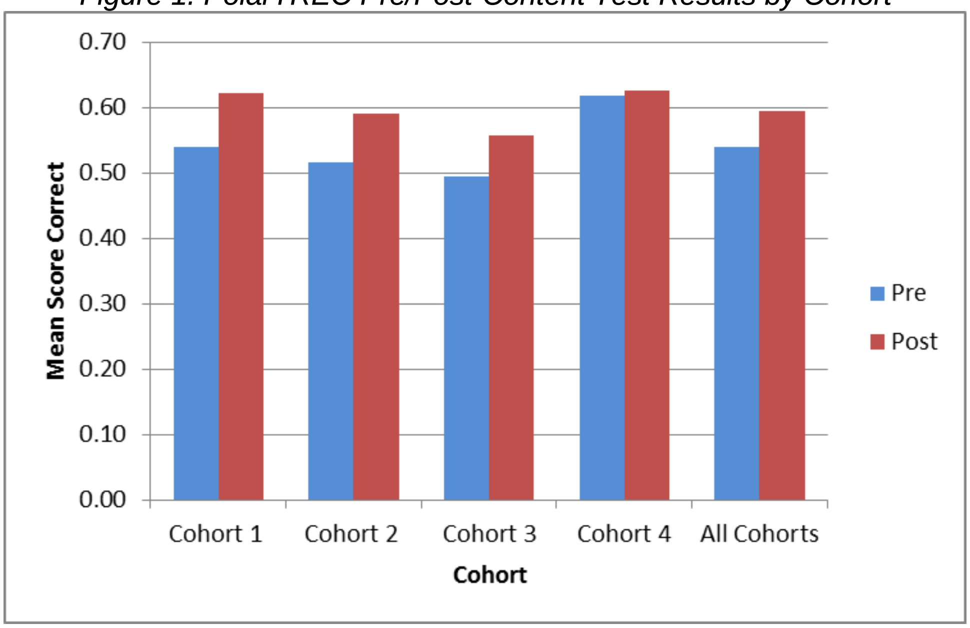
In collaboration with ARCUS, the Goldstream Group developed several evaluation tools, including a pre/post science content test and a pre/post science instruction efficacy survey to better understand the immediate impact on teachers' content knowledge and science efficacy; a pre/post student survey to gather information about student knowledge and interest in the polar regions; a researcher survey to gather feedback about the *PolarTREC* program's implementation and researchers' perspectives about their post-program understanding of K-12 education; and an online survey to assess user's feedback of the *PolarTREC* website resources. To better understand the long-term impacts of the programs, the evaluation team designed a case study to look at the most successful *PolarTREC* teacher participants. This purposive sample provides a picture of what a motivated, talented teacher can do with his or her *PolarTREC* experience and includes a diverse group of teachers from Florida to Hawaii, from small private schools with 10 students to a classroom to large urban schools with 40 students per classroom, and a broad range of ethnicities and economic backgrounds. The case study included extensive interviews, classroom observations and lesson review, and student pre/post surveys. Finally, the evaluation team developed a written survey of all former *PolarTREC* teachers to assess their ongoing use of inquiry-based instruction, relationships with researchers, and instruction of polar content.

Summary of Findings

Evaluation data collected over the four program years indicates that *PolarTREC* has clearly achieved it goals and strongly suggests *PolarTREC*'s potential to transform the nature of STEM education by giving teachers the content knowledge, pedagogical tools, confidence, understanding of science in the broader society, and experiences with scientific inquiry they need to promote authentic scientific research in their classroom (Avery &Carlsen, 2001; Barnett & Hodson, 2001).

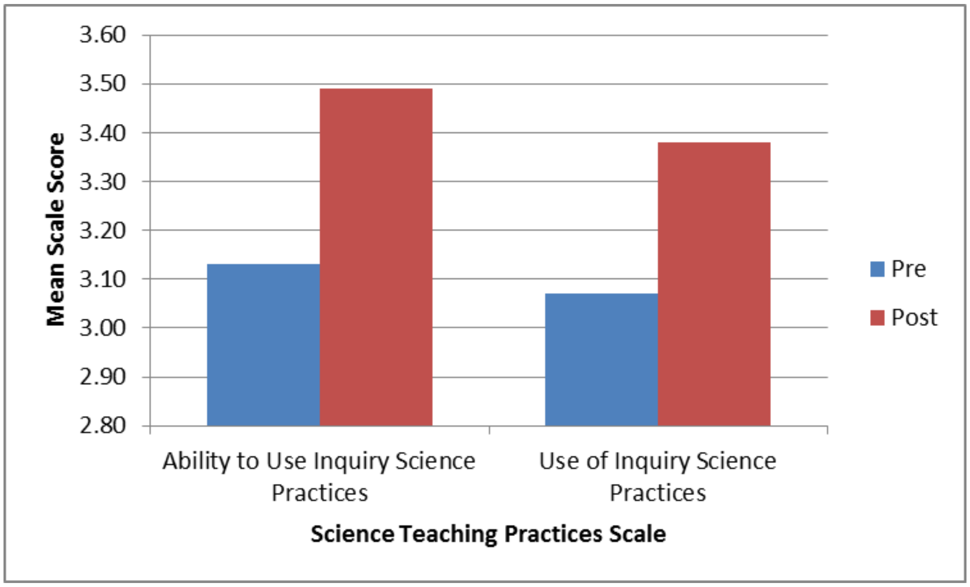
PolarTREC teachers have significantly increased their content knowledge of the polar regions as demonstrated in a written pre/post-test (Section 3). The pre/post change for all *PolarTREC* teachers combined was statistically significant ($P<0.000$), increasing from a mean ratio of correct answers on the pre-test of 0.539 to a mean ratio of correct answers on the post-test of 0.595, a mean difference of 0.056 (Figure 1).

Figure 1. PolarTREC Pre/Post-Content Test Results by Cohort



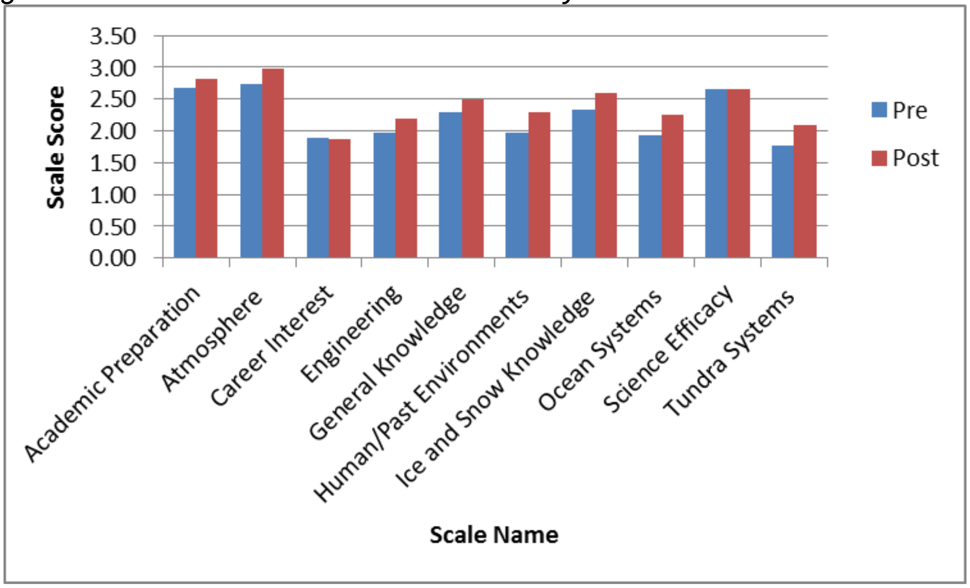
A separate pre/post survey on teaching practices indicated that participating teachers also significantly increased their confidence in their ability to use inquiry science practices and their actual use of inquiry practices with their students (Section 4). Overall the ability scale score increased by 0.343 ($P<0.000$) and the overall mean use scale score which increased by 0.306 ($P<0.000$) (Figure 2). These practices included expectations of students to: ask scientific questions, gather data to answer their questions, create scientific claims based on their evidence, defend their claims and make the results of their investigations public.

Figure 2. PolarTREC Pre/Post Survey Results on Ability and Use of Inquiry Science Practices, All Years Combined



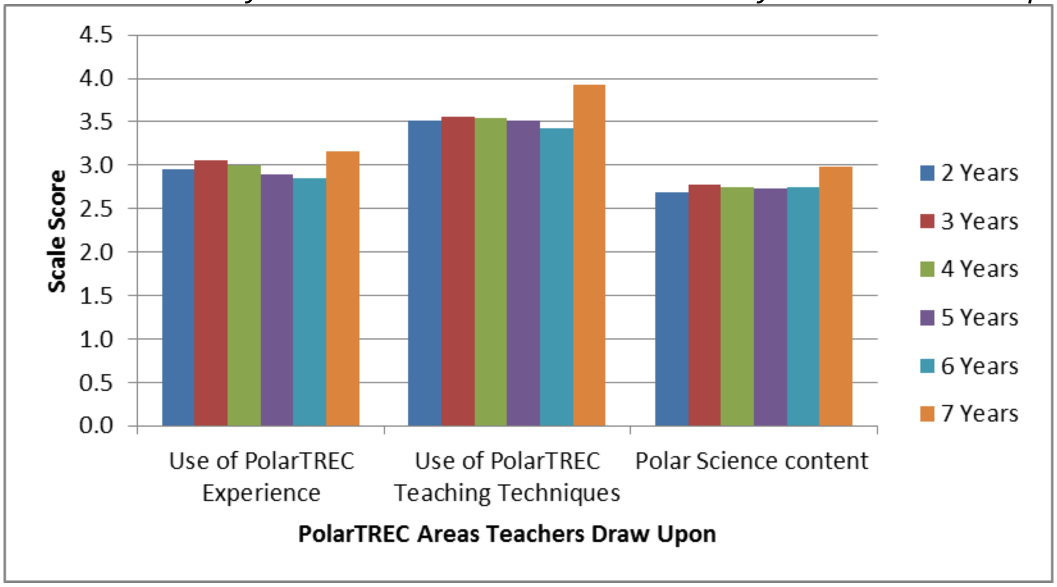
The participating teachers' experiences as well as their increased knowledge and use of inquiry science practices contributed to an increase in student interest and knowledge about the polar regions (Figure 3). Students reported increased experience using inquiry science practices, and knowledge about the polar regions, including knowledge of ice and snow, past human environments, ocean systems, tundra systems, engineering, and atmospheric sciences (Section 5).

Figure 3. PolarTREC Student Pre/Post Survey Results for All Years Combined



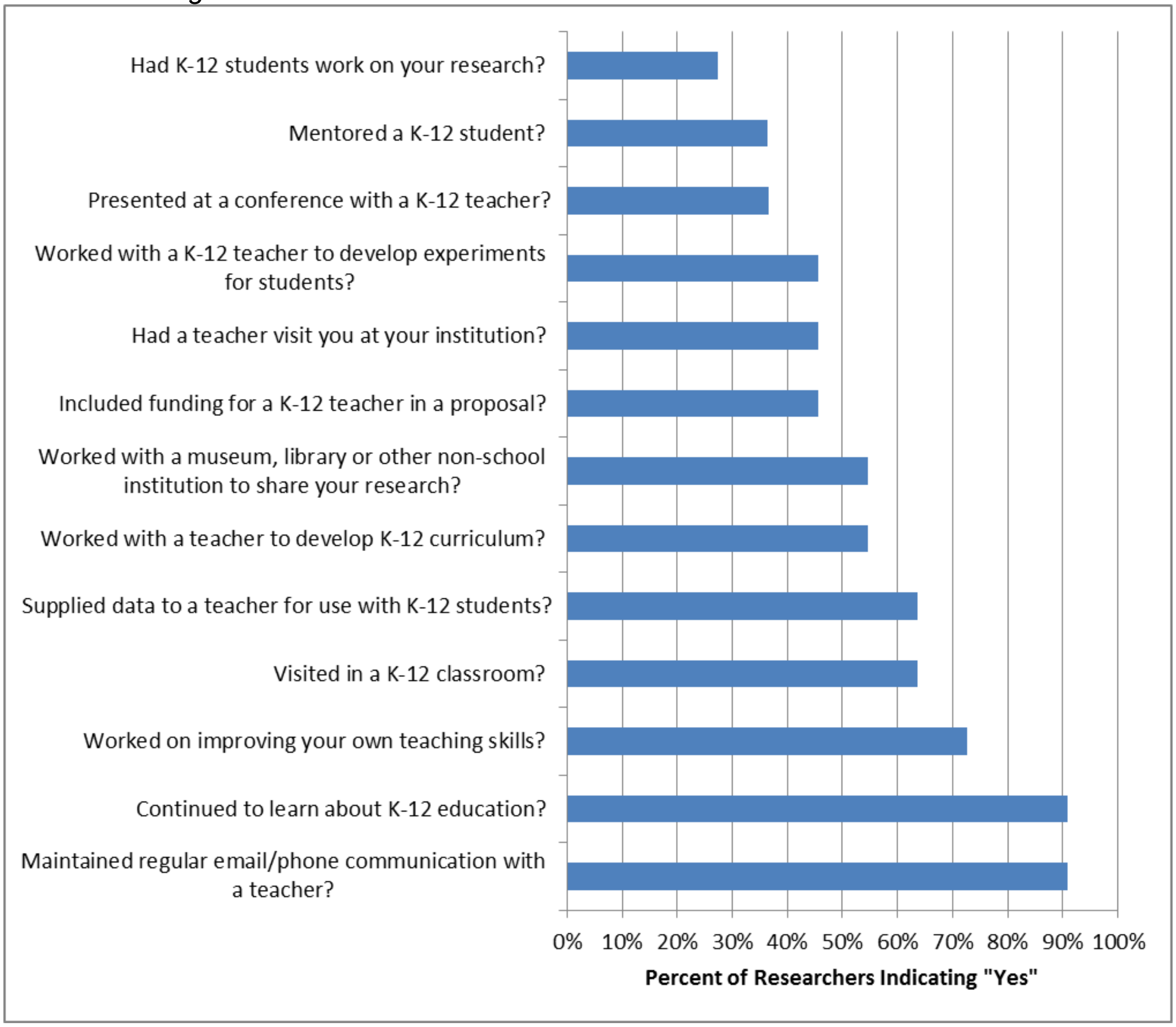
An annual survey of *PolarTREC* alumni shows that the benefits of the program persist. For years after the experience, teachers continue to bring what they learned about polar science and science teaching techniques to their students (Figure 4). They continue to consider themselves “scientists” and participate both alone and with their students in real research (Section 8 and Section 9).

Figure 4. Alumni Survey Scale Scores for Use of PolarTREC by Years Since Participation



Finally, researchers were also positive about their *PolarTREC* experiences and reported increased understanding of K-12 education. The majority of researchers developed and continued positive, professional relationships with K-12 teachers and students (Figure 5). These are relationships that the case study has demonstrated have the potential to grow into long-term partnerships (Section 6).

Figure 5. Continued Researcher Collaboration with K-12 Teachers



Introduction

In 2010, building on the success and momentum of the International Polar Year (IPY), the Arctic Research Consortium of the United States (ARCUS) was awarded funding from the National Science Foundation (NSF PLR 0956825), to continue *PolarTREC*–Teachers and Researchers Exploring and Collaborating, a teacher professional development program. For the past ten years, *PolarTREC* has brought K-12 teachers and polar researchers together using best practices for Teacher Research Experiences (TRE) programs and their own working model for the program. *PolarTREC* teachers spend three to six weeks in research locations located throughout the Arctic and Antarctic. During the field-based experience, the teachers work with researchers to learn first-hand about the research being conducted in the polar regions. During the research experience, teachers become research team members, filling a variety of roles in the team as well as a unique role of public outreach officer for the research. From the field locations, teachers conduct live "*PolarConnect*" presentations about their location and research, keep a web-based polar journal, answer students' and others' questions, and post pictures of their daily experiences. Prior to their research experience, teachers receive extensive training in logistics, outreach, and education planning. Upon their return, participants are expected to integrate their experiences into their classroom instruction as part of their ongoing professional development. They also continue their public outreach as part of the program requirements.

Research has found that TRE participation improves teachers' ability to connect new research to their classroom curriculum (Glasson and Bently, 2000), improves teachers' instructional practices (Alters, 1998; Gilmer, 1999; Kielborn, 1999; Redfield, 2000), leads to improved student outcomes, and leads to effective researcher-educator partnerships that have numerous and far-reaching benefits for researchers as well. Scientists gain access to professional educators who have expertise in translating research approaches and results into programs (Franks et al., 2006).

PolarTREC's goals reflect this research: 1) to improve teacher content knowledge of the polar regions and the science conducted in these regions; 2) to increase teachers' use of authentic scientific research or inquiry; 3) to increase students' understanding and interest in the polar regions; and 4) to increase researchers' understanding of K-12 education. In addition, the program expects long-term professional relationships between teachers and researchers and among *PolarTREC* teachers will develop and grow to expand teachers' ability to integrate polar science content in their classrooms.

Evaluation Questions and Methodology

ARCUS contracted with the external evaluation team, Goldstream Group, to evaluate the *PolarTREC* program. The evaluation had two primary goals: 1) to better understand the immediate impacts of the program on participating teachers, their students, and the researchers with whom they partnered; and 2) to explore the long-term impacts of the *PolarTREC* experiences on participating teachers professional experiences, and in particular their use of authentic scientific research with their students and ongoing relationships with researcher team members and other *PolarTREC* teachers.

Methodology

The evaluation uses Guskey's (2000) model of professional development evaluation as a framework to answer these questions. Guskey's model is widely used to assess a wide range of teacher professional development programs. It includes five levels: participant reaction to professional development experiences (e.g., Did they like their field experience? Was their time well spent during the orientation? Were presenters/instructors well qualified?); participant learning (e.g., science content, pedagogical skills, confidence, and relationships with researchers); participant use of new knowledge and skills (e.g., use of new science instructional methods, use of scientific process, continued relationships with researchers); and student learning outcomes (e.g., increased understanding of science content, interest in science careers).In addition, the Guskey model includes organizational support and change. However, this was not included in our analysis. Both qualitative and quantitative data were gathered using multiple instruments and from multiple sources. The use of multiple data sources allowed us to triangulate the evaluation conclusions and to ensure a clear picture of the evaluation results (Davidson, 2005).

Table 1. Evaluation Instruments

Evaluation Level	**Questions Asked**	**Methods to Gather Information**	**What was Measured**
Participants Reactions	Were *PolarTREC* participants satisfied with their experiences?	Surveys disseminated at the end of orientation and end of participation	Teacher and researcher satisfaction with the program
	Were users satisfied with the *PolarTREC* online resources?	Online survey	Users' satisfaction with online resources.
Participants Learning	Did participants increase their understanding of polar science?	Pre-Post survey	The difference in teachers' knowledge of content specifically related to the research being conducted by Arctic and Antarctic researchers.
	Did participants increase their science self-efficacy?	Pre-Post Survey	The differences in teachers self-reported self-efficacy to teach science before and after *PolarTREC*.
Participants Use of New Knowledge	How did *PolarTREC* participants use the skills and knowledge they gained during their experience?	Longitudinal Survey	Teachers' reported use of knowledge and skills gained during *PolarTREC* and ongoing relationships with researchers up to 7 years after participation.
		Case Study	Detailed description of teachers' ongoing use of *PolarTREC* learning, use of *PolarTREC* knowledge and skills, and relationships with researchers.
Student Learning	How did *PolarTREC* impact students of participating teachers?	Student Pre-Post Survey	The difference in students self-reported understanding of science content and factors that The following factors that contribute to students' pursuit of STEM careers described by Dorsen et al. 2006 – career awareness; academic preparation and achievement; identification with STEM careers; self-efficacy to do science; and interest, enjoyment and motivation in science

Limitations of the Evaluation

The evaluation methods have several limitations. The evaluation's sample size is too small to generalize the findings to other TRE programs. Second, the evaluation relies heavily on self-reported data. Self-reported data is limited by the fact that it rarely can be independently verified. Further, self-reported data contain several potential sources of bias that should be noted as limitations: (1) selective memory (remembering or not remembering experiences or events that occurred at some point in the past); (2) telescoping [recalling events that occurred at one time as if they occurred at another time]; (3) attribution [the act of attributing positive events and outcomes to one's own agency but attributing negative events and outcomes to external forces]; and, (4) exaggeration [the act of representing outcomes or embellishing events as more significant than is actually suggested from other data].[1]

Organization of this Report

This report provides the summative evaluation results of the *PolarTREC* project from 2010 to 2014. It is divided into ten sections. The first section provides demographic information about the participating teachers, their students, and the research projects in which they participated. The next eight sections provide the evaluation results by evaluation instrument. These sections look at participant satisfaction with orientation activities (Section 2), teacher pre/post content knowledge (Section 3), teacher pre/post science efficacy (Section 4), student pre/post interest in and knowledge about the polar regions (Section 5), researcher satisfaction and perceptions related to the *PolarTREC* program (Section 6), user satisfaction with the *PolarTREC* Learning Resources (Section 7), long-term impacts of the *PolarTREC* program gathered from *PolarTREC* alumni annually (Section 8), the multiple ways successful *PolarTREC* teachers have used their *PolarTREC* experience in their classroom and beyond (Section 9), and students of alumni pre/post interest in and knowledge about the polar regions. In the final section we synthesize the data and make conclusions about the *PolarTREC* program and its impact on teachers, students, researchers and science education.

[1] See description of self-report data limitations at: http://libguides.usc.edu/content.php?pid=83009&sid=616083.

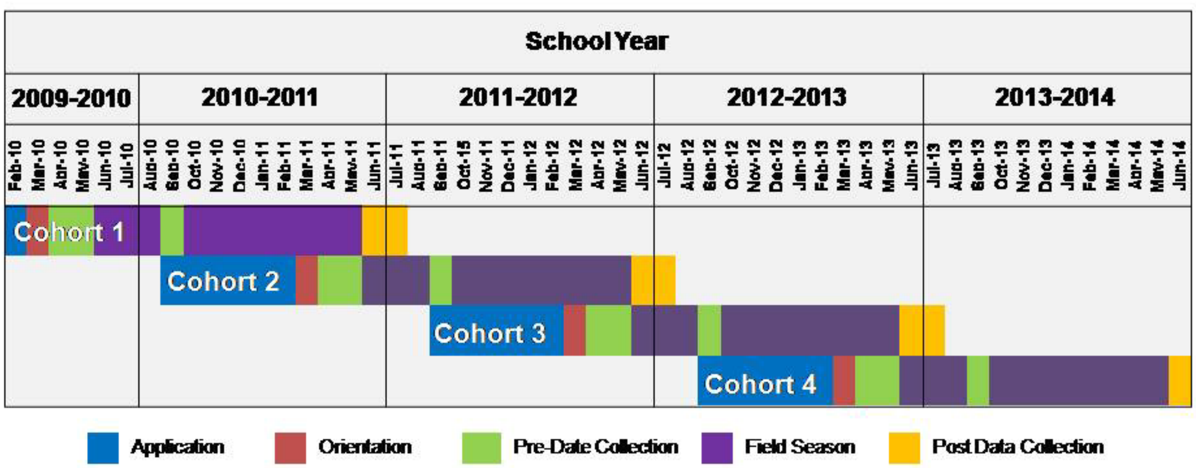
Section 1: Demographics of *PolarTREC* Teachers and Students

This section of the report provides an overview of the teacher and student demographics. First we look at how many individuals participated in *PolarTREC* and when their participation took place. Then we look at the gender, race, and ethnicity of selected applicants compared to all applicants, after which we look at the race and ethnicity of students whose teachers participated in *PolarTREC* compared to those who applied to *PolarTREC*. In the next part we look at the type of school in which selected and all applicants taught as well as grade levels and courses they taught. Then we look at the educational background of the selected *PolarTREC* teachers. Finally, we look at the research projects in which the selected *PolarTREC* teachers participated.

Participants by Year

Four cohorts of teachers participated in *PolarTREC* from 2010-2014 (Figure 6). Figure 6 depicts the staggered approach to the program with cohorts being accepted into the program one year and overlapping with the incoming cohort the next. Regardless, each cohort was tracked and evaluated separately.

Figure 6. Cohort Participation and Data Collection Schedule by Cohort Number



During the four-year grant period, *PolarTREC* received 638 applications from 520 unique applicants (several individuals applied more than once). From the 638 applications, 57 teachers (9%) were selected to participate in *PolarTREC* (14 teachers in Cohort 1, 15 teachers in Cohort 2, 14 teachers in Cohort 3, and 16 teachers in Cohort 4). The teachers represented 28 states.

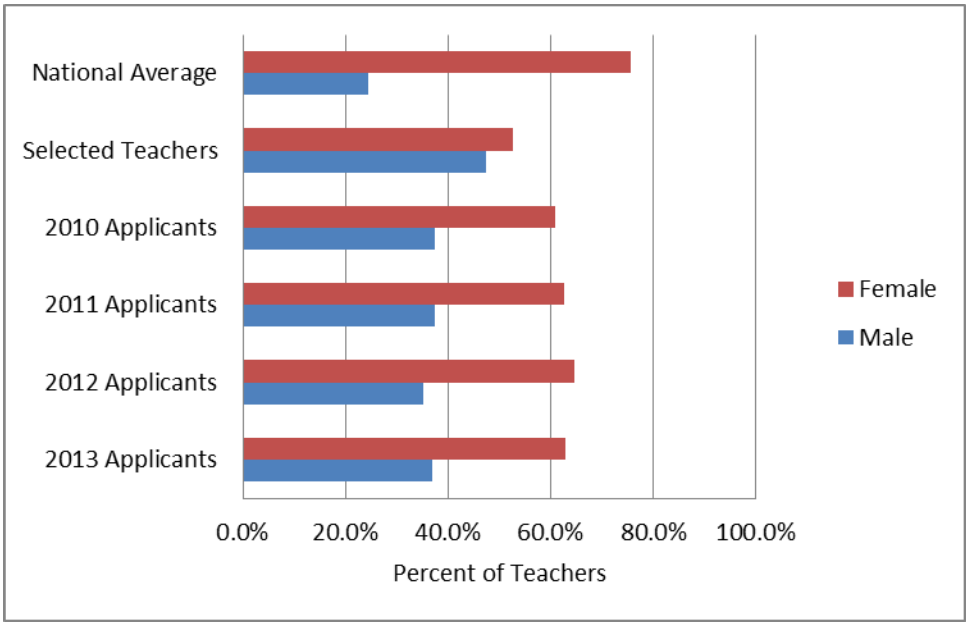
Teacher and Student Demographics

Using the *PolarTREC* Teacher Application, which included questions about the demographics of the teachers themselves and the students at the schools where they taught, data was compiled on teacher gender, teacher race and ethnicity, student race and ethnicity by teacher, and school type.

Gender, Race and Ethnicity

Almost two thirds of the *PolarTREC* applicants were female, somewhat reflecting the breakdown of teachers nationally where teachers are 76% female (National Center for Education Statistics, 2015). Selected *PolarTREC* teachers were 53% female (Figure 7).

Figure 7. Gender of Teachers Nationally Compared to PolarTREC Applicants and Selected PolarTREC Teachers



Applicants to the *PolarTREC* program and selected *PolarTREC* teachers were predominately Caucasian. However, non-Caucasian applicants increased each year. Table 2 provides a summary of the applicant race and ethnicity data for each application period as well as for the selected *PolarTREC* teachers. For comparison, the race and ethnicity of teachers nationally is also provided.

Table 2. Race and Ethnicity of Teachers Nationally Compared to PolarTREC Applicants and Selected PolarTREC Teachers

	National Average	Selected Teachers (n=57)	2010 Applicants (n=176)	2011 Applicants (n=183)	2012 Applicants (n=138)	2013 Applicants (n=141)
Caucasians	82.7%	91.2%	93.8%	91.3%	89.9%	83.7%
African American	6.4%	1.8%	1.7%	0.6%	2.9%	2.1%
American Indian/ Alaska Native	0.4%	0.0%	0.6%	0.0%	1.5%	2.8%
Asian	1.8%	1.8%	2.8%	1.6%	2.2%	2.8%
Native Hawaiian/ Pacific Islander	0.1%	1.8%	1.1%	0.0%	0.7%	1.4%
Hispanic	7.5%	7.0%	1.7%	1.6%	4.4%	6.4%
More than one race	1.0%	1.8%	1.1%	3.3%	1.5%	2.1%
None selected		0.0%	0.0%	1.1%	2.2%	4.3%
Note: Applicants were able to select more than one race/ethnicity, therefore the total does not sum to 100. This table includes the national average for comparison. The national average is drawn from National Center for Education Statistics, 2015.						

While the applicants to the *PolarTREC* program and the selected *PolarTREC* teachers predominately reported their race as Caucasian, their students were more diverse. More than 50% of the students of selected *PolarTREC* teachers were non-Caucasian (Table 3).

Table 3. Average Student Race and Ethnicity by Applicant

	National Average[2]	Selected Applicants *(Cohorts 1-4)*	2010 Applicants	2011 Applicants	2012 Applicants	2013 Applicants
Caucasian	51.7%	48.1%	62.4%	58.5%	60.9%	55.9%
African American	15.8%	19.5%	13.8%	12.4%	12.2%	14.6%
American Indian/Alaska Native	1.1%	2.8%	7.8%	2.7%	7.4%	4.4%
Asian	5.1%	5.2%	5.9%	7.6%	7.6%	5.9%
Native Hawaiian/Pacific Islander	--	10.3%	4.2%	1.7%	2.1%	1.7%
Hispanic	23.7%	16.7%	19.1%	17.2%	19.9%	19.9%
More than one race	2.6%	27.1%	3.5%	5.1%	7.1%	4.9%

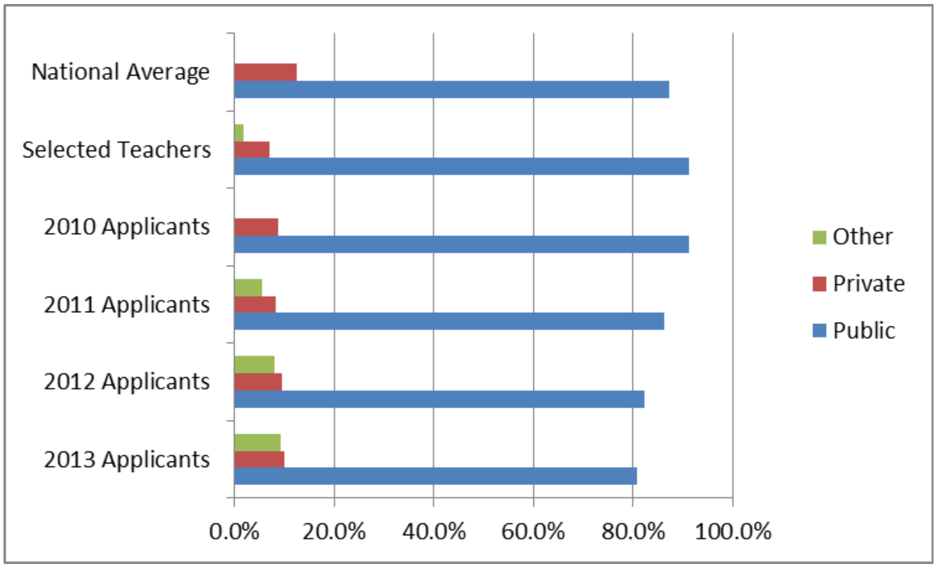
School Type and Educational Assignments

Figure 8 summarizes data on the types of schools at which*PolarTREC* applicants taught and compares this information to the selected *PolarTREC* teachers and national averages. Schools in which the applicants taught were predominantly public (80-91%). The remaining teachers taught in private schools and in informal education settings, like museums. On average, more than 39% of students taught by both applicants and selected teachers received free or reduced lunch.[3]

[2] National Center for Education Statistics. Digest of Education Statistics. Retrieved from http://nces.ed.gov/programs/digest/d13/tables/dt13_203.50.asp. National averages are from 2012 data to average years.

[3]The National School Lunch Program is a federally assisted meal program operating in public and nonprofit private schools and residential child care institutions. It provides nutritionally balanced, low-cost or free lunches to income eligible children (http://www.fns.usda.gov/nslp/national-school-lunch-program-nslp).

Figure 8. School Type for Teachers Nationally and Compared to PolarTREC Applicants and Selected PolarTREC Teachers



More than 70% of the selected teachers taught middle school (grades 6-8) or high school (grades 9-12). Almost 20% of the selected teachers taught in an informal setting although informal education teachers represented fewer than 4% of the applicants. Fewer than 4% of the selected teachers taught in the primary grades although they represented 15% of the applicants. Table 4 describes these teaching assignments in greater detail.

Table 4. Teacher Assignments of Selected PolarTREC Teachers and All Applicants

	Selected Teachers		All Applicants	
Teaching Assignment	**Count**	**Percent (n=56)**	**Count**	**Percent (n=638)**
Primary (Grades 1-5)	2	3.6%	96	15.0%
Middle School (Grades 6-8)	**17**	**30.4%**	**233**	**36.5%**
Secondary (Grades 9-12)	**25**	**44.6%**	**307**	**48.1%**
Informal Education (Science/Nature Center, Museum, etc.)	**10**	**17.9%**	**22**	**3.4%**
Community, Vocational, or Technical College	3	5.4%	9	1.4%
Four-Year College or Institution	1	1.8%	12	1.9%
Gifted	1	1.8%	23	3.6%
Special Education	1	1.8%	15	2.4%
Counselor	0	0.0%	2	0.3%
Librarian	1	1.8%	5	0.8%
Administration	0	0.0%	7	1.1%

More than 90% of selected *PolarTREC* teachers taught in one or more science content subjects, such as earth science, biology, or physics. A handful of selected teachers also taught subjects such as social studies, languages, theatre. Table 5 compares the percent of selected *PolarTREC* teachers and all applicants by subject taught.

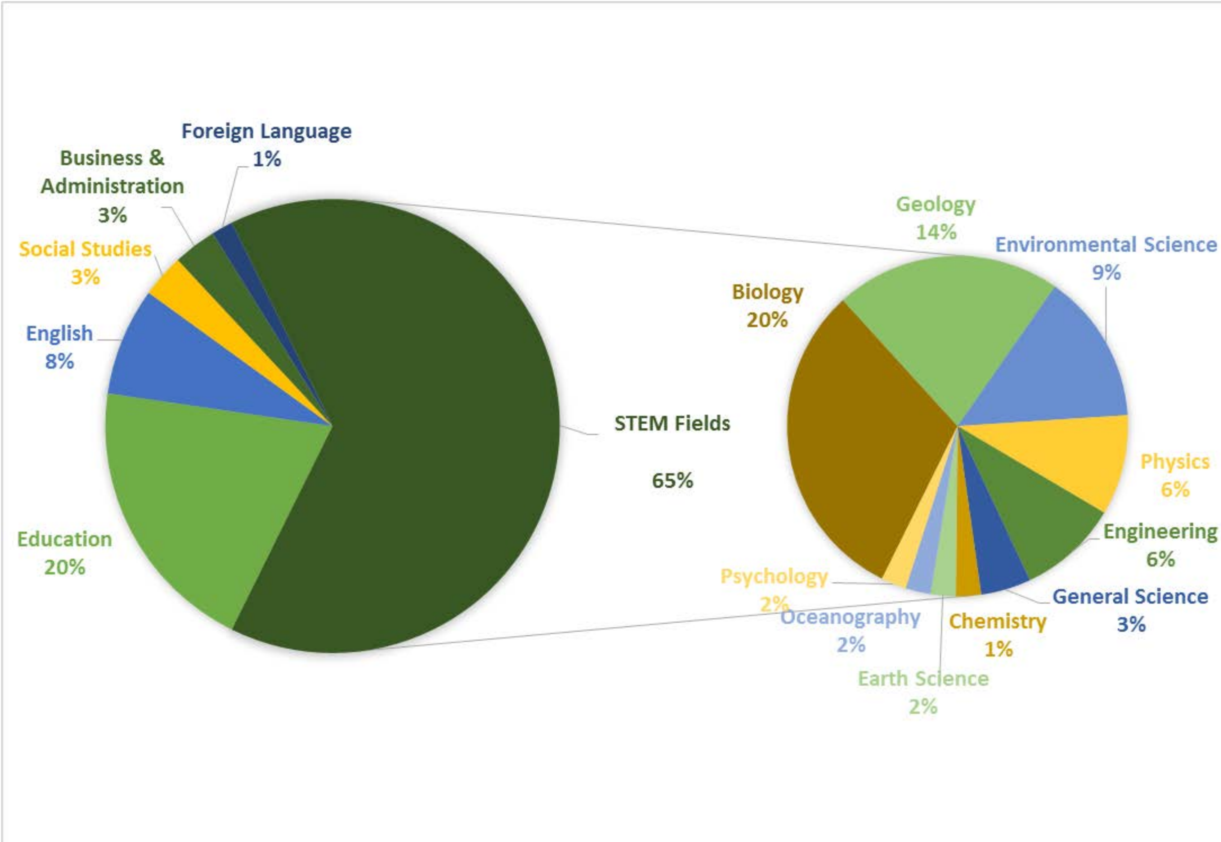
Table 5.Subjects Taught by Selected PolarTREC Teachers and All Applicants

	Selected Teachers		All Applicants	
Subjects Taught	**Count**	**Percent(n=56)**	**Count**	**Percent (n=638)**
Secondary Earth Science	20	35.7%	185	29.0%
Secondary Biology	18	32.1%	213	33.4%
Middle School Science	16	28.6%	248	38.9%
Secondary Physical Science	13	23.2%	98	15.4%
Secondary General Science	9	16.1%	99	15.5%
Secondary Physics	8	14.3%	82	12.9%
Secondary Chemistry	6	10.7%	100	15.7%
Elementary Education	4	7.1%	134	21.0%
Middle School Social Studies	4	7.1%	46	7.2%
Secondary Math	4	7.1%	32	5.0%
Middle School English/Language Arts	2	3.6%	38	6.0%
Middle School Math	2	3.6%	51	8.0%
Secondary Geography	2	3.6%	19	3.0%
Secondary Social Studies	2	3.6%	13	2.0%
Secondary Art	1	1.8%	11	1.7%
Secondary Economics	1	1.8%	7	1.1%
Secondary English	1	1.8%	12	1.9%
Secondary World and U.S. History	1	1.8%	14	2.2%
Secondary Government/Political Science	1	1.8%	10	1.6%
Secondary Spanish	1	1.8%	1	0.2%
Secondary Theatre	1	1.8%	1	0.2%
Secondary Music	0	0.0%	1	0.2%
Secondary Speech Communication	0	0.0%	2	0.3%

Education level of *PolarTREC* teachers

The 56 selected *PolarTREC* teachers had between them 65 bachelor degree majors (some double majors, some more than one degree.) Figure 9 illustrates the distribution of subjects. In addition, 51 participants had a master's degree, and eight had or were working on a PhD degree and two had a law degree.

Figure 9: Bachelor Majors of Selected PolarTREC Teachers



Research Projects

The placement of selected teachers on research projects is a multi-faceted process and is part of the model that was developed by ARCUS for the *PolarTREC* program. A full description of this process is part of the program final report and not part of the evaluation. For this evaluation, data on the type of research project was collected from the research application and website. Of Cohorts 1-4, 68% of selected teachers participated in research projects located in the Arctic and 32% participated in projects located in Antarctica. A wide variety of science disciplines were included. Table 6 lists the research expeditions by cohort year and science topic area. In the researcher application to host a teacher, the researcher determined the science topic area however it should be noted that most of the research projects were interdisciplinary, and could therefore have been categorized multiple ways. For example, "Antarctic Seafloor Ecology" is clearly both oceanography and ecology.

Table 6. Expeditions by Cohort Year and Science Area

Year	Science Topic Area	Expedition Name
Cohort 1		
	Climate	Atmospheric Conditions and Arctic Climate
		Solar Radiation on the Greenland Ice Sheet
	Ecology and Biotic Systems	Impacts of the Larsen Ice Shelf System on the Weddell Sea
		Long-Term Circumpolar Permafrost Monitoring
		Tundra Plants in a Changing Climate
	Education	Greenland Education Tour 10
	Glaciology	Flow Studies on an Antarctic Glacier
		High Arctic Change 2010
		Glacial History in Antarctica
		Ice Core Drilling in West Antarctica 2010
	Human and Social Systems	Prehistoric Human Response to Climate Change 2010
		Early Human Settlement in Arctic Alaska
	Oceanography	Oden Antarctic Expedition 2010
		Antarctic Seafloor Ecology
		International Continental Shelf Survey
	Physics	IceCube In-ice Antarctic Telescope 2010
Cohort 2		
	Climate	Solar Radiation on the Greenland Ice sheet 2011
	Ecology and Biotic Systems	Weddell Seals in the Ross Sea
		Microbial Activity in Thawing Arctic Permafrost
		Carbon Balance in Warming and Drying Tundra
		Adaptations of Marine Worms in Antarctica
		Seafloor Organisms and Changing Ocean Conditions in Antarctic
		Carbon Balance in Warming and Drying Tundra 2012
		Biology of Antarctic Fishes
		Forest Response to Arctic Environmental Change
		Climate-Mediated Coupling of Hydrology and Biogeochemistry In Arctic Hill Slopes
	Education	Greenland Education Tour 2011
	Glaciology	High Arctic Change 2011
		Glacial Movement and Seismicity
		Airborne Survey of Polar Ice
	Human and Social Systems	Human Impacts in Antarctica 2011
		Early Human Settlement in Arctic Alaska 2011
	Oceanography	Seawater Property Changes in the Southern Ocean
		Winter Sampling
		Nitrogen in the Arctic Ocean Ecosystem
	Space Physics	Space Weather Monitoring on the Antarctic Plateau
Cohort 3		
	Climate	The Svalbard REU - Holocene and Modern Climate
		Change Research in the High Arctic
		Buried Ice in Antarctica, Implications for Mars
		Ice Bridge: Changes on the Greenland Ice Sheet
	Ecology and Biotic Systems	Change in the Larsen Ice Shelf
		Microbial Activity in Thawing Arctic Permafrost 2012
		Carbon Balance in Warming and Drying Tundra 2012
		The Polaris Project
		Wolf Spiders in the Food Web
		Tundra Nutrient Cycling

Year	Science Topic Area	Expedition Name
	Geology	Tectonic History of the Transantarctic Mountains
	Human and Social Systems	Paleoindian Adaptations in Eastern Beringia: Prelude or Postscript to the Early Settlement of the Americas?
		Early Human Settlement in Arctic Alaska 2012
	Hydrology	Hydrology and Arctic Hillslopes
	Oceanography	Chukchi Sea Offshore Monitoring
		Bio-Physical Observations in Arctic Waters
	Physics	IceCube In-Ice Antarctic Telescope 2012
Cohort 4		
	Climate	Reconstructing the Past Climate of Central Alaska
	Ecology and Biotic Systems	Biology of Antarctic Fishes 2013
		Arctic Ground Squirrel Studies
		Predatory Spiders in the Arctic Food Web 2013
		Soil Ecology in Antarctic Dry Valleys
		Carbon Balance in Warming and Drying Tundra 2013
		Arctic Wetland Dynamics in Finland
		Chukchi Sea Ecosystem Study
		Northern Alaska Coastal Ecosystems
		Arctic Sunlight and Microbial Interactions
	Glaciology	Totten Glacier System in East Antarctica
		Drumlin Formation in Iceland
		Airborne Survey of Polar Ice 2013
	Oceanography	Sea Floor Changes and the Antarctic Circumpolar Current

Section 2: *PolarTREC* Orientation and ShareFair Feedback

The *PolarTREC* Orientation and ShareFair, held each spring in Fairbanks, Alaska, is an important precursor to joining researchers in the field, with hands-on training in journaling, outreach, communication and educational technologies, and field safety. The five-day, in-person orientation gives teachers ample time to practice communication protocols, converse with program alumni, and learn basic polar science content from participating researchers. Each year program alumni attend the training events (in-person and virtually) to share outreach strategies, lessons, and advice with the current cohort. Additionally, two or three researchers and three representatives from the program logistic providers (CH2MHILL Polar Services, Antarctic Support Contractors, and SRI International) participate in the orientation. During this evaluation period, ARCUS held four *PolarTREC* Orientation and ShareFair events.

Evaluation of the *PolarTREC* Orientation and ShareFair was primarily formative in nature and corresponds to the first two levels of Guskey's framework: participants' reactions and participants' learning. The orientation evaluation focused on the: extent to which the participants were satisfied with their initial *PolarTREC* experience; and how much the participants learned about the topics covered during the orientation to target future learning opportunities.

Sample Size

Each year participating teachers as well as alumni teachers completed the *PolarTREC* Orientation and ShareFair feedback survey. In total our sample size was 56 completed surveys. Table 7 lists the number of surveys completed by year.

Table 7.PolarTRECOrientation and ShareFair Feedback Survey Sample Size

Year	Number of Surveys
2010	13
2011	11
2012	13
2013	19

Analysis

Scale scores were calculated for 8 areas of interest:

- workshop environment satisfaction
- preparation opportunity
- knowledge of education and outreach plans
- knowledge of goals and expectations
- knowledge of journaling skills
- knowledge of life in the polar regions
- knowledge of safety and logistics
- knowledge of technology

To calculate a scale score, a numerical value was assigned to the rating of each item (Strongly Disagree =1, Strongly Agree =4) and the scores of the items were averaged to determine a scale score for each respondent. The closer the scale score is to 4, the more strongly the respondent agrees with the main idea of the scale.

The first scale, workshop environment satisfaction, used the following items to assess satisfaction with the overall workshop environment: objectives of this workshop were clear, time was used effectively, presenters were effective instructors, presenters were well prepared, orientation held my interest, my questions and concerns were addressed, participants were active learners, interactions between presenters and participants were collegial, interactions among participants were collegial, facilities (room, coffee) were conducive to learning, accommodations were of high quality, and an appropriate balance between presentation and interaction was achieved. Responses to these items were averaged to provide a satisfaction scale score.

The second scale, preparation opportunity, measured the extent to which orientation participants perceived the orientation as a good opportunity to prepare for their *PolarTREC* expedition. It used the following items to assess the participants' satisfaction with the focus of the workshop to prepare participants for their *PolarTREC* experience by giving them the opportunity to: improve polar region knowledge; build interest in the polar regions; network with people with similar interests; be part of a professional community; consider classroom applications of *PolarTREC* project; and prepare for their *PolarTREC* experience. Again, responses to these items were averaged to provide a scale score focusing on the focus on the workshop.

Knowledge scales used the following items to assess participants' self-reported knowledge gain: education and outreach planning, program goals and expectations, journaling, life in the polar regions, safety and logistics, and technology. Responses to these items were average to provide a knowledge scale score.

Results

Satisfaction Outcomes

Participants consistently rated these workshops positively. Scale results by year are presented in Table 8.

Table 8. Participant Rating of PolarTREC Orientation Environment

Year	N	Scale Score
2010	13	3.95
2011	11	3.99
2012	13	3.91
2013	19	3.92

Participants also consistently rated the opportunity scale items high. Scale results by year are presented in Table 9.

Table 9. Participant Rating of Opportunities to Prepare for PolarTREC Experience

Year	N	Scale Score
2010	13	3.88
2011	11	3.97
2012	13	3.94
2013	19	3.81

Knowledge Outcomes

The *PolarTREC* Orientation and ShareFairs' focused on the following topics: education and outreach planning, program goals and expectations, journaling, life in the polar regions, safety and logistics, and technology. Overall, participants left the orientations fully prepared in the focus knowledge areas. Results are presented in Table 10.

Table 10. Orientation Knowledge Outcomes

Knowledge Area	2010 (N=13)	2011 (N=11)	2012 (N=13)	2013 (N=19)
Education and Outreach Plan	3.48	3.81	3.77	3.74
Goals and Expectations	3.46	3.86	3.85	3.75
Journaling	3.73	3.82	3.77	3.75
Life in the polar regions	3.04	3.33	3.69	3.08
Safety/Logistics	2.60	3.97	3.79	3.80
Technology	3.32	3.74	3.76	3.64

Written comments by participants were positive. Many comments highlighted the technical information participants gained and the valuable networking opportunities they found. Several respondents stated that the instruction and workshops were inspirational. Comments listed below are illustrative of the range of responses:

- *The ENTIRE program was so thoroughly and thoughtfully planned out to use our time most effectively.*
- *Learning new technology and building relationships with like-minded professionals.*
- *Hearing from past TREC-ers - Having personalized tech help - Having documents already printed out and flash-drive*
- *Learning how to create and post dynamic journals.*
- *The scaffold approach to the process of communicating from the field.*
- *Networking opportunities, learning more about the expectations and requirements of the program. It's been a fabulous week. The ARCUS staff is amazing.*
- *The great tech support and seamless organization and family feel.*

Section 3: Teacher Content Knowledge

ARCUS was interested in understanding what science content teachers learned as a result of their *PolarTREC* participation. To measure teachers' content knowledge changes we developed a multiple choice pre/post-test using questions developed by each researcher. Researchers were asked when applying to the program, to list five multiple choice questions that represent key concepts or information that a teacher should learn by participating in their research expedition. It was assumed that participants would also learn about the other research topics as well as their own by following the experiences of their colleagues. Tests had between 60 and 80 multiple-choice questions depending on the year.

Sample Size

In total 40 of the 59 participating teachers completed both the pre and post content knowledge test and were included in our sample for an overall response rate of 68%. Table 11 lists the response rate by cohort.

Table 11. Teacher Content Knowledge Pre/Post Test Sample Size

Cohort	**Number of completed tests (n)**	**Number of Participants (N)**	**Response Rate**
Cohort 1	7	14	50.0%
Cohort 2	11	15	73.3%
Cohort 3	12	14	85.7%
Cohort 4	10	16	62.5%
All Cohorts	40	59	67.8%

Analysis

Pre-tests were disseminated electronically to participants in March of each program year and post-test approximately one year later. The tests were graded and test item responses were recoded as correct or incorrect. A paired t-test was used to determine if the proportion of correct test items was significantly ($P< 0.05$)different from pre-test to post-test.

Results

The mean pre-post knowledge score increased for all four cohorts, and significantly ($P<0.05$)for cohorts 1 and 2.The overall change from pre- to post-test was statistically significant ($P<0.000$). The mean ratio of correct answers on the pre-test was 0.539 and the mean ratio of correct answers on the post-test was 0.595, a mean difference of 0.056 (Table 12).

Table 12. Participant Content Knowledge Test Scores

		Mean Ratio of Correct Answers					
Cohort	**n**	**Pre- Test**	**Post- Test**	**Difference**	**t**	**df**	**Sig**
Cohort 1	7	0.540	0.622	0.083	3.400	6	**0.014**
Cohort 2	11	0.515	0.590	0.075	3.101	9	**0.013**
Cohort 3	12	0.494	0.558	0.064	2.139	11	0.056
Cohort 4	10	0.617	0.625	0.009	0.305	9	0.768
All Cohorts	40	0.539	0.595	0.056	3.940	38	**0.000**

Section 4: Teacher Science Instruction Survey Results

ARCUS was also interested in understanding how participating teachers' *science efficacy* – or their confidence in their own ability to use inquiry science practices with their students after participating in *PolarTREC*. To measure teachers' self-reported ability to use inquiry methods with their students as well as their actual use of inquiry methods in the classroom, the evaluation team developed a science instruction practices survey, which included 37 Likert-scale survey items drawn from a published inquiry practices survey (Dira-Smolleck, 2004).

The survey items were grouped into two scales: 1) ability to guide students in scientific inquiry and 2) use of inquiry practices in their classrooms. To measure the reliability of the scales, we calculated Crohbach's alpha coefficient for each scale (ability and use) using SPSS. Cronbach's alpha is a measure of internal consistency among items included in a scale (Trochim, 2006). A Cronbach's alpha that is greater than 0.7 is considered evidence that the items included measure an underlying construct (George and Mallery, 2003).The ability scale (ability to guide students in scientific inquiry) included 20 items. The Cronbach's alpha reliability coefficient for these items is 0.942. The use scale (use of inquiry practices in their classrooms) included 18 items. The Cronbach's alpha reliability coefficient for these items is 0.888. For both of the scales there was a high rate of internal consistency among the survey items.

Sample Size

Pre-surveys were disseminated electronically to participants in March of each program year and post-surveys approximately one year later. In total 38 of the 59 participating teachers completed both the pre and post instruction survey and were included in our sample for an overall response rate of 64%. Table 13 lists the response rate by cohort.

Table 13. Teacher Content Knowledge Pre/Post Test Sample Size

Cohort	Number of Completed Tests (n)	Number of Participants (N)	Response Rate
Cohort 1	7	14	50.0%
Cohort 2	9	15	60.0%
Cohort 3	13	14	92.9%
Cohort 4	9	16	56.3%
All Cohorts	40	59	64.0%

Analysis

Scale scores were calculated for each respondent. The scale score is the average of the responses to items included in each scale. A paired samples t-test was used to test whether the pre- and post-mean scale scores were significantly ($P < 0.05$) different.

Results

In each of the program years, the mean ability scale scores increased significantly, indicating that teachers were more confident in the ability to use inquiry science practices after their *PolarTREC* experience. In all but one of the program years, the mean use scale score also significantly increased, indicating that teachers felt they used inquiry science practices more often after their *PolarTREC* experience. Table 14 and Table 15 summarize the results by year as well as provide the overall results, which were also statistically significant for both the ability scale score which increased by 0.343 ($P <0.000$) and the overall mean use scale score which increased by 0.306 ($P< 0.000$).

Table 14. Participant Ability Scale Results

		Mean Score					
Cohort	**n**	**Pre**	**Post**	**Difference**	**T**	**df**	**Sig**
Cohort 1	7	3.154	3.536	0.382	2.683	6	0.036
Cohort 2	11	3.170	3.490	0.320	3.594	8	0.007
Cohort 3	12	3.089	3.569	0.481	4.923	12	0.000
Cohort 4	10	3.117	3.350	0.233	2.317	8	0.049
All Cohorts	38	3.13	3.49	0.343	6.868	37	0.000

Table 15. Participant Use Scale Results

		Mean Score					
Cohort	**n**	**Pre**	**Post**	**Difference**	**T**	**df**	**Sig**
Cohort 1	7	3.087	3.365	0.278	1.909	6	0.105
Cohort 2	11	3.000	3.340	0.336	4.159	8	0.003
Cohort 3	12	3.054	3.443	0.389	3.395	12	0.005
Cohort 4	10	3.154	3.333	0.180	2.317	8	0.049
All Cohorts	38	3.070	3.380	0.306	0.306	37	0.000

Section 5: Student Interest and Knowledge about the polar regions

ARCUS was interested in understanding whether student interest and knowledge about the polar regions changed as a result of their teacher's *PolarTREC* participation. To measure changes, a pre-post student survey was developed around the factors that contribute to students' pursuit of STEM careers, such as career interest, science efficacy, science content knowledge, and academic preparation and achievement (Dorsen, et al. 2006).

The *PolarTREC* student survey included four scales: career interest, science efficacy, polar region science content knowledge, and academic preparation/achievement. The polar region science content knowledge is broken down into science content areas, including general polar region knowledge, atmospheric science ice and snow, human and social systems, ocean systems, tundra systems, and engineering. To measure the reliability of the scales to measure student interest, science efficacy, content knowledge, and academic preparation/achievement, a Cronbach's alpha coefficient was calculated for each scale using SPSS. For all of the scales the Cronbach's alpha was greater than 0.7; evidence that the scale items measure the underlying construct (George and Mallery, 2003). Table 16 lists the Cronbach's alpha for each scale.

Table 16. Student Interest and Knowledge Survey Scale Reliability

Scale	Number of Items	Cronbach's alpha	N
Career Interest	12	0.850	4,448
Science Efficacy	10	0.839	4,928
Academic Preparation/Achievement	11	0.954	3,778
Polar Region Science Content Knowledge			
General Polar Region Knowledge	6	0.798	4,982
Atmospheric Science	2	0.840	5,134
Ice And Snow	4	0.816	5,007
Human And Social Systems	6	0.893	5,037
Ocean Systems	5	0.831	5,014
Tundra Systems	5	0.938	5,003
Engineering	3	0.830	4,976

Sample Size

The pre-survey was disseminated electronically by participating *PolarTREC* teachers and former *PolarTREC* teachers involved in the case study in the fall of 2010, 2011,2012, and 2013. The post-survey was disseminated electronically by participating teachers in the spring of 2011,2012, 2013, and 2014.Our sample includes the student survey results of the 26 teachers whose students completed both a pre- and post-survey during any one of the four program years. Of the teachers, 23 were current participants and three were part of the case study. This sample provides 1,263 student pre-surveys and 1,432 student post-surveys for analysis. Table15 lists the number of pre- and post-surveys completed by students and the number of teachers who disseminated pre- and post-surveys by analysis group.

Table 17. Student Survey Sample

	Number of Teachers who Disseminated Pre and Post Surveys	Pre Surveys	Post Surveys
Cohort 1	6	159	128
Cohort 2	7	412	375
Cohort 3	11	762	675
Cohort 4	8	535	338
Case Study	3	185	149
Total	35	2,053	1,665

Analysis

Scale scores were calculated for each respondent. The scale score is the average of the responses to items included in each scale. Then an independent samples t-test was used to test whether the pre- and post-mean scale scores were significantly (P < 0.05) different for each group of students separately (participating teachers and control group teachers).

Results

The pre- to post-mean scale scores measuring student interests and knowledge significantly increased for all of the scales tested by the student survey, except for Career Interest and Science Efficacy (Table 18). Career interest in science shifted in a negative direction, though not significantly.

Table 18. Student Survey Results for All Years Combined

Scale	Test	N	Mean	Std. Deviation	Std. Error Mean	Change	t	df	P-Value
Career Interest	Pre	2,053	1.89	0.59	0.01	-0.02	-0.979	3716	0.328
	Post	1,665	1.87	0.59	0.01				
Science Efficacy	Pre	2,053	2.65	0.50	0.01	-0.00	-0.070	3716	0.944
	Post	1,665	2.65	0.55	0.01				
Academic Preparation	Pre	1,670	2.67	0.72	0.02	0.15	5.85	3070	**0.000**
	Post	1,402	2.82	0.73	0.02				
General Knowledge	Pre	2,045	2.29	0.56	0.01	0.21	10.82	3697	**0.000**
	Post	1,654	2.50	0.64	0.02				
Atmosphere	Pre	2,032	2.73	0.71	0.02	0.25	10.29	3677	**0.000**
	Post	1,647	2.98	0.75	0.02				
Ice and Snow Knowledge	Pre	2,024	2.34	0.66	0.01	0.26	11.61	3665	**0.000**
	Post	1,643	2.60	0.70	0.02				
Human/Past Environments	Pre	2,020	1.98	0.66	0.01	0.32	14.19	3658	**0.000**
	Post	1,640	2.30	0.71	0.02				
Ocean Systems	Pre	2,010	1.93	0.63	0.01	0.32	14.75	3643	**0.000**
	Post	1,635	2.25	0.70	0.02				
Tundra Systems	Pre	1,994	1.77	0.72	0.02	0.32	12.66	3608	**0.000**
	Post	1,616	2.09	0.80	0.02				
Engineering	Pre	1,975	1.98	0.73	0.02	0.21	8.35	3570	**0.000**
	Post	1,597	2.19	0.78	0.02				

When broken down by program year and case study groups (Table 19), Science Efficacy had a significant negative shift only with Cohort 3. Academic Preparation questions were added in the second year of the program so cannot be calculated for those groups that completed survey in the first year.

Table 19. Change in Scale Mean by Year

	All Years	**Cohort 1**	**Cohort 2**	**Cohort 3**	**Cohort 4**	**Case Studies**
Career Interest	-0.02	-0.04	-0.02	-0.03	-0.05	-0.09
Science Efficacy	-0.00	-0.06	-0.05	**-0.08**	0.06	0.08
Academic Preparation	0.15	na	0.15	0.10	0.25	na
General Knowledge	0.21	0.22	0.28	0.15	0.27	0.20
Atmosphere	0.25	0.27	0.29	0.22	0.30	0.16
Ice and Snow Knowledge	0.03	0.45	0.24	0.20	0.39	0.16
Human/Past Environments	0.03	0.39	0.28	0.27	0.41	0.36
Ocean Systems	0.32	0.52	0.33	0.26	0.40	0.19
Tundra Systems	0.32	0.26	0.29	0.27	0.49	0.32
Engineering	0.21	0.37	0.23	0.16	0.25	0.54

Section 6: Researcher Survey Results

This section discusses the researchers' survey results from Cohorts 1, 2, 3 and 4. The results of this survey will help ARCUS understand how *PolarTREC* impacted researchers' knowledge about K-12 education and outreach practices over time. The written survey included four sections: researchers' opinion of *PolarTREC*, their report of teachers' roles as part of their research team, their understanding of K-12 education after working with a teacher, and *PolarTREC*'s impact on their outreach activities.

Sample Size

In the summer of 2012, a survey was sent to 38 researchers who participated in *PolarTREC* in Cohorts 1 or 2. The survey was distributed again in the summers of 2013 (17 researchers) and 2014 (12 researchers). Twenty-seven surveys were completed over the three years (a response rate of 40%). Four individuals answered the survey twice, because they participated for more than one year with different teachers. Researchers who participated in *PolarTREC* for more than one year, were asked to answer the teacher related questions about their most recent teacher.

Analysis

The researcher survey was analyzed using descriptive statistics and content analysis.

Results

Researcher Opinions of *PolarTREC*

The researchers were generally positive about their *PolarTREC* experience, reporting among other things that the programs expectations were clear, communication was easy, and they were pleased with the qualifications of their teacher matched to their project. Table 20 presents satisfaction results.

Table 20. Researcher Ratings of the PolarTREC Experience

	Count	Strongly Disagree	Disagree	Agree	Strongly Agree
My experience with *PolarTREC* was positive.	27	3.7%	3.7%	11.1%	81.5%
The expectations of the program were clear.	27	0.0%	3.7%	29.6%	66.7%
I found it easy to communicate with ARCUS.	27	0.0%	0.0%	18.5%	81.5%
ARCUS was responsive to my needs.	27	0.0%	3.7%	14.8%	81.5%
ARCUS supplied needed technological assistance to communicate my research to the public.	27	0.0%	3.7%	40.7%	55.6%
My *PolarTREC* experience surpassed my expectations.	27	7.4%	7.4%	48.2%	37.0%
I will apply for another *PolarTREC* teacher.	27	3.7%	7.4%	29.6%	59.3%
The *PolarTREC* program was beneficial to the scientific process for my project.	27	0.0%	14.8%	40.7%	44.4%
I was pleased with the qualifications of the teacher matched to my project.	27	7.4%	0.0%	33.3%	59.3%

Twenty-six out of twenty-seven respondents wrote a response to the question "What was the best aspect about participating in *PolarTREC*?" Ten mentioned the increased outreach for their project. Nine mentioned the positive experience of getting to know and working with the teacher. Examples follow:

- *Interactions with teachers brought out aspects of our science relevant to the public and students.*
- *I love interacting with the teachers -- they have incredible enthusiasm for the experience and for the research, and they genuinely care about translating their experiences and knowledge into something beneficial for their students.*
- *Best aspect was having someone in the group who was an intelligent and receptive participant but not a practicing scientist already immersed in the jargon and ideas behind the project. This forced us to think through and explain what we were doing in clear everyday terms, always a good discipline for scientists. The fact that much of what we were explaining and describing would be passed on to high-school students made it doubly challenging and doubly beneficial.*
- *The program managers were fantastic! They had a great handle on best practices to communicate with teachers and did a great job running the show.*

Twenty-five out of twenty-seven respondents also answered the question, "What was the worst aspect about participating in the *PolarTREC* project?" Thirteen of them answered, "nothing" or similar. Other comments follow.

- *Carrying out scientific research with non-scientists was much more challenging than I anticipated.*
- *Conference calls that went much longer than expected.*
- *Occasionally participation made demands on scarce time leading up to, and after the fieldwork (e.g. orientation discussions, phone conferences, surveys etc.). Along the same lines, I did get a sense that in some cases the main beneficiaries of the program are the teachers who participate rather than their students. It would be good if the program could find a way to establish firmer links from scientist to classroom as opposed to the current emphasis from scientist to teacher.*
- *At this point, I can't really think of any negative aspects.*
- *It's hard to do follow-up and keep contact with teachers after the field season.*

Researcher Perception of Participating Teacher Role

All of the researchers felt that they and the teacher had a clear understanding of what the role of the teacher would be before leaving on the expedition. Only 67% of researchers met with their teacher before going to the field. More than 80% of respondents reported: 1) the teacher was a quick learner; 2) the teacher helped with data collection closely supervised; 3) the teacher was prepared academically for the demands of the project; 4)the teacher was a valuable member of the research team; 5) the teacher was a good match for the project; 6) the teacher pitched in to help however needed in the field; and 7) the teacher was prepared physically for the demands of fieldwork. More than 69% of respondents agreed: 1)the teacher learned to think like a scientist and 2)the teacher was the main PR/outreach for the expedition. Forty-six percent of respondents reported the teacher helped with data collection independently.

Though most researchers reported positive experiences, two of the twenty-seven respondents did not have a positive opinion of their most recent teacher. Results are shown in Table 21. These researchers did not believe the teacher was a good match for the project, and they felt that the teacher interfered with scientific progress. It is important to note that one of these researchers had had positive experiences with Polar TREC teachers in previous years.

Table 21. Researcher Assessment of the Polar TREC Teacher's Role.

	Count	Strongly Disagree	Disagree	Agree	Strongly Agree
I met with the teacher before the expedition.	27	7.41%	25.9%	25.9%	40.7%
The teacher and I had a clear understanding of what work the teacher would perform before leaving on the expedition.	27	0.0%	0.0%	55.6%	44.4%
In the field, the teacher mainly preformed menial tasks.	27	18.5%	59.3%	14.8%	7.4%
The teacher helped with data collection independently.	26	15.4%	38.5%	30.8%	15.4%
The teacher helped with data collection closely supervised.	25	4.0%	16.0%	64.0%	16.0%
The teacher was the main PR/outreach for the expedition.	27	3.7%	22.2%	51.9%	22.2%
The teacher pitched in to help however needed in the field.	27	3.7%	3.7%	25.9%	66.7%
The teacher was prepared physically for the demands of fieldwork.	27	0.0%	7.4%	44.4%	48.3%
The teacher was prepared academically for the demands of the project.	27	3.7%	14.8%	37.0%	44.4%
The teacher was a valuable member of the research team.	27	11.1%	3.7%	22.2%	63.0%
The teacher was a good match for my project.	27	11.1%	0.0%	25.9%	63.0%
The teacher was a quick learner.	27	11.1%	7.4%	18.5%	63.0%
The teacher learned to think like a scientist.	26	11.5%	19.2%	34.6%	34.6%
The teacher interfered with progress.	27	66.7%	22.2%	0.0%	11.1%

Twenty-three of the researchers provided a response to "Please describe the teacher's role in your project." Almost half (11) mentioned the teacher as "team member." Eleven said the teacher's duties included, "data collection" and nine also said the teacher was the "outreach specialist" for their projects. The following comments are illustrative.

- *[Our Teacher] was an invaluable part of my research team. He helped in all aspects of field work--sometimes this meant menial tasks, others times more involved data collection. I try to perform all tasks as a crew, and he was right in line with this team-work mentality. In addition to collection data, we worked closely together to understand and review all data that were collected. After a full field day, he spent his evenings on outreach, and as a result, the outreach component of my research program has been strongly bolstered by his work.*
- *As mentioned previously, my teacher actively helped prep equipment and deploy our stations in the field. He picked-up things very quickly and anticipated the next items that needed to be done. His help was invaluable in this sense. He also spent a lot of time putting together videos and other outreach materials to convey what we were doing to the public.*
- *We planned for her to be fully participatory as a field researcher. However she was a very slow learner and did not pay attention to details, making her a danger to herself and others in the field. So we switched her to more familiar work, in a more controlled setting, and kept everyone safe.*
- *The teacher performed a wide range of geological field tasks and participated in sampling discussions and decisions. The teacher became quite expert at many of the daily scientific tasks involved in the fieldwork.*

- *…he was 100% involved in all field activities and really pitched in on far more than his fair share. He was fantastic to have in the field with us.*

Understanding of K-12 Education

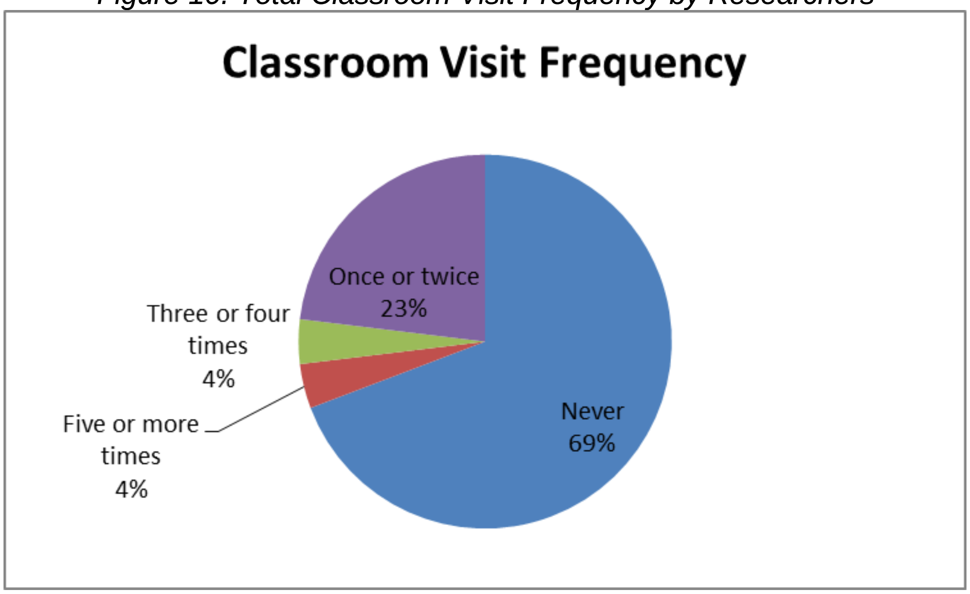
All respondents agreed that the *PolarTREC* experience gave them a better understanding of teachers' knowledge of science (Table 22). Most (>85%) also thought they had a better understanding of 1) translating science to the K-12 classroom, 2) the job of a teacher; 3)what students do or do not know about science; 4) student engagement or interest in science; and 5) how to explain their work to a young audience. Only 52% of the researchers better understood testing and curriculum requirements after the *PolarTREC* experience.

Table 22. Researcher Understanding of K-12 Education after PolarTREC.

Because of my *PolarTREC* experience I have a better understanding of:	**Count**	**Strongly disagree**	**Disagree**	**Agree**	**Strongly Agree**
Translating science to the K-12 classroom.	27	0.0%	7.4%	59.3%	33.3%
The job of a teacher.	27	0.0%	11.1%	55.6%	33.3%
What students do or do not know about science.	27	0.0%	14.8%	70.4%	14.8%
Testing and curriculum requirements.	27	3.7%	44.4%	44.4%	7.4%
Student engagement or interest in science.	27	0.0%	3.7%	77.8%	18.5%
Teacher's knowledge of science.	27	0.0%	0.0%	59.3%	40.7%
How to explain my work to a young audience.	27	0.0%	14.8%	63.0%	22.2%

Two-thirds of the responding researchers met their teacher before the expedition. It was most common for teachers to visit the researcher's labs and/or institutions, rather researchers visiting classrooms, as teachers were encouraged to become more familiar with the science project while preparing for expedition. Thirty-one percent of researchers reported visiting the classrooms at least once. Sixty-nine percent of respondents reported never visiting the teacher's classroom (Figure 10).

Figure 10. Total Classroom Visit Frequency by Researchers



Nineteen respondents commented on what *PolarTREC* taught them about K-12 education. Even though only 52% reported a better understanding of curriculum requirements, a third of respondents commented about their increased understanding. The following comments are illustrative.

- *There is strong adherence to standards and established curricula. It seems difficult to incorporate new dimensions into what is taught at many schools.*
- *I have gotten a better sense of how to "break-down" complicated topics so that children can understand them.*
- *That the standards that are driving K-12 education are very irrelevant to learning or any real STEM progress for students.*
- *The tremendous time challenges and classroom management issues teacher face. The teachers are also have many people they must respond to---their students, parents, colleagues, and administrators. They also have to worry about standards and testing.*
- *That we should appreciate our good teachers! Reinforced my belief that the science teachers we have are good communicators with their audience and that I am not!*

PolarTREC Expanding Researchers' Science Outreach

All respondents but one agreed that participating in *PolarTREC* expanded their project outreach and reached a K-12 audience which otherwise would not have been included. Most (>85%) agreed that *PolarTREC* enhanced outreach through technology and helped articulate the project to the public. Results are presented in Table 23.

Table 23. PolarTREC's Role in Project Outreach

	Count	Strongly Disagree	Disagree	Agree	Strongly Agree
PolarTREC expanded my outreach on this project.	27	0.0%	3.7%	29.6%	66.7%
PolarTREC helped articulate my project to the public.	27	0.0%	11.1%	33.3%	55.6%
PolarTREC reached a K-12 audience that otherwise wouldn't have been included in outreach.	27	0.0%	3.7%	40.7%	55.6%
PolarTREC enhanced my outreach through technology (websites, blogs, etc.).	27	0.0%	7.4%	44.4%	48.2%

Feedback on Program Improvement

When asked for suggestions to improve *PolarTREC*, 21 researchers responded and 10 said *PolarTREC* was doing a great job. The suggestions included:

- *Nothing critical - the whole experience worked very well for me.*
- *Having more contact with the teacher and classroom prior to the expedition would be great. And of course post-expedition, I feel that it's super important to keep the professional relationship going (as well as the personal one!). Sometimes it's hard to keep the big goals that you developed in the field going once everyone returns to their 'real lives.' Any way to facilitate that in order to keep these collaborations going for years to come is helpful. Continued funding to attend conferences together, visit each other's schools, etc. are some ways that PolarTREC is already encouraging long lasting collaboration.*
- *Great program. I'd encourage researchers to visit the classrooms before and after the field work.*
- *Honestly I would like to do PolarTREC if there was a good match, but I do not want to apply and then be given a bad match. I would suggest that projects be listed as potential and then if someone fits the project, then they do it. For me the most important aspect would be to meet the teacher before agreeing to take them on and for the teacher*

to be from the same region (within 1-3 hours' drive) so that we can forge a lasting relationship.

- *I think having opportunities to teachers to stay connected after their experiences is important. That is beyond the scope of the PolarTREC project but I think is essential for building on the tremendous experiences, expertise, and relationships that PolarTREC provides.*

Continued Collaboration

ARCUS was also interested in understanding whether researchers maintained collaborative relationships with the *PolarTREC* teacher with whom they were matched or other teachers as a result of their *PolarTREC* experiences. To measure this question, recent and past *PolarTREC* researchers were surveyed about their continued collaboration with K-12 teachers in the summer of 2014. Results are shown in Table 24. More than 90% of responding researchers 1) maintain regular communication with a teacher and 64% maintained regular communication with their *PolarTREC* teacher and 2) continue to learn about K-12 education. In the last year, more than 50% of respondents 1) worked on improving their own teaching skills, 2) visited in a K-12 classroom, 3) supplied data to a teacher for use with K-12 students, 4) worked with a teacher to develop K-12 curriculum, and/or 5) worked with a museum, library or other non-school institution to share research. Forty-five percent of respondents 1) included funding for a K-12 teacher in a proposal, 2) had a teacher visit their institution and/or 3) worked with a K-12 teacher to develop experiments for students. None of the responding researchers had published a paper with a teacher in the last year.

Table 24. Continued Researcher Collaboration with K-12 Teachers.

In the past year, have you	**Count**	**No, not this year.**	**Yes, with both my *PolarTREC* teacher and another educator.**	**Yes, with another K-12 educator**	**Yes, with my *PolarTREC* teacher**	**Total Yes**
Maintained regular email/phone communication with a teacher?	11	9.1%	27.3%	0.0%	63.6%	90.9%
Continued to learn about K-12 education?	11	9.1%	36.4%	18.2%	36.4%	90.9%
Worked on improving your own teaching skills?	11	27.3%	36.4%	9.1%	27.3%	72.7%
Visited in a K-12 classroom?	11	36.4%	18.2%	27.3%	18.2%	63.6%
Supplied data to a teacher for use with K-12 students?	11	36.4%	18.2%	9.1%	36.4%	63.6%
Worked with a teacher to develop K-12 curriculum?	11	45.5%	0.0%	9.1%	45.5%	54.6%
Worked with a museum, library or other non-school institution to share your research?	11	45.5%	0.0%	45.5%	9.1%	54.6%
Included funding for a K-12 teacher in a proposal?	11	54.6%	18.2%	18.2%	9.1%	45.5%
Had a teacher visit you at your institution?	11	54.6%	9.1%	18.2%	18.2%	45.5%
Worked with a K-12 teacher to develop experiments for students?	11	54.6%	18.2%	9.1%	18.2%	45.5%
Presented at a conference with a K-12 teacher?	11	63.6%	18.2%	0.0%	18.2%	36.5%
Mentored a K-12 student?	11	63.6%	9.1%	9.1%	18.2%	36.4%
Had K-12 students work on your research?	11	72.7%	0.0%	18.2%	9.1%	27.3%
Published a paper with a K-12 teacher?	11	100.0%	0.0%	0.0%	0.0%	0.0%

Section 7: *PolarTREC* Learning Resources Users' Survey Results

The *PolarTREC* Learning Community includes past and present program participants as well as the public. Educational resources are available through virtual platforms on the *PolarTREC* website such as the Learning Resources Database and the Virtual Base Camp. This website is the main venue for dissemination of *PolarTREC* experiences and products for the educator, student, researcher, and public audience. To assess the user satisfaction with this tool, an online survey was developed and disseminated and data was collected from November 15, 2010 to June 30, 2014.

Sample Size

During this time period, 222 individuals completed the web feedback survey. Fifty-nine percent (114) of respondents were female and 41% (77) were male. The highest numbers of respondents were students (37%) and teachers (29%). Table 25 below shows the breakdown of all respondents' affiliations.

Table 25. Learning Resources User Survey, Respondents' Affiliations

Answer Options	Count	Response Percent
K-12 Teacher	50	26.2%
Post-Secondary Teacher	2	1.1%
Informal Educator	5	2.6%
Student	70	36.7%
School Administrator	6	3.1%
School Support Staff	6	3.1%
Researcher	11	5.8%
Media	4	2.1%
General Public	37	19.4%

The age range of respondents varied from age six to 60 and older. Most respondents were in the six to 18 range (38%) or the over 40 range (47%). Only 14% of respondents were in the 19 to 39 age range. A more detailed breakdown follows in Table 26 below.

Table 26. Learning Resources User Survey, Respondents' Age

Answer Options	Count	Response Percent
6-12	35	17.4%
13-14	21	10.5%
15-18	21	10.5%
19-25	8	4.0%
26-29	7	3.5%
30-39	14	7.0%
40-49	25	12.4%
50-59	31	15.4%
60+	39	19.4%

Ethnicity of respondents was predominately Caucasian (55%). More than 19% of respondents did not respond to this question. Table 27 below shows this breakdown.

Table 27. Learning Resources User Survey, Respondents' Ethnicity

Answer Options	Count	Response Percent
Caucasian	105	54.7%
African American	10	5.2%
American Indian/Alaska Native	4	2.1%
Asian	7	3.7%
Native Hawaiian/other Pacific Islander	1	0.5%
Hispanic/Latino	16	8.3%
More than one race	12	6.3%
"I do not wish to respond"	37	19.3%

Forty-seven percent of respondents said this was their first visit to the site. Twenty-three percent of respondents visited site daily; 20% visited weekly and 6% monthly. Another 16% visited occasionally. Table 28 lists the visit frequency.

Table 28. Learning Resources User Survey, Respondents' Visit Number

Answer Options	Count	Response Percent
This is my first visit	91	46.9%
Occasionally	32	16.5%
Monthly	6	3.1%
Weekly	20	10.3%
Daily	45	23.2%

Results

More than 50% of respondents were "extremely satisfied" with 1) the overall impression of the site; 2) the accessibility of information and 3) quality of information. Thirty-nine percent of respondents were "extremely satisfied" with their ability to navigate within the site. Table 29 shows the complete results.

Table 29. Learning Resources User Survey, Respondents' Satisfaction with Site

Answer Options	Extremely Dissatisfied	Dissatisfied	Satisfied	Extremely Satisfied	No Opinion
Your overall impression of our site	8.1%	1.2%	31.4%	52.3%	7.0%
Ability to navigate within our site	7.5%	5.2%	41.6%	39.3%	6.4%
Accessibility of information	7.7%	9.5%	32.0%	53.3%	4.1%
Quality of information	9.4%	1.8%	21.6%	62.6%	4.7%
Ability to download information from our site	6.4%	1.8%	24.6%	33.3%	33.9%

When asked to comment on website performance, 40 people responded. Sixteen of them complemented *PolarTREC* on a nice website. The following are illustrative:

- *A more advanced "Ask the Team" options. Sending photos would be fun for teachers' classrooms.*
- *I have so enjoyed and been enriched by John Woods's journal entries, along with the great photos and the videos. They are filled with clear information and pictures that have helped me understand the project and gain insight into the importance of the work being done. The photos, especially, have given me an appreciation for the great amount*

of physical work involved. I wish I had had a science teacher like John when I was in school. I would not have dreaded those classes as I did. Most importantly, I would have learned something and enjoyed the learning process. But, as they say, it is never too late.

- *I would like you to put videos so I can see what are the activities in each project*
- *It is difficult to find all journal entries if a person has many. Also the timeline seems to be cut off, difficult to see*
- *Love being able to check in on my teacher when he is in the field...wish I was there too!*

Reasons for visiting the site varied. Most respondents, 58%, wanted to follow or read journals. Twenty-four respondents wrote in “other.” Six of the respondents were doing a school project and 9 of them were following a specific teacher or person that they knew (Table 30).

Table 30. Learning Resources User Survey, Reasons for Visiting the Site

Answer Options	**Count**	**Response Percent**
Follow or read journals	83	58.9%
Just browsing	35	24.8%
View photo gallery	31	22.0%
Access article	24	17.0%
Post question(s)	20	14.2%
Find learning resources	18	12.8%
Participate in a live event or PolarConnect	12	8.5%
View video file	11	7.8%
Find lesson	10	7.1%
Listen to audio file	9	6.2%
Apply to *PolarTREC* program	7	5.0%
Join *PolarTREC* listserve	7	5.0%

When asked if they were able to find the information they were looking for, 53% said that if they were looking for specific information and were able to find it easily and 23% were just browsing (Table 31).

Table 31. Learning Resources User Survey, Did Respondents Find Information?

Answer Options	**Count**	**Response Percent**
Yes, easily	89	53.0%
Yes, but it took some effort	19	11.3%
Only part of it	6	3.6%
No	15	8.9%
I was just browsing	39	23.2%

When asked how respondents used the *PolarTREC* information that they were looking for in an open ended question, 60 people responded. Many of them (28%) were going to use it in a school project either as a student or a teacher. Twenty-five percent of respondents were just looking for general knowledge or interest and 32% were tracking a specific *PolarTREC* teacher that they knew.

When asked if the information they found met their expectations, 50% of respondents found that the *PolarTREC* information met their expectations very well and 27% found that the information exceeded their expectations (Table 32).

Table 32. Learning Resources User Survey, Information Met Expectations?

Answer Options	Count	Response Percent
Not at all	10	6.3%
Fairly well	27	16.9%
Very well	80	50.0%
Exceeded my expectations	43	26.9%

When asked how likely respondents were to visit the site again, more than 60% said they were extremely likely to do so (Table 33).

Table 33. Learning Resources User Survey, Visit Again?

Answer Options	Count	Response Percent
Extremely likely	12	7.6%
Likely	6	3.8%
Unlikely	44	27.9%
Extremely unlikely	96	60.8%

Section 8: *PolarTREC* Alumni Survey Results

Finally, to track long-term impacts and changes in instruction, collaboration with researchers, and collaboration with other teachers, *PolarTREC* alumni were surveyed annually. The survey included five scales:

1) Continued use of the *PolarTREC* experience in the classroom,
2) Continued use of teaching techniques learned from the *PolarTREC* program,
3) Continued inclusion of polar science content in the teacher's lessons,
4) Continued involvement with researchers
5) Continued *PolarTREC* outreach

To measure the reliability of the scales to measure long-term impacts of *PolarTREC*, a Cronbach's alpha coefficient was calculated for each scale using SPSS. Table 34 shows the Cronbach's Alpha calculated for each scale. For all of the scales, except outreach, the Cronbach's alpha was greater than 0.7; evidence that the scale items measure the underlying construct (George and Mallery, 2003).

Table 34. PolarTREC Alumni Survey Scale Reliability Analysis

Scale	Items in Scale	Cronbach's Alpha	N
Use of *PolarTREC* Experience	6	.893	160
Use of *PolarTREC* Teaching Techniques	8	.943	161
Use of Polar Science Content	29	.960	150
Work with Researchers	12	.840	153
Outreach	4	.634	156

Sample Size

PolarTREC alumni were surveyed in the springs of 2011, 2012, 2013 and 2014. Table 35 shows the distribution of years the respondents participated in *PolarTREC* and the total number respondents per year.

Table 35. Alumni Survey Respondents by year they participated in PolarTREC

PolarTREC **Participation Year**	**2011 Alumni Survey**	**2012 Alumni Survey**	**2013 Alumni Survey**	**2014 Alumni Survey**
2007-2008	12	11	9	5
2008-2009	14	11	11	8
2009-2010	17	9	10	10
2010-2011	-	9	6	5
2011-2012	-	-	7	5
2012-2013	-	-	1	7
Grand Total	43	40	44	40

Most survey respondents were middle and secondary school teachers. Twenty-two percent of those who answered the survey more than one year, changed their profession, half of them from teacher to administrator or coordinator and a third of them to PhD student. Professions listed under "other" included: college instructor, NOAA Einstein Fellow, PhD graduate student, informal educator, museum educator, retail shop owner, zoo outreach coordinator, STEM coordinator, and environmental education teacher K-12.

Changes Over Years

There was very little change in the average scale scores for any of the Alumni Survey scale scores, strongly indicating that teachers continue to draw on their *PolarTREC* experience over time. Table 36 below illustrates the average scale scores by years since the respondent's *PolarTREC* experience.

Table 36. Alumni Survey Scale Scores by Years since Participation

Item	**Years since *PolarTREC* experience**					
	2 years (n=39)	**3 years (n=33)**	**4 years (n=37)**	**5 years (n=32)**	**6 years (n=16)**	**7 years (n=5)**
Use of *PolarTREC* Experience	2.96	3.06	2.99	2.89	2.85	3.16
Use of *PolarTREC* Teaching Techniques	3.51	3.56	3.54	3.52	3.42	3.93
Polar Science content	2.69	2.78	2.74	2.73	2.75	2.98
Work with Researchers	1.37	1.30	1.30	1.33	1.45	1.39
Outreach	1.69	1.58	1.56	1.56	1.41	1.31
Note: For the first three constructs (use of *PolarTREC* experience, use of *PolarTREC* teaching techniques, Polar science content), the response range was 1 to 4 with values closer to 4 more positive. The last 2 constructs (work with researchers and outreach) response range from 1 to 2 with 2 being more positive.						

Below is a detailed description of the results of each scale, starting with continued use of the *PolarTREC* experience, followed by use of *PolarTREC* teaching techniques, science content, science research, and outreach.

Use of *PolarTREC* Experiences in the Classroom

Table 37 shows that seven years after their first experience with *PolarTREC*, respondents continued to report "more than occasionally" 1) drawing on anecdotal experiences from their *PolarTREC* expedition; 2) integrating technology learned from *PolarTREC* in the classroom; 3) showing videos or pictures from the *PolarTREC* expedition to students and 4) developing science lessons that directly relate to Polar research. Further, there is not a decrease in the frequency respondents report using their *PolarTREC* lessons based on how many years it has been since their *PolarTREC* experience. Lessons from the *PolarTREC* website, data from the *PolarTREC* researcher, and collaborating with researcher to develop lessons were done least frequently.

Table 37. Alumni Respondent's use of PolarTREC Experiences in Current Lessons

Item	Years since *PolarTREC* experience					
	2 years (n=39)	**3 years (n=33)**	**4 years (n=37)**	**5 years (n=32)**	**6 years (n=16)**	**7 years (n=5)**
Draw on anecdotal experiences that I had during my *PolarTREC* expedition	3.72	3.82	3.76	3.69	3.50	3.80
Integrate technology you learned about during *PolarTREC* into my classroom instruction.	3.31	3.45	3.49	3.22	3.19	3.60
Show videos/pictures from my *PolarTREC* experience to my students	3.38	3.61	3.30	3.13	2.88	3.60
Develop science lessons that make use of the polar science processes	3.15	3.31	3.27	3.19	3.38	3.20
Develop science lessons that directly relate to Polar research	3.13	3.18	3.27	3.00	3.19	3.40
Show videos/pictures posted on the *PolarTREC* website by other teachers to my students	2.95	2.94	2.76	2.72	2.38	3.00
Use *PolarTREC* researchers' data with my students	2.28	2.48	2.62	2.53	2.44	2.60
Collaborate with *PolarTREC* or other researchers to develop lessons/activities	2.31	2.39	2.24	2.28	2.50	2.80
Use lessons posted on the *PolarTREC* website	2.38	2.36	2.17	2.19	2.25	2.40

Note: The numbers are the values assigned to the Likert scale where "never" is equal to 1, "rarely is equal to 2, "occasionally" is equal to 3, and "frequently" is equal to 4. The closer the average of a group of respondents is to four, the more frequently that activity takes place.

Use of *PolarTREC* Teaching Techniques

PolarTREC Alumni teachers also continue guiding their students in the scientific process many years after their expedition. Teachers increasingly continued to "more than occasionally" help students 1) develop hypotheses and scientific questions, 2) interpret and evaluate day, and 3) determine what evidence would be most useful to answer their scientific questions. Teachers were least likely to require students to make results of their investigations public. There was not a decrease in frequency respondents reported using any of the activities over time. Table 38 illustrates the frequency *PolarTREC* Alumni report using science teaching techniques by the number of years since their *PolarTREC* experience.

Table 38. PolarTREC Alumni Use of Science Teaching Techniques

Item	**Years since *PolarTREC* Experience**					
	2 years (n=39)	**3 years (n=33)**	**4 years (n=37)**	**5 years (n=32)**	**6 years (n=16)**	**7 years (n=5)**
Help students develop hypotheses and scientific questions.	3.68	3.82	3.70	3.72	3.69	4.00
Help students interpret and evaluate data.	3.68	3.70	3.76	3.69	3.56	4.00
Help students determine what evidence would be most useful to answer their scientific questions.	3.66	3.70	3.65	3.69	3.38	4.00
Require students to collect data to answer their scientific questions.	3.58	3.70	3.70	3.63	3.50	4.00
Require students to communicate and justify their explanations.	3.66	3.66	3.57	3.56	3.50	4.00
Require students to think about other reasonable explanations that can be derived from the evidence presented.	3.55	3.55	3.62	3.59	3.44	4.00
Guide students in the connection of their results to the big ideas or powerful explanatory models of science.	3.61	3.48	3.51	3.50	3.56	3.80
Require students to make the results of their investigations public.	2.68	2.85	2.84	2.78	2.75	3.60
Note: The numbers are the values assigned to the Likert scale where "never" is equal to 1, "rarely is equal to 2, "occasionally" is equal to 3, and "frequently" is equal to 4. The closer the average of a group of respondents is to four, the more frequently that activity takes place.						

Use of Polar Science Content

The frequency that respondents reported covering topics related to polar science did not decrease as the years since the *PolarTREC* experience increased (Table 39).

Table 39. PolarTREC Alumni Frequency of Science Topic Discussed

	Years since *PolarTREC* Experience					
Item	**2 years (n=39)**	**3 years (n=33)**	**4 years (n=37)**	**5 years (n=32)**	**6 years (n=16)**	**7 years (n=5)**
Scientific research equipment/tools	3.54	3.52	3.56	3.50	3.60	3.75
Climate change in the Arctic or Antarctic	3.36	3.48	3.35	3.26	3.07	3.40
Polar climate	3.28	3.36	3.22	3.26	3.07	3.20
Human impacts on the polar regions	3.28	3.15	3.22	3.29	3.07	3.40
Understanding environmental changes in the polar regions	3.15	3.24	3.16	3.29	2.80	3.25
Glaciers	3.10	3.09	3.14	3.00	3.20	3.00
Polar weather	3.10	3.12	3.08	3.03	3.00	3.00
Sea ice	2.97	3.06	3.08	2.94	3.07	3.25
Ice caps	3.05	3.00	3.05	2.93	3.07	2.80
Snow	2.89	3.09	2.92	2.94	3.20	3.00
The job of a polar scientist	3.08	3.09	2.95	2.94	2.60	3.00
Ocean currents	2.77	2.94	3.05	2.94	3.33	3.20
Oceanography	2.64	2.76	2.92	2.84	3.33	3.40
Marine wildlife	2.69	2.79	2.92	2.94	3.27	2.60
Living conditions in the polar regions	2.77	2.79	2.62	2.74	2.60	3.20
Sediments	2.44	2.76	2.84	2.74	2.93	3.00
Adaptations to life in extreme cold and prolonged darkness	2.61	2.76	2.62	2.81	2.87	3.00
Polar travel/transport (ships, planes, snowmobiles, etc.)	2.69	2.67	2.54	2.58	2.27	2.80
Past polar environments and life forms	2.56	2.70	2.43	2.53	2.40	3.40
Remote communications	2.28	2.48	2.49	2.65	2.40	3.20
Polar animal and plant interactions	2.45	2.48	2.43	2.35	2.47	2.80
Tundra permafrost	2.34	2.42	2.51	2.35	2.33	2.80
People in the polar regions	2.38	2.36	2.35	2.26	2.33	3.00
Tundra wildlife	2.15	2.38	2.30	2.35	2.27	2.40
Bathymetry	2.21	2.30	2.22	2.19	2.67	2.80
Native people of the Arctic	2.18	2.18	2.22	2.23	2.27	2.80
Tundra plants	2.05	2.24	2.08	2.19	2.20	2.40
Tundra trees and shrubs	2.03	2.21	2.08	2.19	2.13	2.40
Tundra rivers and lakes	1.95	2.21	2.05	2.00	2.07	2.40
Note: The numbers are the values assigned to the Likert scale where “never” is equal to 1, “rarely is equal to 2, “occasionally” is equal to 3, and “frequently” is equal to 4. The closer the average of a group of respondents is to four, the more frequently that activity takes place.						

Changes in Teaching

Most alumni respondents reported significant changes to their teaching as a result of their *PolarTREC* experiences. The most common way that respondent's teaching has changed is that concepts are now taught in the context of global issues and students are now collecting and/or analyzing real deal data as they are learning. Table 40 lists the changes reported.

Table 40. Reported Changes to Teaching

Theme	Count	Percent of Reponses
Science fits into the world/climate & global issues	70	44.3%
Using real data/doing real science	65	41.1%
More credibility/ I am a research scientist/first-hand experience	42	26.6%
More inquiry methods	40	25.3%
Talking to researchers/professional connections	36	22.8%
I have more knowledge	19	12.0%
I use more technology- websites, blogging, cameras, robotics kits	13	8.2%
Inspiration	13	8.2%
New lesson ideas/more teaching resources	12	7.6%
I teach new techniques/skills	6	3.8%
Enthusiasm and interest in Polar Science	6	3.8%
Unspecific "use" of experience	6	3.8%
Currently not teaching	3	1.9%
Note: Many responses expressed more than one idea, so the total of the percentages is more than 100%.		

The following responses are illustrative of the themes listed above:

- *It has made my teaching come more alive and interactive. I definitely make more real-world connections with my subjects and try to make the concepts more relevant to my students' daily lives*
- *Before my PolarTREC experience I inspired my students to like science by doing fun activities in class and teaching them interesting facts. The problem was that I was teaching them to like science, but I was not inspiring them to be future scientists. Since my PolarTREC experience I have inspired my students by getting them to think like scientists by teaching them to ask questions and be users and collectors of data. My students now not only think of me as being a scientist but they also think of themselves as being scientists.*
- *It is truly hard to express all of the ways that PolarTREC has changed my teaching after 7- 8 years. Most recently I have been taking students to international science conferences. Because of my involvement with Teacher Researcher Experiences my students have taken on the term Students of Teacher of Researcher Experiences - So Tre's. They present posters communicating to science the value of partnering teachers with researchers in order to share that message. Because of PolarTREC I am a firm of believer of bringing scientists and teachers together. I am hosting a workshop in a few weeks during my time off, because I believe in these relationships- because of my initial interactions with PolarTREC. I now teach marine science and find myself continually mentioning things that I learned during my PolarTREC experience, my arctic experience and all of my conferences. My teaching utilizes more technology and "real" science (both experiences and data). My students and I have greatly benefitted from PolarTREC!*

Work with Researchers

Respondents also continued to work with researchers. More than half of respondents are still contacting their *PolarTREC* research team with questions, even six or seven years since their first *PolarTREC* experience. Table 41 illustrates the frequency *PolarTREC* Alumni report working with researchers by the number of years since their *PolarTREC* experience.

Table 41. Respondent's Continued Interaction with PolarTREC Researchers

Item	Years since *PolarTREC* Experience					
	2 years (n=39)	3 years (n=33)	4 years (n=37)	5 years (n=32)	6 years (n=16)	7 years (n=5)
Contacted your *PolarTREC* research team or other researchers with questions - *PolarTREC* Researchers	1.74	1.67	1.57	1.68	1.86	1.60
Maintained regular email/phone communication with your *PolarTREC* researcher or other researchers - *PolarTREC* Researchers	1.74	1.55	1.57	1.52	1.86	1.40
Received real data from your *PolarTREC* researcher or other researchers for student work - *PolarTREC* Researchers	1.42	1.47	1.38	1.42	1.43	1.25
Visited your *PolarTREC* researcher or other researchers at his or her university/institute - *PolarTREC* Researchers	1.38	1.33	1.30	1.33	1.64	1.80
Had your students contact your *PolarTREC* research team or other researchers with questions - *PolarTREC* Researchers	1.38	1.27	1.35	1.35	1.43	1.40
Had your *PolarTREC* researcher or other researchers visit your classroom - *PolarTREC* Researchers	1.33	1.30	1.24	1.27	1.57	1.80
Held conference calls or skyped with my *PolarTREC* researchers or other researchers. - *PolarTREC* Researchers	1.37	1.28	1.30	1.29	1.36	1.40
Worked with your *PolarTREC* researcher or other researcher to develop experiments for your students - *PolarTREC* Researchers	1.37	1.24	1.22	1.35	1.57	1.20
Had your *PolarTREC* researcher or other researcher include you in another research project - *PolarTREC* Researchers	1.24	1.25	1.27	1.32	1.29	1.20
Presented papers with your *PolarTREC* researcher/research team or other researchers - *PolarTREC* Researchers	1.23	1.18	1.22	1.23	1.21	1.40
Sent students to work with researchers - *PolarTREC* Researchers	1.08	1.03	1.08	1.06	1.14	1.00
Had students attend conferences with researchers - *PolarTREC* Researchers	1.00	1.09	1.08	1.06	1.07	1.20
Note: For these questions there was a choice between "no" (equals 1) or "yes" (equals 2.). The closer the average of a group of respondents is to two, the more frequently that activity takes place.						

In the comment section of this question, respondents had an opportunity to list ways they still have contact with researchers. The following are illustrative:

- *Some of our students were email "pen pals" with my PolarTREC research team and shared their findings with the class.*

- *Student wrote 200 polar scientist letters. Collaborated with native villages that the scientists work with.*
- *Students created scientific poster with researcher based on analyzing samples I helped to retrieve while in Antarctica*
- *Borrowed equipment for snow science field trip. Had webinars with other scientists with online classes that I teach.*
- *Presented at NSTA with PolarTREC researcher. Developed on-going collaborative relationship for PolarTREC project outreach. Visited NSF and had NSF scientists present to my school about polar research.*

Further Outreach

The majority of teachers continued *PolarTREC* outreach after their expedition. No matter how many years it had been since the expedition, more than half of respondents made presentations to faculty and students related to their *PolarTREC* experience within the past year. Fewer than half of the respondents reported that they received local press coverage of their outreach activity. Table 42 illustrates the frequency *PolarTREC* Alumni report participating in outreach by the number of years since their *PolarTREC* experience.

Table 42. Respondent's Continued Polar TREC Outreach

Item	**Years since *PolarTREC* Experience**					
	2 years (n=39)	**3 years (n=33)**	**4 years (n=37)**	**5 years (n=32)**	**6 years (n=16)**	**7 years (n=5)**
Made presentations to faculty and students related to your *PolarTREC* experience	1.90	1.84	1.81	1.74	1.64	1.75
Made presentations to community groups related to your *PolarTREC* experience	1.82	1.64	1.59	1.58	1.50	1.25
Made presentations at educational conferences related to your *PolarTREC* experience	1.59	1.45	1.56	1.58	1.46	1.25
Received local press coverage related to your *PolarTREC* experience	1.44	1.39	1.27	1.35	1.07	1.00
Note: For these questions there was a choice between "no" (equals 1) or "yes" (equals 2.). The closer the average of a group of respondents is to two, the more frequently that activity takes place.						

"Other" outreach included:

- photo posted in national magazine
- Presented nationally and internationally on *PolarTREC* experience
- Shared *PolarTREC* experience with other archaeologists
- As the 2011 New York Teacher of the Year, I have been a keynote and workshop presenter over 20 times this year and I usually share my *PolarTREC* experiences and videos as part of my presentations.
- Developing Antarctic related eMissions with a local organization. These will be similar to the simulated missions that the Challenger Centers provide to classrooms across the country.
- Made presentations at the USA Science & Engineering Festival
- Student teams presented their research projects to the school board.

Significance

When asked what the most significant part of the *PolarTREC* experience was, Alumni often mentioned that the "real science" experience gave them credibility as a teacher and/or the connections they made with researchers and other teachers continue to be valuable. Table 43 lists the most common changes.

Table 43. Significant Aspects of the PolarTREC Experience

Theme	Count	Percent of Responses
Authentic Science Experience/real scientist	69	45.4%
People Connections	60	39.5%
Better, more engaging teacher	35	23.0%
Travel	19	12.5%
Better Science Content Knowledge	19	12.5%
Ongoing experience	16	10.5%
More confidence	14	9.2%
Global View	8	5.3%
Education Leader	4	2.6%
Learning new technology	1	0.7%
Note: Many responses expressed more than one idea, so the total of the percentages is more than 100%.		

The following are comments illustrative of the themes listed in Table 43 above:

- *The world has opened up. I have connected with educators who really set the standard of the profession. I am inspired by them and the researchers who work with us to expand my own knowledge and skills as an educator. The PolarTREC experience for me has become much more than the 8.5 weeks I spent in Antarctica. The continued connection with the organization and alumni has led to even more growth for me professionally*
- *At this point, I feel my PolarTREC experience has not been utilized by me as a teacher as I'd hoped. However, it is an incredible program that is influencing my teaching, my collaboration locally, and my input at the district level. Hopefully we will move from a test-driven curriculum/teaching methods soon. My PolarTREC experience can help. It may not be immediate. So the most significant part of my experience is its long-lasting influence to my teaching.*
- *I love being able to draw on my experiences in Antarctica to share with students about how scientists think and do their work. It allows me to frame conversations through the lens of a scientist and help them frame their own learning in that context. "I'm training you to be a scientist, so in order to be a scientist, you need to have these skills."*
- *The most significant part of my experience has been how my experience has changed how I teach. My PolarTREC experience has also given me the confidence to step up and be a teacher leader in my school and in the education community. After my experience I went on to be a Albert Einstein Distinguished Educator Fellow, I have made several presentations at state, regional, national, and international conferences, I have been asked to be a reviewer for many programs, journals, and education websites, and I have risen to be a leader in my school district.*
- *The collaboration and networking with polar researchers and PolarTREC continued programs has been the most significant component for me. PolarTREC has taken a one month summer field experience and parlayed it into over four years of classroom enhancement for me and my students.*

Section 9: Case Study Summaries

Annual and summative evaluation results confirmed that *PolarTREC* teachers did in fact increase their knowledge and their confidence to STEM content and practices to their students. However, it is expected that any significant change in teaching practice that results from a professional development program will occur over the long-term (Dresner and Worley, 2006). The case study was designed to help ARCUS better understand the long-term impact of *PolarTREC* on participating teachers. The case study specifically focused on how participants continued to use the science knowledge they gained, their relationship with the research team, and the *PolarTREC* support network provided by CARE. In addition, the case study includes student pre/post data.

Sample

The case study sample used a purposive sample to *PolarTREC* alumni. Participants were selected based on three criteria: 1) successful participation in *PolarTREC*; 2) ongoing involvement in *PolarTREC*; and 3) interest and willingness to be a case study participant. Eight *PolarTREC* alumni participated in the case study. The case study sample, while representing the "best" *PolarTREC* teachers is otherwise quite diverse. It represents teachers from Florida to Hawaii, from small private schools with 10 students to a classroom to large urban schools with 40 students per classroom, and a broad range of ethnicities and economic backgrounds.

Teacher	Years Teaching	School Type	Education	State	Previous TRE	Research Location
Elizabeth	2008	Urban Private Catholic K-12 School	BS Zoology; MA Education	Florida	no	Arctic
Jillian	2008/2013	Urban Public Middle School	BS Forestry/Education; MA Bilingual Education	Arizona	yes	Arctic
Jacquelyn	2008/2012	Urban Community College	BS Geology; MS Geology	California	no	Antarctic
Lollie	2007	Urban Private Middle School	BA Spanish, Romantic Languages, English; MA Science Teaching	Texas	no	Antarctic
Maggie	2007	Urban Public Middle School	BS Biology; MS Curriculum and Instruction	Hawaii	yes	Arctic
Mary	2007	Urban Public Middle School	BS Biology, Chemistry; MS Biology and Geography	California	no	Arctic
Deanna	2009	Urban Public Elementary School	BS Chemistry/Math; MA Counseling	Maryland	no	Arctic
Tim	2009	Urban Private Middle and High School	BS Natural Sciences; MS Teaching Geosciences	North Carolina	no	Arctic

Methods

Data collection for the case study includes: 1) An in-depth interview that followed a written protocol, but also included informal spontaneous discussions with the case study teachers during the site visit; 2) observation of the case study teaching his/her students and review of lessons; 3) pre/post survey of students interest and knowledge of polar regions (results are included in Section 10).

Results

Major Themes

Three major themes emerged from the case study. First, case study teachers brought their experiences back to their students in countless ways, but most importantly in their increased use of STEM practices. For some of the case study teachers, this use represented an increase from past practices prior to their *PolarTREC* experience. For others use of STEM practices represented new instructional practices. These STEM practices included providing real world research activities for the class (Dresner and Worley, 2006), modeling the behavior of professional scientists (Dresner and Worley, 2006), enabling students to collect and analyze real-world data (Dresner and Worley, 2006).

Second, *PolarTREC* positioned case study teachers to collaborate, network and train other teachers. Adoption of this leadership role has been confirmed in other research about the impacts of TRE experiences on teachers (Dresner & Worley, 2006; Timm, 2012). Case study teachers took on numerous leadership roles such as, resources provider -- sharing instructional resources about the polar regions and STEM practices with their colleagues; instructional specialist – planning lessons in partnership with other teachers; curriculum specialist -- ; mentor – catalyst for change; learner – focusing on continual improvement, lifelong learning, and using what they learned to help all students achieve (Harrison and Killion, 2007).

Third, while others (Dresner and Worley, 2006) have found continued work with scientists tends to be low four to five years after a TRE experience, *PolarTREC* case study teachers continued to work closely with scientists in a range of ways. Several case study teachers joined their researchers on another field experience. Other case study teachers coordinated ongoing interaction between their classrooms and research teams. For example, one case study teacher's students collected data for an ongoing research project. Another case study teacher's students interacted via skype with researchers as mentors throughout the school year. Another case study teacher's students analyzed a researcher's data. Another case study teacher wrote several grants with her *PolarTREC* research team and teachers in Georgia and Barrow, Alaska to compare water pollution in three areas – the Gulf of Mexico, the Atlantic Ocean, and Arctic Ocean.

Individual Case Study Summaries

Maggie: It is not difficult to find a recurring theme in the life and career of Maggie, a middle school science teacher in Makawao, Hawaii. Maggie, a National Board Certified Teacher, believes in the immediacy and relevancy of science in everyday life and the application of scientific inquiry and research to fully investigate and understand our world. Her career reflects a commitment to lifelong learning, creativity in science and passionate exploration of science with her students.

Prior to her participation as a *PolarTREC* teacher on a 2007 Bering Sea Ecosystem research expedition, Maggie was no stranger to polar science or scientific research. In 2005 she spent ten days with research scientists and educators on a boat in the Northwest Hawaiian Islands. That same year, she traveled to Antarctica on an eco-voyage, attending daily science lectures relevant to the Antarctic habitat.

These experiences – watching scientists conduct research in Hawaii and listening to scientific presentations in the Antarctic – led Maggie to re-define science from a hypothesis-driven method of inquiry to a dynamic and creative process of data-driven exploration, and it also piqued her interest in polar science and the influence of the changing polar regions on the rest of the earth, particularly the Hawaiian Islands. Combined with her background in science and curriculum development, these experiences became a boon to her students and the polar science world at large.

Maggie believes that science helps people understand the world and their relationship to it, and as an educator she is driven by student learning. "*I am an individual that is very student centered. So what drives me is my student learning…. The big goal is for them to understand themselves, their relationship to others and the world around them through learning science*."

Her teaching philosophy necessitates student involvement and engages students through multiple learning styles and hands-on, data-driven scientific inquiry. A teacher since 1979, Maggie realizes that a typical science curriculum generates little enthusiasm among her students. She adapts her teaching to better meet the needs of her students, and she continues educating herself as well: "*I learn, learn, learn, learn, learn…. I need to learn my content, and I need to learn how to teach, because the students we are getting nowadays are not the way I was brought up or born. They are a totally different generation that learned in a whole different way, and we need to address that*."

Specifically, she uses state and national science standards to develop curricula that are relevant and meaningful to her students in Hawaii, students who are extremely familiar with the environment in which they live but who do not come from a strong culture of reading or western-world thinking. "*I try to use the standards… to create a curriculum which is specific for my indigenous, spaghetti ball of wild, rascal kids that look at the world in a totally different way than any other kinds of students I've ever had the wonderful chance to teach*." Maggie makes science real for students by relating it to their lives and the environment around them.

Bringing PolarTREC Experiences Back to Students
For Maggie, incorporating her *PolarTREC* experience and polar science into the classroom requires creating connections between her students and the polar regions. While other teachers may find it difficult to connect their own students' experiences with the arctic, Maggie can find a direct connection through the animals that migrate between Hawaii and Alaska. She states,

"The connection with the Arctic is with our creatures that go to areas outside of Hawaii to eat because they have to, because we don't have food here. And then they bring the nutrient back and they poop in the ocean, and they have babies and they lose all their weight, and all of that is here. But our connection then with the poles is through these creatures. The reason they exist is because they're getting their nutrients from further north….

"I wanted them to understand about global climate change, and the basis of that is the phytoplankton. And we don't have phytoplankton here, but we have the results of the photosynthesis in these creatures that have to go far away to get their food and then bring it back here. So that is that connection. It's extremely important that they realize global climate change isn't affecting them here in Maui that it's going to affect the poles first. And so Hawaii

will be especially impacted because our Hawaiian animals go up there to eat. So this is extremely important."

Maggie also brings her connection with the Alaska Native representative on board her research vessel to the classroom. The Alaska Native representative provided her with an entirely different focus and an enhanced understanding of the critical role of polar research in the lives of indigenous populations. This experience propelled her to create the research collaboration between her Hawaiian Native students and the Alaska Native students she met living in the Pribilof Islands. "*So that was my hook, because that's an indigenous group. And my kids are indigenous. And the more I talked to him and I saw pictures of his family, and I met the kids on the Pribilof Islands, the more I realized my kids have got to meet these kids and learn about them. So thank you PolarTREC*."

<u>*Using STEM Practices*</u>

Maggie has been teaching science by inquiry since 2002-2003, but her experiences with *PolarTREC* changed the way she looked at science and presented science to her students. As the scientists in her midst conducted research, she observed that they were not tied to a specific sequence of data collection events but were constantly adjusting to cope with unexpected phenomena.

For example, when scientists found that their samples were being contaminated by the research vessel, they changed their data collection protocols to eliminate the source of contamination. Maggie realized that scientific procedure is not static and involves creativity to solve unexpected problems. *"I found out that I really had to redo what I was doing with the kids. If they were going to learn how science was done, I had to add an element of creativity to it…. So did it change the way that I teach my kids? Oh yeah. And it verified for me that if I don't teach them to be creative, outside of the box thinkers, I am doing a disservice to science…."*

Additionally, Maggie recognized the tremendous impact of student-led data collection on their individual investment in science. *"The only way my kids here are going to get into it is if they take their own data…. I believe that in order for science to be meaningful, it has to be their data."* She initiated a research project at Waihe'e Land Reserve on global climate change and coordinated this project to compare results with an Alaskan sister school that she visited while on her *PolarTREC* expedition.

Maggie refers to another change in her instruction resulting from her *PolarTREC* experience as the "Cal influence." Cal was a scientist on the RV Healy, the research vessel on which Maggie spent six weeks through *PolarTREC*, who explained that replication in science is a necessity. "*The Cal influence. Cal was a scientist on the boat [*who said that*] three is a magic number. Why do you take your data in threes? Because it's a magic number,' he'd say. And he told me the reason why is because then you're able to see if there's an abnormality. So three is a magic number. So ever since I've come back from PolarTREC, three is a magic number. And then they have to average, average, average, average. And that is different. Rather than once, that's the data, they do it three times, and that's a really big deal."* Maggie now requires that students repeat data collection and testing at least three times.

A final impact of *PolarTREC* on Maggie' teaching relates to the very same research she conducted on her *PolarTREC* expedition and also goes back to her realization years earlier that she could not provide her students with concrete answers about the impact of global climate change on their island. As the data from her 2007 trip becomes available, Maggie shares with students her experience collecting the data. She then helps them relate the research to life on their own island through the common sea and land animals that Hawaii shares with Alaska. "*So I could look at it then and tell the kids I was there and this is the research….. And so they're able to get more information now, so I can bring that into the picture. The kids are able to connect to it because we have these animals that have to go up there to get their food and then come back."* Maggie' experience with *PolarTREC* and the data she collected helps students personalize the science of climate change and concretely link what they're learning to the immediate world around them.

For example, Maggie has always wanted to connect her students and their life in the tropics to the people of Alaska and the issue of global climate change, but she did not previously have the data to do so. Now that the data is becoming available, students are able to see immediate connections to Hawaii through the relation between many animals whose habitat includes both the tropics and arctic and the livelihood of the Alaska Native people.

Maggie states, "*I'm able to use this to connect the kids to the Alaskan people, and I've always wanted to do this in a logical way through learning through the food chain. So the students are going to learn about the food chain at the poles… then to look at the seasonality involved with it. And that how the seasons then change the indigenous, what they eat and how important that is…. And then to compare it with them, do the seasons here impact what you eat? No. You can always go fishing in [Hawaii]. And then to look at how the poles are going to affect life here, well if it's going be affecting our creatures that go up there, then is it going to be affecting Hawaii? Yes."*

"I can use these concepts to look at getting the data and connecting it to the students, and then [have] them connecting it to another indigenous people. And they have connections with those people because I have connections with those people. And my students through the research in Waihe'e, they know about our connections."

<u>Leadership, Networking, and Collaboration with other Teachers</u>
Maggie has used her professional connections forged through *PolarTREC* to create further collaborations between herself and other teachers. The project that she began at the Waihe'e Land Reserve involves data collection and data sharing in conjunction with a sister school in Alaska that Maggie visited during her *PolarTREC* expedition. This collaboration was a direct result of her *PolarTREC* experience, and ties into her goal of introducing her students to Alaska's ecosystem and Alaska's indigenous people and recognizing the natural linkages between Hawaii and Alaska.

Maggie finds the collaboration with her Alaskan counterpart and sister school extremely exciting and a tremendous opportunity for her students, yet she has found that her assumptions about data collection are regularly challenged. "*And so in this most recent collaboration that I've been doing with Tonya on the [Pribilofs]…. We have protocols, and they're able to take basic data. But now it's, well, the ocean is frozen now, so we can't take the data…. I didn't really think about that. I said, "Four times a year we'll exchange data." And Tonya's like, "Oh? Okay. Well it's freezing.""*"

<u>Collaboration with Scientists</u>
Maggie had been collaborating with scientists well before her participation in *PolarTREC*, and she uses this collaboration as another tool to make science real for her students. From collaboration with scientists at the Hawaiian Humpback Whale National Sanctuary, to those studying the composition of Maui beach sand, to researchers working with monk seals, Maggie is not intimidated in scientific circles and instead works hard to get scientists in her classroom.

Maggie actually saw one of her roles in *PolarTREC* as that of interpreter for the science community. *"I saw my scientists on PolarTREC as many of them were not able to communicate their ideas to kids, and I'd see what they're doing and I'd say, "Hmm, what you're doing is really this." And they're like, "Yeah, that's it." And so I saw me as like being able to interpret what they do."*

PolarTREC scientists also encouraged Maggie to start research projects with her own students. She notes that one of the *PolarTREC* researchers told her it was important for her students to create their own research project to fully engage them. "*He said, "Well you really got to have the kids make their own plankton then, because if you get them then with their own plankton and they go down to the beach, you're going to get them." So it's like, well how do I do that? Well you got to write a grant. Okay, well here I go. I write a grant. So I wrote a grant to Seymour and then I got this money. And then we started going to Waihe'e. And then they made their nets. And I mean it was all because of that that I did these things and got off my rear, because the kids needed to do it.*"

Elizabeth: Though diverse and far from repetitive, the forty-four journal entries from Elizabeth's 2008 Arctic Tundra Dynamics *PolarTREC* expedition share one common thread: each begins with modern song lyrics directly or indirectly relevant to the journal entries themselves. Green Day, The Beatles, Hank Williams, Crash Test Dummies – they all became a part of the expedition and rest as evidence of Elizabeth' unique talent for translating science into everyday language and attracting youth and non-scientists alike to polar research.

It's a gift that teachers and researchers alike appreciate immensely. Elizabeth, a 2008 William T. Dwyer Award winner for Excellence in Education in Palm Beach County, Florida, and middle school science teacher at a private Catholic School in Florida, has been the keynote speaker for a symposium of 600 science teachers, was featured on the local National Public Radio station in Palm Beach, and has received extensive coverage through local and national newspapers.

Throughout it all, Elizabeth has communicated with her students and the general public, weaving personal tales and observations among scientific research and discovery, gaining an audience of budding scientists and supporters. Her motto, "*We're all connected. We're all affected,*" can be, in essence, the theme of her life and career in science and in the broader world.

Elizabeth sees her role as a middle school science teacher as that of a "facilitator of learning." While some teachers may see students as empty vessels into which they pump knowledge, Elizabeth hopes that students come to her class with a desire to learn, and she encourages students to take responsibility for their learning while she facilitates through instruction, direction and encouragement.

She explains, *"My objective with them is for them to learn and for them to engage in how to learn and for them to take responsibility for learning and so I just want to be the person around to go, 'This is how you can do it. And here are some things that I have to tell you and this is how you can learn it and this is how you can become engaged in it'.*"

In practice, this means that rather than directly answering a student's question, she leads the student through the thought process that will provide him/her with the answer. She involves other students or classroom resources to further engage the student and to explore the science surrounding the question. She states, "*Just because I'm an adult doesn't mean that I'm smarter* *than* [them]…. *So* [I ask] *them questions to prompt them to figure things out on their own, learn how to be a learner*." Elizabeth believes that her job is to get kids excited about learning.

<u>*Bringing PolarTREC Experiences Back to Students*</u>
Despite the fact that Elizabeth was already an acclaimed teacher and had previously participated in a two-week research trip studying sharks in the Pacific Ocean, Elizabeth admitted that her participation in the *PolarTREC* expedition changed the way in which she teaches. "*It's changed my teaching and made an impact*," she says. "*I've learned so much*."

One of the first things that Elizabeth changed as a result of *PolarTREC* was her language. Rather than referring to the basis for scientific research as a problem, she's realized that it's simply a question. "*For years… introduction for the scientific method… was* [called] *a problem*. *But… problem implies problem. It's a question. And so we changed it and now from all these years on and still in the book, it'll say "problem" but we're like, "No, it's a question." We're asking a question; we're finding an answer.*"

She's also become much more adept at using technology to communicate with her students and others. *"I've learned so much from them (her research trips), so I mean, from technology, like, I'm so much more comfortable with using technology because of them and making videos with my students and things that I gained from their journaling."* Elizabeth integrates technology into her teaching at a level that she previously couldn't.

Elizabeth was also surprised to learn that there are no concrete answers in the field of climate change science. The *"first whole thing that I learned that I was really happy about nobody knows, nobody knows, nobody knows, nobody knows. They can make all these hypotheses, they don't know…. I really thought they did and I really thought things were more definitive." She had expected solid explanations, but realized that climate change science is relatively new and definitely not static."*

But her knowledge grew exponentially, and she was able to carry it back to her students. *"I learned about carbon and the change of carbon and carbon dioxide and things that I didn't know that could kind of bring it home. And so, of course, whenever we talk about photosynthesis and respiration I have a whole different addition to talk about a little bit with them."*

Additionally, Elizabeth states that her *PolarTREC* experience has taught her that no variables can be discounted, a fact that she teaches to her students. "*I learned that they have so many variables. Like I try to teach my students even with the birding, simple, one variable, don't be ridiculous here*."

<u>*Using STEM Practices*</u>
As a result of her *PolarTREC* experience, Elizabeth insists that students practice real science to produce real data that can impact their own communities. The use of science practices in her classroom has "*been amped up because of* [*PolarTREC*]." No longer do students grow bread mold in Petri dishes. Instead, they are "*doing real science. And knowing that* [they're] *connected to something is huge*."

Elizabeth has exposed her students to community-based research, research that involves collaboration between scientists and community members. Her students are working with one of the researchers from Elizabeth' *PolarTREC* expedition, a professor at neighboring Florida International University, to collect data on tree growth by taking dendrometer readings in the mangrove forest behind the school. "*What excites me most right now is, because of that, you* *know, working with Steve with the dendrometers is phenomenal because it's real science that we're really sending him data to. It really matters; it's not just bread mold*." She follows up with a thought that it matters to the students more than traditional science instruction. "*I think it makes a big difference to them because it's real. It's real*."

Another difference in her science instruction goes back to a discovery that other *PolarTREC* teachers have made as well: having a hypothesis is not the driving force behind scientific discovery. "*If we have a known hypothesis… that doesn't matter, either, and I think… we all know that, it doesn't matter what you get as long as you get something, an answer, and finish…. There's not just a hypothesis, there's the known hypothesis, there's an alternative hypothesis and so my knowledge has built through the years*."

Elizabeth' students benefit from her increased knowledge of technology and her community-based research focus, both attributed to her *PolarTREC* experiences. Her classes have begun a birding project in collaboration with The Cornell Lab of Ornithology and are gathering and entering their own data. "*Not only are they doing their birding project, but they're submitting it. So Cornell keeps that and they publish it or whatever they want to do with it….* [Without *PolarTREC*] *I really wouldn't have a use for the Excel program. I mean, a computer teacher would really take care of that, but we're putting our dendrometer readers – readings on it*."

PolarTREC has led Elizabeth to teach her students about the many forms of scientific inquiry. *"There's observational questions or researcher questions or experimental or things that they can get from the internet or versus using variables, so it's developed through the years…. With and without the help of PolarTREC, but almost everything that I've done in the past, I mean, since PolarTREC, there's a connection."*

Students now learn from Elizabeth that the discussion is often as important as the conclusion in the scientific process. "*Now we have different hypotheses and again, I've extended my scientific method over there because we have, instead of just methods, or instead of just results, we have results and analysis. And instead of just conclusion, we have conclusion and discussion…. So a lot of these kids that did the bird sleuth, you'll notice in their discussion, hopefully, there should be about a paragraph of, "This worked and this didn't and I would recommend doing this. If I ever did it again, I would add this, this and this. It worked great, there were no problems," or whatever."*

"So they're bringing it – they're integrating it a little bit more and bringing other ideas from other projects, maybe that other students have done via their peer reviewing and mixing it up some…. And so even if we didn't use Excel prior to PolarTREC, [we would conclude] so there's your chart and that's that. Well, now, analysis is, what does the chart say? And it can be very basic. We've seen acceleration in whatever. It doesn't matter. But they have to explain, and it's not just a subtitle."

Finally, Elizabeth tries to connect her students with the broader sense of the scientific method as a constant in the world around them. She states, "*They should be able to take what they've gotten, and they do, because we do that a lot, labs and things in class. Take what they learn from that and they should be able to replicate it with anything, you know, basically using these principles and understanding the difference between an experimental question versus observational or whatever*."

She goes on to say that her intent is to teach them scientific inquiry and how to apply the scientific method rather than specific facts from a textbook. "*I'd rather focus on the scientific* *method and make that a stronger thing for them rather than them knowing the difference between a flesh eater and a seed eater.*"

Collaboration with Scientists

Elizabeth' collaboration with scientists increased dramatically after her *PolarTREC* experience, a fact aided by her school's relative proximity to the researchers with whom she worked. "*It's wonderful having Steve here, I mean, that's just such a bonus…. he came up in the very beginning and we talked a bunch and he sent me all kinds of research and things for me to overview before I went on my expedition and then he came up and met the kids*."
She goes on to say that her collaboration with the scientists in *PolarTREC* created a drive within her to incorporate their knowledge and their experience into her students' lives. "*Then when we came back, I wanted to do the dendrometers, thinking the kids could actually make them. So I went to Miami and met with him and he sat for hours with me and showed me how to make them*."

She notes that her collaboration with scientists has not been limited to those researchers with whom she worked and believes that her *PolarTREC* experience has enabled her to approach other scientists, like a polar researcher from Fairbanks. "H*e doesn't know me, but I was a PolarTREC teacher and so he was able to answer their questions and so having that connection with them has been great*."

Furthermore, she isn't intimidated by researchers and feels comfortable approaching them. *"So any time we need something, I need to know something, he is available and he will get back to me relatively quick. I've learned that I can't ask him five questions at once. One at a time is perfect; maybe two and I might get one of them answered."*

Elizabeth has passed along her confidence and her collaborative approach to her students, encouraging them to participate in activities that are not typically offered to middle school students. Her students submitted a poster for the 2010 State of the Arctic, writing the abstract and designing it. "*They submitted an abstract for, you know, a collegiate level conference, which is crazy. And really, they wrote a lot of it, we just – I just tweaked it and we submitted it together*."

She required full participation in the conference and expected her students to attend lectures and present their poster publicly. "*I had a whole packet for them, so they had to attend certain lectures, they could pick some if they wanted to go to them, they had to interview scientists, they had to present their poster at the poster session…. They had to talk. They had to collect posters, you know, how they have the little ones that you can take? So they had to collect sample posters and they had to write on it, was it a good poster or not? Why or why not?*"
Elizabeth treated her students as scientists and expected them to collaborate with their scientific peers. She finishes by saying, "*I think the scientists got a kick out of seeing kids there in their little uniforms and then they had their PolarTREC in there with T-shirts and I know I sent a bunch of swag, so they had stuff, you know?*"

Elizabeth also found, through her collaboration with scientists, that she was very good at bringing science into everyday lives, acting as public relations between the scientific community and others who don't spend their lives immersed in research. "*I just got so hooked on journaling and stuff like that during the PolarTREC stuff, so I had already had a connection with these magazines, or these newspapers, and then I brought the research – I mean, the girl from the Palm Beach Post, who's a friend, a personal friend, but she came and, but he's like, "You're good at the PR part and spreading the word and getting interviews with us and everything*."

Her communication skills led to further collaborations with the researchers she met through *PolarTREC*, including a research trip to Costa Rica. "*We were sitting in Barrow* (she and her research team)*, we were in the lab and he's like, "You're good at this." Like, the PR part, because I really, I – before PolarTREC and before NOAA, I have a real strong drive for that and writing…. I just got so hooked on journaling and stuff like that during the PolarTREC stuff…. So he said, "I'd like to duplicate what you're doing here in the whole website, you mean, the PolarTREC aspect of it as well." And he said, "I would like to write you into a grant to go to Costa Rica"…. hopefully I will have the opportunity to do a substantial amount and work with them in the field, but I'm also going be writing and Skyping and probably do a webinar*."

Deanna: Deanna is the science teacher at an ethnically and racially diverse elementary school in Maryland, 30 minutes outside of Washington DC. She teaches grades 3, 4, and 5. She believes that learning, education has to be fun and wants students to be engaged and learning in the world around them. Passionate about land and water, Deanna is inspired to make sure that "no child is left inside". Hands on, real science is her priority. Deanna's love of learning and the outdoors meld together in her professional and personal life. She is dedicated as a teacher and as a citizen to better understand and protect the environment for positive impacts on individuals, the community, and the health of our environment

Bringing PolarTREC Experiences Back to Students

For Deanna her PolarTREC experience recharged her, giving her the energy she needed to expand her teaching practices. PolarTREC, she said, *"gave me a whole new energy outlook to everything. I wrote grants, I had always been writing grants. I had gotten lots and lots of little grants here and there, but after [PolarTREC] I wrote two grants -- we got $137,000 to transform the outside of the classroom into an outdoor classroom. I think I attribute that to just being recharged, you know from science that happens right now back into the classroom. "*

The grants she wrote helped to transform a part of the school yard into an outdoor classroom. She led a year-long process of planning with students and teachers meeting regularly with a landscape architect in series of charrettes. During the planning meetings, they discussed ideas about *"what is the best way to learn and where would you like to learn and what does it look like?"* Some of the students helped test the soil to see what plants would grow best in the area, others helped plan the wetlands. Because the students played an integral role in installing and maintaining the outside classrooms, they feel that they "own" the outdoor space.

The school restored much of the school land, transforming it from a barren monoculture of grass into a thriving and largely self-sustaining wetland. They planted 4,000 wetland plants, created an upland forest areas and an arboretum by planting 500 native trees and shrubs, and established meadows, and rain gardens. Many teachers, in addition to Deanne use the outdoors to enhance student learning. For example, the physical education classes are held outside every day, weather permitting. As students are reading about seeds or frogs, they go outside and to find, compare, or collect different examples of what they are studying, including Marsh Hibiscus seeds or frogs and tadpoles in their natural habitat. According to Deanne, *"Education of the natural world has become more real and relevant because plant and animal life cycle studies are experienced in the outside classrooms."*

Another example of how the outdoor classroom is the partnership Deanne developed with the Science Museum. This *"five-week, school-wide inquiry-based investigation of our watershed that is infused with authentic STEM experiences. Starting with students' questions, students and* *teachers move through the process of inquiry. Community partners assist students with various parts of their projects. The process culminates in a final celebration as students display and communicate their findings to community members and other grade levels."*

Deanna also brought her PolarTREC experience back to students with the development of a Polar week for whole school. *"The teachers get a whole set of resources integrated in math and language arts, art, and even PE...we did all these different activities in the classrooms. The younger grades did polar animals, the fourth grade did a comparison between Antarctica and the Arctic."*

The county's new standards include climate change and Deanna is able to incorporate her PolarTREC experience in many ways. For example, 3rd graders answering questions like "if there were changes in the Arctic how would it affect the animals?" *And they gave numerous reasons, fabulous answers...and that type of rigorous thinking is just great to see happen."*

<u>Using STEM Practices</u>
Deanne has incorporated the STEM practices she learned into her classroom instruction in numerous ways. First, she tries to incorporate as much current research, what is happening in the world of science into the classroom every single day. *"Every day for the past couple of years, I have a clip of something that related to whatever the students were doing that was happening in real science."* Additionally, she has specifically changed the way she speaks about science data collection processes. *"I try to emphasize how the scientists use tools [to gather data]...trying to get the kids to think about the tools they need to collect data. And then when they make a claim they either have to prove it with evidence or change your claim based on the evidence."*

One particular data collection method she has integrated into her instruction is using cores. *"If it hadn't been for PolarTREC, [I wouldn't have used cores]. With my students, I went outside and took cores. They understand that animals and things go captured in the [cores] and we compared it to ocean cores looking at microfossils and the 4th grade did ice cores."* In addition, she has used the data collected during her PolarTREC experience. *"When I taught bathymetry, I used the bathymetry [information] i was able to pull off of the ship's instruments."*

Her new understanding of STEM practices also led her to participate in the Cornell University Mastodon Matrix Project. *The Mastodon Matrix Project was initiated in 2000 as a collaboration between PRI and the Dept. of Earth and Atmospheric Sciences at Cornell, to engage K-12 students and other members of the general public in actual scientific research via distribution of samples of mud "matrix" collected at these three excavation sites. Since 2000, the Mastodon Matrix Project has distributed more than 4000 samples of matrix to schools, classes and groups to 49 US states and four other countries. Sediment is divided into 1 kg samples and sent to groups who request them, along with general instructions which describe objects to sort from the matrix and activities connected with their interpretation. The open-ended nature of the directions encourages teachers and groups to tailor the activities to the age of the participants, their own curricula, the availability of resources and equipment, and the amount of time they could devote to the project. When done with the project, participants are then asked to return the sorted samples for cataloging and assessment*
(http://outreach.cornell.edu/programs/program_view.cfm?ProgramID=2381).

<u>Leadership, Networking, and Collaboration with Other Teachers</u>
Deanne's collaboration and partnerships have extended from her own county all the way to Savoonga Alaska where she partnered with the school's principal to share between the

schools. *"They sent us trinkets for our students and our students stent them stuff from Maryland. I actually visited the school when I was in the Bering Sea the first year, so I took a lot of stuff from J.C. Parks [my school] and made a video for them."*

Deanne has also taken on a major leadership role in her the Charles County Public Schools revising the elementary science curriculum. The county school system includes 21 elementary schools that will share science curriculum and lessons. Deanna was responsible for writing the lessons specifically focused on climate change.

<u>Relationship with Researchers</u>
From hatching, raising, and releasing yellow perch and horseshoe crabs to participating in a pilot sturgeon project, Deanna has continued to work closely with researchers from the State of Maryland Department of Natural Resources to the researchers with whom she traveled to the Bering and Chukchi Seas. She invited numerous researchers to her school for Polar week and they ran stations for the students. For example one researcher led an Arctic food chain activity, another had students taking ice cores, another presented about polar clothing. Her students -- 300 of them -- also wrote letters to polar scientists. At least 200 of the scientists wrote back to her students describing their research and including pictures and other materials to better describe their work.

Finally, in 2012 she was invited to participate in a second PolarTREC expedition to the Chukchi Sea. The team lived and worked from the United States Coast Guard Icebreaker Healy. The USCGC Healy is a research vessel designed to conduct a wide range of research activities and can break through 4 ½ feet of ice continuously. The team traveled to the Hanna Shoal, northwest of Barrow, Alaska in the Chukchi Sea, which may be a sensitive ecological system close to areas planned to be exploited for oil and gas exploration.

Tim: Although he grew up in several locations around the country, Tim has always felt most at home in the natural world. His persistent curiosity led to his undergraduate study of the natural sciences and art at Goshen College and recently he completed his M.S. in teaching geosciences through Mississippi State University. Whether using recent data for weather forecasting, seismograms for mapping plate tectonics, or making real-time observations with an Internet accessible radio telescope, Mr. Martin has a passion for bringing real time science into his Earth Science classroom at Greensboro Day School.

Tim traveled to Lake El'gygytgyn (pronounced el'geegitgin), located 100 km (62 miles) north of the Arctic Circle and 250 km (155 miles) inland from the Arctic Ocean (67.5° N and 172° E) on the remote Chukchi Peninsula in the Russian Far East. This large lake measures 12 km (7.5 miles) wide and roughly 170 m (558 feet) deep. It is positioned on the continental divide between the Arctic Ocean and the Bering Sea in the middle of Anadyr Mountains. The team lived and worked out of a temporary camp located on the west shore of the frozen lake ice.

<u>*Bringing PolarTREC Experiences Back to Students and Using STEM Practices*</u>
Tim has brought his PolarTREC experience back to his students in countless ways, from sharing the hundreds of pictures he took while on his expedition to Lake El'gygytgyn to using the data collected during his expedition, to peppering his class with stories of his experiences. At the heart of the way he integrates his experience is to use the experience to illustrate the "how" of science. Tim's philosophy of education can be summed up in one sentence: *"my number one job is not necessarily to cram facts and figures, I want them to know how we know what we know."* And to go along with that, Tim believes it is essential to use real data and his PolarTREC experience cemented this idea. *"...Following my time at PolarTREC, I think a lot of*

the ideas are cemented as far as getting kids to [work with real data]. I've messed around with kids doing real data [collection] before, but its kink of pushed me [into thinking] this is not just a good thing to do, it's the right thing to do." And his experience gave him incentive to involve his students in more activities where they are using real data. For example, Tim has his students making isotherms and isobars and weather maps using National Weather Service data. *"We are doing real-time weather analysis, and so [the students] can check their homework against the weather channel to see if they did their homework right."*

Another STEM practice he implemented after his PolarTREC experience is use of GPS and topographical maps. *"I basically do a micro version of geocache day."*

Using photography to document observations and changes is also a STEM practices Tim has brought back to his classroom after his PolarTREC experience. *"We build a cloud identification guide. [I tell the students to] go out there and observe your surroundings and then document it. Take pictures of it. It is a little easier now because kids have phones [to use]. "*

Tim's students are also looking at sediment samples he collected at Lake El'gygytgyn. *"No one else has ever looked at these [sediment samples]. And so I have students prepare smear slides like we did in the field and they are the ones that put them under the microscope for the very first time and they are looking at them -- looking for whatever they can find - which is pretty fun."*

Collaboration with Scientists

Tim continued to collaborate closely with Julie Brigham-Grette and other K-12 teachers. Tim's students aren't the only ones benefitting from his PolarTREC experience. Since returning from Siberia, he's given myriad talks on how best to teach earth science to kids. Dr. Brigham-Grette, the PI on the Lake El'gygytgyn project, has created a communications and outreach role for Tim for that specific research.

Tim's network now includes colleagues who work around the world and who share his love of learning. He's become an advocate to "help science teachers get involved in real science," which is to say he's working to create and foster opportunities where educators immerse themselves in the world they teach about.

Tim and Brigham-Grette have worked together to create geoscience teacher workshops at the University of Massachusetts to teach other teachers how apply these lessons and activities in their own classrooms. Additionally, Tim and several of the first workshop participants presented this work at the 2015 National Science Teachers Association annual conference in Chicago.

Lollie: When the departure date for Lollie's November 2007 *PolarTREC* expedition to Antarctica drew near, the entire student body and teaching faculty at her small Texas K-8 school supported her with a school-wide countdown. Lollie found support in many other corners as well. A former student created a mural in the science lab featuring icebergs and penguins. The first grade class created a departure countdown poster using penguins diving into the sea to mark each passing day. And the school held a Black and White Day celebration to say good-bye, completed by the appearance of a dancing, mascot-like penguin.

Lollie's journal entries from her pre-departure days illustrate the level to which her colleagues, students, family and friends were engaged in the preparation for her trip. Besides her school connections, Lollie's supporters included an extensive collection of family and friends, and a friend and fellow teacher and her students in Michigan.

The amount of support that she received prior to and throughout her expedition is not unusual for Lollie, however, and in fact typifies the wide range of professional and collaborative partnerships that Lollie has cultivated throughout her life, her career and her experience with *PolarTREC*. Lollie champions collaboration and emerged from her Antarctic expedition with new partnerships and ideas that have provided unique opportunities for her students, for researchers, and for her own career.

As a teacher who teaches by example, Lollie is always asking questions. She interviewed all the members of her expedition team and the crew of the icebreaker Oden, her home during her trip to the Antarctic. She volunteered to help researchers in any capacity, simply because she wanted to learn as much as she could while surrounded by science professionals. Lollie believes that her role as a science teacher is to teach her students to "*ask questions, to want to learn*."

She uses a strategy of actively involving students in their learning. Following her philosophy, students need to develop *"ownership of their learning, and the best way to do that is to involve them in the process of planning their learning… getting them to ask questions that will guide their learning."* She believes that it is critical to give students a direction and *"get them actively involved in the process of that learning, whether it is through hands-on activity or researching or developing the game plan."*

Thus, students in her science classes are successful in their learning because they have the opportunity to control it. With guidance from her, they are the principal investigators in their scientific pursuits. She states, "*Probably one of the main reasons that they're so into it,*[is] *because it is their program. It is their research. It's their work. It is not, 'This is what you're going to do, and this is how you're going to do it.'*"

Student ownership of learning is a critical piece of Lollie's teaching philosophy. Students learn not only to develop their learning, but to take risks and learn from their mistakes. "*They learn by doing, but also* [by] *teaching them that you have to take some risk. Risk is good. You can't be afraid to fail. We make a lot of mistakes, but they learned from them, and that's a life skill that is so important for them to learn… that you're going make mistakes. That happens, but that's how you learn.*"

<u>*Bringing PolarTREC Experiences Back to Students*</u>
Lollie's *PolarTREC* experience didn't change her teaching philosophy as much as reinforce what she already practiced in her classroom. "*It didn't change my philosophy so much, but it expanded my content knowledge. I could not have taught a lot of the things that I'm teaching now without that experience. That experience was a catalyst.*"

She explains that *PolarTREC* set her off on an entirely new learning path, one in which she became the student again, learning about ocean science. This in turn, became a driver in her students' learning by inquiry. She states that she began raising "*questions in my own mind that I needed to get answered, which in turn leads to more questions and more questions*. *It exposed my children to, my classroom children, to new experiences that brought new questions. See, the whole thing about inquiry is questioning.*"

Lollie finds that her *PolarTREC* experience creates a terrific amount of interest among her students, interest that inspires learning. "*The thing about the PolarTREC thing was… everybody dreams about going to Antarctica. And I have kids saying all the time, "That's where* *we want to go." The fifth graders, right after that introduction that I gave them, that's the first thing they said was, 'Can we go there?'*"

The diverse amount of scientific activity that Lollie witnessed aboard the Oden also impacted her classroom activities. While she and her class researched the Antarctic and tried to anticipate the types of science that she would be observing and participating in, the experience was much more profound than she had anticipated. She states, "*Once I was on the boat watching what these people were doing, seeing the environment around me…. It was like a major light bulb turned on. 'The things you could do with this or that.'*"

She describes how the experience has enhanced her classroom instruction this way: *"It really brings it home to them, and the other part too is that working with all the different kinds of scientists; there was a great cross section. I mean we had people who were working on microbiology. We had people who studied water chemistry only; people who were studying the ice, people who were studying the air. So, there were so many different things that got me to thinking, 'Wow. This is a topic that is very underrepresented in middle school science. You learn a lot about the carbon cycles on land. You learn about the nitrogen cycles on land. So, everything has a focus, but it's all terrestrial.' Those are things that are invaluable for the kids to be able to experience, but the really good part is that … I can tell them what it's like, what it felt like, what it smelled like, what it tasted like on there and give them a real sense, that gives them a totally different aspect to it."*

The Antarctic expedition and the networks and partnerships that followed have dramatically increased Lollie's knowledge of polar science and that of her students. She's learned "*so many things about the geography, the ice dynamics, learning about the ice.... that's something I'm trying to get across to the fifth grade right now and every class that's been in fifth grade.*"

She relates how her research during the expedition taught her about the different kinds of ice and how she brought that knowledge back to her classroom. "*When I was learning how to do the ice observations on the ocean, I had no idea there were so many different kinds of ices. And it was such a wonderful feeling to be able to understand that, to see it, to be there and actually see it firsthand, and then to bring that back to the classroom.*"

Lollie learned firsthand about the equipment used in polar science as well. "*The other thing was learning about the CTD (*equipment to measure ocean Conductivity, Temperature and Depth)*. When I first went on the Oden, that was my first experience with any kind of marine technology or any kind of process. And then the other thing was the ice core, learning about the ice core. And I actually got to go on the ice with the ice team. So I learned about how they drill into the water. I learned about the brine channels in the ice.*"

<u>Using STEM Practices</u>

Lollie has incorporated her experience into the classroom by taking the students out of the classroom. A direct result of her *PolarTREC* experience, her middle school class collaborates with high school classes in Hinesville, Georgia and a middle school class in Barrow, Alaska to examine the human impact on global climate change through the ocean, in the Students Monitoring Ocean Response to Eutrophication (SMORE) project. Lollie's students monitor nutrient loads in freshwater sources and in coastal estuaries and share their data and results with each other and with mentor scientists to develop an understanding of locale-specific impacts on the global ocean.

The project involves Dr. Tish Yager from the University of Georgia and the lead principal investigator from Lollie's Antarctic *PolarTREC* expedition. Lollie conceived of the project as she attempted to integrate Dr. Yager's research on critical biogeochemical cycles into classroom curricula and educational outreach. A second researcher, Dr. Marc Frischer from the Skidaway Institute of Oceanography, became involved through contacts made when Lollie was invited to participate in a second *PolarTREC* expedition, this time to the Arctic in Alaska.

Lollie believes that involving her students in research that can be used to increase knowledge of climate change gives her students a realistic perspective of scientific research. She states, "*In school you learn, come up with a question, you make a hypothesis, you go through steps A, B and C and make a conclusion based on your experiment. And that's all well and fine, but I have learned over the years that the scientific process doesn't work that way…. I don't want them to walk away from the classroom thinking that in order to do a scientific investigation, I've got to follow steps A, B, C and D and then everything's going to be fine…. So by virtue of them following these scientists… they get to see that no matter what, no matter how many mistakes happen or no matter what things they didn't count on happen, that they're still able to get the job done.*"

She puts students in charge of their research, lets them make decisions about research methods and variables and then makes sure that they understand why they have made these decisions. For example, when selecting sampling points for the SMORE project, she questioned students on the sampling site selection. "*Some of* [the students] *said we should sample along the same point, because that way it's the same point. I want them to understand that that's why we should do it at the same spot. When oceanographers go out, that's why they make sure they mark their lat-longs. Now you can't always get to exact the same spot…. But you get as close as you can because you don't want environmental factors to change your readings. You want to get as close to the same water column as possible.*"

Leadership, Networking, and Collaboration with Other Teachers

Lollie's collaboration and partnerships are not restricted to scientists, however. As evidenced by the concept and collaboration inherent in the SMORE project, Lollie reaches out to many of the teachers who have been involved in *PolarTREC*. Their collaborations, however, are not limited to polar science, however. She states, "*I can't even begin to tell you how many PolarTREC teachers I regularly e-mail and said, "We're doing this or that. What do you have? Can you recommend a site?"…. We're always exchanging information back and forth that didn't always have to do with polar science. It could just be in astronomy. It could be on each science…. We've been able to compile quite a great database, and then I share that with other teachers, teachers at the school.*"

It's clear that these the networks excite Lollie and enhance her classroom instruction. She says, *"Networking is incredible. Then you expand from there. You have conferences, and somebody introduces you to somebody who is doing this, and it just keeps branching out and branching out. Networking is invaluable if you really want to do a good job at teaching because you have to change it."*

Collaboration with Scientists

Lollie has continued collaborating with scientists since her Antarctic expedition in many ways. She kept in contact with Dr. Yager and is included on research team emails. Dr. Yager also sends Lollie data and resources to use in her classroom. "*Every email she sends to her team, I get. And she'll send me things and say, "This is the data from so and so. See if you can use it or what you could do with it." She'll send me pictures. She'll send me links to stuff.*"

Her collaboration with Dr. Yager led to Lollie's involvement with other scientific research collaborations, such as the ANACONDAS project, a multi-disciplinary aquatic and marine science project along the Amazon River testing the hypothesis that climate and land-use driven modifications to river discharge and upriver carbon and nutrient concentrations and ratios will significantly impact carbon fluxes across the entire Amazon continuum, including the tropical open ocean. As the sole educator-researcher on the team, Lollie analyzes seawater samples for CO2 and measures respiration rates, as well as documents the ANACONDA project through an online blog. Her focus is to translate her research into science content that can be used in the classroom.

Lollie also participated as a member of the ArcticNitro team during a second *PolarTREC* expedition to Barrow, Alaska to sample the coastal waters of the Arctic Ocean to investigate how microbial creatures affect the productivity of a coastal Arctic ecosystem. It was through this project that she first encountered Dr. Frischer, who later, along with Dr. Yager, became involved in the SMORE project.

Her engagement with scientists has grown since her *PolarTREC* experience and is not limited to her *PolarTREC* contacts, however. She feels comfortable approaching scientists for information and ideas and has done so frequently. "*My robotics team was working on a project and I needed information…. I knew* [a researcher who] *had deployed one in Antarctica last year…. So I emailed him….* [and] *he answered and also gave us the name of someone else to contact. So we have those kind of working relationships.*"

She continues describing collaborations that have developed: *"[Another researcher] also had a real important project going in Antarctica [and] helped one of my students to develop an analogous experiment, something similar to what he was trying to do, something that she could do on the classroom level. So it's those kinds of relationships that we didn't have before…. I can even contact the Swedish scientists that worked with us and ask them questions. So everyone's really open about doing that, and that's made a big difference. That's a totally different type of partnership there. That's a true partnership."*

She concludes by stating that even without direct contact, her students feel invested in the science to which they are exposed. "*Even though* [Dr. Yager] *hasn't been to Houston, just by virtue of the fact that she's willing to teleconference with us, she talks to the kids, we've done interviews by phone with her. So I think I told you earlier that last year the students were calling her 'our scientist.'*"

Mary Anne: Listening to the audio recording of a large colony of little auks, created by science teacher Mary Anne during her *PolarTREC* research expedition to Greenland in 2007, one can easily imagine that the sounds of these small migratory seabirds was intended as a soothing CD to reduce stress or to conceal the ambient noise of city life. Yet for Mary Anne, a middle school teacher in California, obtaining the recording was not quite as relaxing as the end result.

As a member of a science team studying foraging conditions for little auks in the Greenland Sea, Mary Anne traversed three steep, sloped boulder fields on her daily trek to the field site. Crossing each of the boulder fields required a twenty minute exercise in balance and concentration, maneuvering over precariously perched rocks covered in lichen that became slippery when wet, a crossing made even more difficult while carrying a backpack filled with research supplies and a loaded rifle for potential polar bear encounters.

It was such a unique experience that Mary Anne presented both the sights, through photos and videos, and the sounds of her expedition. Her journals reflect a desire to provide her students with more than one way to explore science and scientific research. It's a method she's used for over twenty years as a means of engaging her students in scientific thought and process.

Mary Anne believes that students should be engaged in science and tries to find ways in which each student will begin to discover the world around them. She encourages her students to look beyond the textbooks to explore science in what's around them. She states, "*I want to engage them in science and have them realize that being part of the world is looking at it scientifically…. I want them to realize that they don't – everything that's out there is not known and they will have an opportunity to discover it.*"

<u>*Bringing PolarTREC Experiences Back to Students*</u>

Her experience with *PolarTREC* did not radically change Mary Anne's teaching philosophy. But it made her think about the history of science and the tools that were developed to unlock the scientific knowledge that we have. "*A lot of it has to do with developing new tools. So among other things, I've changed how we teach the history of scientific understanding, and I focus on the history of scientific understanding as based on the development of the tools to give us the information and how important it is to get the right tools.*"

This focus on tools lends itself to future scientific understanding because if new tools are developed, new scientific exploration will take place. "*As we get the tools we'll get greater understanding. So we've got to start inventing those tools, and we have to change our understanding of science based on new evidence that's developed, based partly on having new tools and new methods to do the research.*" Mary Anne's students are encouraged not only to explore their world and to develop the tools they need to do so, they are encouraged to change their understanding of the world based on what they discover.

"I want to teach kids that we have to change our understanding as we get new evidence. Good or bad, what we consider right or wrong… we need to base our understanding on scientifically gathered evidence. And if it changes and blows our theory out of the water, then it does, but we can't stop looking for evidence." As a result of *PolarTREC*, Mary Anne teaches the value of research and inquiry and looks for ways to support inquiry-driven science in her classroom. *"It [PolarTREC] got me to be a lot more involved in finding research-type lessons or opportunities,"* she states.

Implementing her teaching philosophy can be challenging when students are used to getting science from a textbook, but it excites students to be able to put together their own research projects or explore a science topic that involves current scientific research. Her students do "current science" every month, an opportunity to gather information on a current issue that is being explored in scientific circles. Mary Anne explains that her students find current scientific research in any scientific field and then discuss it. The topics are exciting to students and facilitate rich discussions. She explains:

"We have a discussion on new discoveries, things that people don't know, new medicine, new diseases, so the kids are starting to look at science all around them, and it's a lot of fun…. Global warming has been on the forefront a lot. Diseases are always something that is discussed. A lot of things on planets. The kids come with some really interesting things that they want to talk about that are cool, so we have fun doing that."

She also uses unique teaching methods that enable her students to understand science in different ways. She collaborates with Chico State University to present her students with current research in bacteriology, but she expands the study to go beyond simply looking at data and studying the names and meaning of bacteria. She creates hands on activities that reinforce what the students are learning. For example,

"We were just looking at classification of organisms and using binomial nomenclature and scientific terms. I'd found a nice little activity where there were shape creatures drawn, and the kids had to use Latin prefixes and terms to come up with names for them, fictitious names but they're based on features…. I realized it would be a lot more interesting if we made three-dimensional critters. So we made Play-Doh animals that had scientific names, and the kids then could start looking, dissecting the Latin terms and matching the scientific name to the critter based on features, which was really nice and engaging, but it had them start to pay more attention to where Latin and Greek prefixes and suffixes are in our language and the fact that they had that content knowledge that they didn't know."

Using STEM Practices

Mary Anne found that her *PolarTREC* experience reinforced the need for consistency and standardization, and she has used those lessons in her classroom. While on her *PolarTREC* expedition, her team was working in conjunction with two other teams in other locations. Communicating via satellite, "*they are testing the same thing within one day or two of each other. They are using the same equipment. They are standardizing all of their measurements, and I emphasized that to kids over and over.*"

She's teaching her students how to set up experiments, create variables and measure them. Her students now create their own data using research methods reinforced on the slopes of Greenland. In an experiment with pinto beans, her students had to subject their beans to some type of treatment. "*You know set up a variable and keep measuring it, and so that was doing a lot of measurements. And then after two weeks they had to come up with a conclusion – what had a positive or negative impact and what's your evidence.*"

The students create their own data and *"do an analysis. Like with our bean project, they had to write an analysis and a conclusion and make suggestions how they would change that project in the future. And everything that we gather information about we have to have the kids analyze it, or there's no meaning to it."* Mary Anne finds that students come up with a variety of conclusions and are more engaged as a result of detailing the experiments and variables themselves.

She encourages students to make the connection between their research and the broader science topic at hand. *"I guide them through a series of questions, detailed questions to have them think more thoroughly about whatever that investigation was…. The bean project was part of an introduction to cells…. I do one good size project for each unit. And the genetics project that we did the kids all ended up with different information and had to write different conclusions based on their results. But the analysis is a big focus of whatever we're doing."*

Collaboration with Scientists

Through the contacts she made during *PolarTREC*, Mary Anne realized the potential for engaging students in broad scientific concepts like climate change or evolution. She began using her contacts with scientists to enhance her students' understanding of the broader issues facing them. She finds that introducing her students to scientists offers them a glimpse into the reality of a career in science. She explains that *PolarTREC* "*showed me the value of linking* *students remotely with scientists, and the reason is to show them that scientists are real people. You know they have different sizes and shapes, and they're regular people that are interested in children, interested in my students. And they're able to explain how they got interested in that science, and it's giving kids a little window into another world so they're not feeling like that's so unrealistic, but maybe they can say I could do something like that.*"

As a result of her collaboration with *PolarTREC* researchers, Mary Anne has introduced her students to the concept of monitoring environment changes over time, involving them in time lapse observational photography. Through her *PolarTREC* experience, she was able to attend the Oslo Science Conference, specifically a workshop by James Balog, who is leading the Extreme Ice Survey, a long-term photography project that merges art and science to give a "visual voice" to the planet's changing ecosystems.

Mary Anne's students have begun their own time lapse project, where a group of students will pick *"one location at school that they'll position a camera, and every day at the beginning of the period they go take a picture and upload it." While she admits that having multiple photographers who use slightly different camera angles can cause problems in consistency, it has proven to be a project that offers students a broader perspective of change in their environment. In fact, "two of [her students] were able to turn it into wonderful little videos last year, and I presented that as part of the National Science Teachers Association…. It's a nice project that's getting kids to pay attention to their environment and subtle changes."*

Her collaboration with scientists has involved both *PolarTREC* and non-*PolarTREC* researchers, and Mary Anne tries to connect each scientist's research to activities in the classroom. For example, through her participation in the Oslo Science Conference, Mary Anne attended a climate summit conducted by Louise Huffman, the Education and Outreach Coordinator for Andrill, a multinational collaboration to recover stratigraphic records from the Antarctic margin. Mary Anne combined some of the lessons presented in the climate summit and used other lessons from *PolarTREC* teachers to create her own climate summit that had 16 stations that focused on different aspects of climate change. She explains,

"You know I had kids make windmills and then using a fan to look at windmill design and pulling up weights so they could show an alternative energy form. We had kilowatt meters to show that there are lots of places where energy is leaking out slowly and that if we turned off power cords we could reduce the energy consumption. And we looked at CO2 consumption per capita in different countries and who contributes the most and what can be done and things like that."

The summit led to a summer exhibition at the local museum and was written up in the local paper. It created enthusiasm among her students and the local community.

Another example is the collaboration she has with the lead researcher on her *PolarTREC* expedition, Ann Harding. Harding has connected with Mary Anne's students on several occasions through Skype and in-person. Mary Anne connected Harding to her own students and those who aren't her own classes. She explains that Harding can provide inspiration to those who find school challenging. "*Ann didn't graduate high school, went to a continuation school. So when she came down and visited with my classrooms we made sure to take her over to the continuation school and give presentations to them, and it was a real good insight for those students to say no this doesn't mean it's the end of the road for me.*"

Since her participation in *PolarTREC*, Pella-Harding believes that scientists should be in the classroom as much as possible. "I just have not thought about having scientists as part of my classroom experience until *PolarTREC*, and having Ann come I think probably really solidified that yeah the scientists should be in a classroom. There should be that transition. There should be that familiarity with both ends of things."

She goes on to say that it can be challenging to have scientists involved in the classroom or to take students to visit scientists because of the time constraints in schools. "*I've had scientists come a few times, and then like I said we went over to the bacteriology lab. But the drawback I'm finding is there's – you know we're under pressure to do our standards, and I'm having a few teachers say 'your kids are leaving our classrooms too much.' Because I can't do it in just one period, just during the science period.*"

Jacquelyn: With a scientific background in environmental and subsurface investigations in terrestrial and marine environments and experience working with Fortune 100 companies as an environmental consultant and petroleum geologist, Jacquelyn was professionally ready for her 2008 Antarctic expedition to the Dry Valleys to tackle the extraction and study of ice cores that provide a record of atmospheric and climatic change extending back for many millions of years.

Feeling physically and emotionally ready, however, was a different matter altogether. Faced with the realities of rustic camp life in one of the world's most extreme environments, Jacquelyn had to channel the "inner child" of her undergraduate life, one who could cope with rudimentary toilet facilities, tent accommodations in sub-zero temperatures, and a Thanksgiving dinner consisting of sliced turkey loaf wrapped and fried in bacon.

Jacquelyn could hardly have traveled farther from her home back in sunny, ultra-urban Los Angeles, where she left a warm 81°F to fly to a continent with an average summer temperature well below freezing. Yet summoning her inner child made all the difference for this Kansas native who not only succeeded as a member of the six-person research team but found herself invited back by the project's principal investigator for a second Antarctic research expedition in late fall 2012.

As an Assistant Professor and Chair of the Earth Science Department at a California community college, Jacquelyn teaches a diverse student body, including many pupils who are first generation college students. The challenges in teaching in the largest community college district in the nation, with 122,000 students, are great. She admits that the diversity of the students she teaches forces her to find ways to teach science despite language barriers and a wide range of skills. She addresses this by finding ways in which to teach her students to think scientifically despite which language they speak.

"It's hard to have one philosophy when you're at a diverse institution, first of all, because you have lots of different issues. The students don't fit into one… set of skills. They have language problems. So I guess my whole thing – right now my philosophy is to try and teach them to think scientifically in any language."

Jacquelyn assesses each student's abilities throughout her instruction and uses hands-on and inquiry-based methods to teach students how to explore each topic. *"I try to see where their skills are, you know, just try and see how* [I] *can reach them with inquiry-based science, and hands-on…. I want the students to sort of think for themselves and not just give me back an answer. I try to guide them with questions. And when they ask me a question about "Well, my hypothesis says this. Is that correct?" I say, "Well, what do you think? What is your data showing?"… I try to let them know that sometimes in science there's no right or wrong answer. Sometimes there is, but sometimes there isn't."*

Bringing PolarTREC Experiences Back to Students

Before her *PolarTREC* expedition, Jacquelyn taught out of her textbooks; she based instruction on memorization of facts and lectured in the same way. "*I was teaching from a textbook, especially on glaciers. I mean it was sort of like I could recite all the data and everything I'd read.*" After her *PolarTREC* experience, Jacquelyn began incorporating her personal experience into her teaching, and using that experience to convey the broader picture of science in the world. She finds it more challenging but also more rewarding. And she sees a difference in her students.

"I try to move toward concepts. And that's hard because these students aren't used to thinking conceptually. They're used to memorizing, and that's what they like because they can spit it back and get that easy grade. So I've tried to move into more concepts. I try to move away to the bigger picture. And they've been telling us for years we should be teaching concepts, and we've been fighting it saying, "Oh, our students don't understand anything. They don't have the background. They haven't been, you know." And that's true, but it still doesn't mean they can't understand. I mean even my little class clown, he asked some very meaningful questions today."

She asks her students to back up their statements with data and encourages them to question what they hear *"If a celebrity gets online and says something, oh my god. It's a very media-driven society out here…. My students believe them because they saw it on TV. I always tell my students…, "If you think there's a global warming [problem] then you have to prove it to me." And they're like, "Well, how can you say that?" And I said, "Give me your pieces of evidence that show it." And they said, "Well, the Polar Bears are – the ice is melting in the Arctic." I said, "It's not melting in Antarctica."*

Using STEM Practices

PolarTREC has led Jacquelyn to throw out her textbooks and lab manuals and instead focus on inquiry-based learning. She uses her *PolarTREC* experience as a backdrop for what she teaches, and finds that she is able to translate polar research into science to which her California students can relate. "*They're more project-related. I don't have lab manuals anymore. And I put together a lot of activities based on what I did… on the trip with PolarTREC."*

The collaboration with Marchant (*PolarTREC* researcher) has made it easy for her to bring STEM practices she learned through *PolarTREC* into the classroom. She finds that despite the extreme temperature differences, there are similarities between her Los Angeles community and the Dry Valleys that she can use to build lessons in her classroom. Both the Dry Valleys and Los Angeles contain little moisture and feature strong, seasonal winds. She notes, "*California's a desert; Los Angeles. People forget that…. And I got the idea because when I came back and I had the lessons plans, our winds are the same, those katabatic winds are just like our Santa Anas. It's dry. It's just not cold here.*"

Jacquelyn describes the Virtual Deserts project as a study of *"a polar desert versus a subtropical desert…. We can contrast the weather data in Antarctica with the weather data we have here… I knew the winds would strike the students [and] they'd see that the speeds are pretty much the same."*

She works with the students as they gather the data but first asks them to look at the weather data, propose parameters and develop a hypothesis. Her experience in Antarctica helps her personalize the project and lead students through it. She guides them in the beginning *"because these are different places in Antarctica, and* [they have to] *pick one or two places to contrast their weather with ours. In terms of wind, what they want to study.*" She asks the students to "*compare and contrast throughout Antarctica with what they see on our campus.*"

Her use of real data is a direct result of her *PolarTREC* experience: *"I think for me it was actually being there and seeing cutting-edge data, and understanding it…. I just found it easier to incorporate hands-on after [doing research] with Dave. And he had four graduate students with him, so when he was busy I could always go to somebody else and see what they were doing. And it just made it real easy. And like, oh, here's the data. And oh here's the data. And you'd go to this site. And after I came back I though I've got all this data that's like real. I think that was it. After talking to all the grad students and seeing what they were doing, and they were modeling, they're just crunching numbers…. It just kind of pushed me into the edge of using real data."*

This impact of *PolarTREC* will benefit her students as they use data from the research project to test their hypotheses.   Jacquelyn believes that the students will be overwhelmed by the amount of data and will have to be led through the process of sorting through what they need for their own projects. She states, "*They'll look at the weather data when we have it all loaded. And I know what they're going* [to say]… *"Look at all these numbers!" So I might say, "How do the winds vary between Sperm Bluff and Pearce Valley Station?" And they're still going to* [say]… *"There's so much data!" I said, "All you have to do is look at the wind speed and the wind gusts."* Jacquelyn will be teaching her students to sort through data to find those that are relevant to the study parameters and their hypotheses.

Collaboration with Scientists

Jacquelyn has continued to collaborate with Dave Marchant, the principal investigator from her *PolarTREC* expedition. When she developed the idea and found funding to set up meteorological stations to collect weather data in Antarctica and Los Angeles, she asked Marchant if he would be willing to collaborate with her. As a result, anemometers were sent to Marchant to be set up in three separate locations in the Dry Valleys area: Upper Beacon Valley, Sperm Bluff, and Pearse Valley. One was kept in the Los Angeles Valley for local data. The goal of this project, titled Virtual Deserts, is to use datasets and GIS to enhance science education and introduce research to two-year college students. Students will collect and contrast original data from meteorological stations in both areas which will be used for research into climate modeling.

Jacquelyn was invited back to Antarctica by Marchant to participate in a second expedition in the Dry Valleys. This time, Jacquelyn and Marchant will be seeking a better understanding of surface processes above buried ice on Earth. As the cold-polar desert of the Dry Valleys is one of the most Mars-like climatic environments and landscapes on Earth, this research may provide insight into Martian history and the potential for life on Mars.

And while Jacquelyn never anticipated a return trip to Antarctica, she is once again channeling her "inner child" to take her back to the frigid cold and rustic facilities. It is a challenge for which she is ready and eager to face.

Jillian: Jillian, a 2008 Bering Ecosystem Study *PolarTREC* teacher and NOAA Teacher-at-Sea, couldn't contain herself on the research expedition. Naturally outgoing and gregarious, she found it difficult to confine herself to one scientific team and investigated all aspects of the research taking place on the ship. She inserted herself into the diverse and unique aspects of life on the coast guard research vessel, including getting to know the ship's crew and the structure of life in the coast guard, learning how to conduct a readiness drill, finding out why a researcher would blow up Bering Sea life specimens, and pitching in to make apple crisps for an entire boatload of people.

Casual observation is not in Jillian's nature. She has traveled to every state in the U.S., lived and worked in the Philippines as a Peace Corps Volunteer and opened herself up to new adventures and experiences at every turn. It's a drive within her to uncover the meaning and the forces behind the world… up close and at-large.

This hands-on approach to life has translated into a hands-on style of teaching as the all-curricular teacher of at-risk middle school students in Flagstaff, Arizona. Her students experience learning that extends beyond the confines of their school walls and even their landlocked desert state. They regularly discuss ocean currents and krill, despite the fact that many of them have never even seen the ocean. Though Jillian is a natural teacher, her *PolarTREC* experience has enhanced and expanded her hands-on teaching philosophy and enhanced and enriched the lives of her students.

Jillian believes that teaching should be activity-based. Though textbooks are a regular part of her teaching, she relies on them as a reference tool, a resource to add to the content in which students are actively engaging. She routinely recruits scientists and people who are experienced in the field or content to visit her class and work with students. "*The more hands-on, interactive I can provide in a classroom, that's my philosophy. As well as, the more people-based…. The more scientists, the more individuals from the field that I can get into the classroom, the more effective I feel that I am as a teacher*."

She teaches science by connecting students to the materials they're studying, be it through demonstration, discussion or interaction with guest scientists in her classroom. "*That's what science is all about. It's showing that relevance to the lives of where you're at and how we're all interconnected scientifically on this planet. And, so having that hands-on with scientists who are in the field, to bring them to the classroom, is a huge tool that I like to use in teaching*."

Jillian strives to connect her instruction to the broader world around her students. She truly wants them to learn locally and think globally, and to appreciate interconnectivity between life in landlocked Arizona and the polar regions. "*My purpose, one of the reasons why I do this is, and it is part of my philosophy of education, is I think that we should train students, or educate students to see that we are part of a bigger system of where we live. And, for them – and even if they don't ever want to live in an ocean, or they don't want to go to the Arctic or go to the Poles, that they know that these are vital components of the system that we live in. That you're not just here in Northern Arizona. It's a bigger planet than that*."

<u>*Bringing PolarTREC Experiences Back to Students*</u>

The impact of *PolarTREC* on Jillian's teaching philosophy has been profound. Jillian feels confident in introducing difficult scientific topics because of her experience and the contacts that she has made. Prior to *PolarTREC*, she might not introduce a topic that she did not completely understand or that was not covered explicitly in a textbook. Now she is able to introduce hands-on activities with an expanded knowledge of scientific discovery behind her. "*I introduce things now that I would never have introduced before because I have a network behind me to teach them. I'm willing to take more risks. It's made me a more interactive teacher as far as hands-on with the students, especially with science. It's broadened my awareness of some of the fields of science out there that I'd never even thought of before.*"

And while Jillian always preferred a hands-on teaching style, her *PolarTREC* experience reinforced the need to enhance hands-on teaching with her students because it made such a difference in her own understanding and her excitement about learning science. Her students, she says, can only learn if they are enthusiastic about what they're learning. "*They need to be excited about what they're doing and the only way you can do that is with hands-on.*"

Hands-on learning is fun and engages students. Jillian recognizes the importance of fun learning. "It can be fun and it's just like today when that one student was saying, he's like, "*You know, this is fun." When he said that in the classroom, it is fun. And if they're having a good time and they're having fun, then they're engaged and they're not sleeping at their desks and they're learning."*

Jillian feels as if her students have begun learning about science and exploring science with much more depth since her *PolarTREC* experience. She has them explore older scientific concepts with new questions and has them apply new techniques. "*My students are better critical thinkers now because I'm better at teaching them to be critical thinkers, to ask questions…. I think that that increased because of PolarTREC. The fact that I had one group the other day step out of the box and measure their baking soda in that way that was different than everybody else's. I think that's because I'm trying to teach them to be better critical thinkers because I'm a better critical thinker. Do they ask better questions? Yes, they do.*
"For 15-year-olds and 14-year-olds, hello, they've been playing with baking soda and vinegar for 15 to 14 years. But none of them had ever done a lab which we did yesterday to try to control the reaction. It's going to that next level of critical thinking and questioning, can they control the reaction…. And I had never taught like that before. I was, prior to *PolarTREC*, much more standard in what I was doing."

Jillian feels that her ability to teach critical thinking skills has been improved through her *PolarTREC* experience. "There are some patent concrete things that you can do in a science classroom that involve memorization, but you also have to teach those critical thinking skills, those questioning skills, those skills that involve that next cognitive level. And I am better at that now because of *PolarTREC* and especially because I had never really seen scientists in the field do it before."

Using STEM Practices

Jillian's participation in *PolarTREC* enhanced her awareness of the diversity of science and the diversity of study within scientific fields. She felt as if the experience gave her permission to keep learning, even as a teacher, and it has allowed her to take more risks in her pursuit of knowledge. "*It's broadened my awareness of some of the fields of science out there that I'd never even thought of before. It's kind of like those duh moments like oh my gosh, there's not just oceanographers that study the oceans. There are scientists out there that just study the iron in the ocean or just study sedimentation in the ocean…. To be encouraged to still learn and become a better teacher. It's allowed me to take more risks in the classrooms in what I'm doing with students, 'Yes you can fail because that's how we learn.'*"

She notes that her experience on the research vessel, the Healy, showed her first hand that failure can lead to knowledge gain, a fact that she tries to impress on her students. "*I truly believe that that's how we learn, if you do something wrong. And I was able to physically see that while I was on the Healy. I was able to see things not work and what the scientists had to do to problem solve because here they're on this boat in the middle of an ocean and it's not like they can go into town and buy some super glue.*"

She has enhanced her scientific teaching through the use of real data, not just data created by textbook publishing companies, something that she did not know was available prior to her *PolarTREC* experience. "*Five years ago I had no clue and no idea that real data was even available to scientists in a classroom…. Now I have access to scientist data that actually shows me this stuff. And it shows the students – one of the things in yesterday's experiment, there were a lot of students as they were doing the _____ experiment who, of course, with a negative trim line, you expect every single data point to go down. But many of them, their second trial actually went up….And then we could go and we can look at other scientists' data and say, "Okay, why doesn't this directly fit with what they were looking to have it fit?" And then what did they need to do, not to change the data but to change their question or their methods or their procedures because this is what they want to get.*"

As a teacher, Jillian applies this to her use of textbooks and standardized tests. She uses these as required benchmarks for learning but does not see them as indicators of a student's strategic thought process or as an indicator of scientific development or maturation. "*When you teach to the test, you do not teach critical thinking. You do not teach problem solving, only in a very linear way on a standardized test. And through PolarTREC and working with some of these scientists, I am able to – you know, I'm still teaching towards a test able to design and implement teaching strategies in my classroom that teach the skills that future scientists have to know. And that's – that, to me, is vital. They need to be excited about what they're doing and the only way you can do that is with hands-on.*"

While always a teacher who believed in hands-on learning and fun in the classroom, *PolarTREC* has allowed Jillian to move to a higher level of instruction. "*And I think that I am better now at making my fun more valid and meaningful. And that's something that I couldn't do before because I didn't have the resources.*"

<u>Collaboration with Scientists</u>

Jillian has expanded her networking with scientists since her *PolarTREC* experience and has literally incorporated their knowledge and their scientific work into her teaching through in-class presentations, pen pal relationships and increased engagement with the scientific community. She notes that while previously she would lecture on a subject using statements of fact as the main focus, it has changed since *PolarTREC*. "*Now I can have a scientist who's been there talk to my students. I've upped my bar of engagements so that not only are the students still actively having a good time in the classroom but they're at a higher cognitive level in what they're retaining. You saw it today. I had a student in class who used the word krill as if it was a common vocabulary term. I'm sorry, that gives me goose bumps because this is Arizona*…. *And it was perfect with the krill because Tracy* [a *PolarTREC* scientist] *sent us enough live specimens so that all of my students were able to take a krill, put it in a Petri dish with water, Bering Sea water, and allow us to actually observe them in the stereoscope as they're twiddling around in the Petri dish.*"

She also brought real scientists into the lives of her students so that they could learn more about scientific projects and work as a scientist. She and her students designed and built an underwater robot modeled after the SCINI program that conducts research in Antarctica, and that experience cemented her connection with scientists and their connection with her students. "*We used their ideas to design our robot. There's no way I could've done any of these projects without that collaborative nature with the scientists, because – and, this is for me, one of the things I really like about what participation in Polar Trek has given to me towards the future, is*

I'm not scared to take on things now that I know very little about. Because, I know there's people out there that are willing and want to help me teach this to my students."

Her collaboration with *PolarTREC* contacts is not limited to scientists, either. She initiated a pen pal project that included not only *PolarTREC* scientists but the Coast Guard crew as well. And she found that they were just as excited as her students. "*Every one of these scientists when I contacted them after the fact, were 100 percent open to my students, and helping this class. And, not just on the science and stuff, and more than that were pen pals with my students….My students were actually able to write to as pen pals. To be buddies with…. And, that's education. My students each had two scientists, or not two scientists, two pen pals. One was a scientist, one was a U.S. Coast Guard employee. So, some were officers, some were not officers,…. They went above and beyond what you would expect the private sector to do to engage in a student, in a child that they've never met in a classroom. And, that was the gift of PolarTREC.*"

In addition, Jillian brings scientists into her classroom, and students gain an understanding of science careers through the wide diversity presented to them. They are able to hear about different types of scientific research and science careers through personal stories and interviews. For example, to introduce a unit on oceanography, Jillian brought in several different scientists to talk with her students. "*We chose different scientists with different expertise, who I met through PolarTREC, and they were more than willing to do these interviews for us. So, that we could learn about their fields in the ocean sciences, and bring them into our classroom, which is landlocked, which has no ocean. And, we're able to incorporate, using current technology, which is the 21st century way of learning, for the students*."

Section 10: Case Study Student Data Outcomes

The *PolarTREC* case study teachers continued to impact their students understanding of the polar regions (Table 42). For case study teachers, the pre- to post-mean scale scores significantly increased for all of the scales tested by the Student Survey, except for Career Interest and Science Efficacy. The Human/Past Environments, Tundra Systems, and Engineering scales showed the largest increase from pre- to post-survey.

Table 42. Case Study Teacher Students' Pre-Post Survey Results

Test		**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**Change**	**t**	**df**	**P-value**
Career Interest	Pre	181	2.0408	.59466	.04420	-0.089	1.395	308.89	.164
	Post	139	1.9519	.54142	.04592				
Science Efficacy	Pre	178	2.6980	.61963	.04644	0.079	-1.182	314.02	.238
	Post	144	2.7769	.57485	.04790				
General Knowledge	Pre	179	2.2356	.58666	.04385	0.193	-2.938	300.58	**.004**
	Post	140	2.4286	.57878	.04892				
Ice/Snow Knowledge	Pre	182	2.3558	.67983	.05039	0.158	-2.131	316.50	**.034**
	Post	147	2.5136	.65805	.05428				
Humans/Past Environments	Pre	185	1.9261	.66071	.04858	0.363	-4.912	304.37	**.000**
	Post	143	2.2890	.66577	.05567				
Ocean Systems	Pre	182	1.9868	.61351	.04548	0.189	-2.659	294.99	**.008**
	Post	143	2.1762	.65585	.05484				

Tundra Systems	Pre	181	1.6796	.67846	.05043	0.315	-4.026	294.33	**.000**
	Post	141	1.9943	.70950	.05975				
Engineering	Pre	180	1.9778	.75290	.05612	0.544	-3.293	36.94	**.002**
	Post	30	2.5222	.85179	.15551				
Atmosphere	Pre	182	2.6154	.82461	.06112	0.156	-1.833	327.17	.068
	Post	149	2.7718	.72709	.05957				

Section 11: Conclusions

PolarTREC has had an undeniable impact on the teachers, students and researchers who have been associated with the program. Teachers' content knowledge has increased. Teacher efficacy in science instruction has increased. And the program has continued to impact teacher instruction well after their expeditions have ended.

Student knowledge of polar science has also increased. Researchers who have worked with *PolarTREC* teachers agree that the program has increased their understanding of K-12 education and teachers' roles. Most agreed that teachers performed outreach to populations that otherwise would not have been included in the scientific projects. And almost all of the researchers felt that *PolarTREC* was a positive experience, and that ARCUS was a strong organization that provided the support needed to successfully carry out the *PolarTREC* goals and objectives.

Teacher Learning and Long-Term Impact

Content Knowledge

PolarTREC increased teacher knowledge of polar science. Forty teachers completed multiple choice pre and post-tests on science content. The overall increase in teacher content knowledge was statistically significant (Section 3).

Teacher case studies illustrate an increase in content knowledge. Of the six teachers interviewed, all but one of them specifically discussed the knowledge they had gained. From learning about the shared ecosystems between Hawaii and the Arctic, to learning about ice formations now and thousands of years ago, to finding out that no variables can be discounted when conducting experiments, *PolarTREC* teachers have increased their knowledge base in many ways (Section 9).

Science Efficacy

Using a science instruction practices survey that was administered to teachers prior to their *PolarTREC* expedition and again a year after their experience, we found that teacher science efficacy increased significantly. Teachers showed statistically significant increases in their ability to guide students in scientific inquiry and in their use of inquiry practices in the classroom (Section 4).

Evidence for this increase in science instruction efficacy is supported in the case studies of six *PolarTREC* teachers. Measured by the results of the pre/post survey of polar science knowledge, students of case study teachers significantly increased their understanding of the following: general knowledge, ice/snow knowledge, humans/past environments, ocean systems, tundra systems, engineering, and atmosphere (Section 9).

Continued Impact of *PolarTREC*

The continued impact of *PolarTREC* was measured through surveys of *PolarTREC* alumni (Section 8) and case studies of selected *PolarTREC* alumni (Section 9). Teachers continue to use their *PolarTREC* experiences as a vehicle for content knowledge delivery. The alumni survey showed that more than half of teachers in 2011, 2012, 2013, and 2014 frequently drew on anecdotal experiences that they had during their *PolarTREC* expedition and integrated technology they learned about during *PolarTREC* into their classroom instruction.

Teachers also continue to use *PolarTREC* experiences to enhance instruction. Seventy percent or more of teachers in 2011, 2012, 2013,and 2014 stated that they frequently use instruction time to: help students interpret and evaluate data; help students develop hypotheses and scientific questions; help students determine what evidence would be most useful to answer their scientific questions; require students to collect data to answer their scientific questions; require students to communicate and justify their explanations; and require students to think about other reasonable explanations that can be derived from the evidence presented.

Teachers also continued to use Polar science topics throughout the school year. Through the alumni survey, 60% or more of teachers stated that they occasionally or frequently taught their classes about the following topics: scientific research equipment/tools; climate change in the Arctic or Antarctic; polar weather; polar climate; the job of a polar scientist; glaciers; snow; human impacts on the polar regions; sea ice; understanding environmental changes in the polar regions; ice caps; ocean currents; living conditions in the polar regions; and adaptations to life in extreme cold and prolonged darkness.

Case study teachers spoke to the impact of *PolarTREC* on their teaching practices, and all shared that it had long lasting impact. Teachers noted that they are better able to teach science by inquiry after watching researchers on their expeditions. They understand the importance of working with real data and have increased the level of local data collection in their classes. And they encourage students to make connections between their own scientific experiments and the broader scientific topics they are studying (Section 9).

Student Learning Outcomes

Over the four year period, students showed a statistically significant increase in knowledge in the following areas: academic preparation, general knowledge, ice and snow knowledge, human/past environments, ocean systems, and tundra systems. Students did not show a statistically significant increase in career interest or science efficacy (Section 5).

Researcher Outcomes/Impacts

PolarTREC also impacted participating researchers in several ways. Evaluation findings related to researchers' report of teachers' roles as part of their research team, their understanding of K-12 education after working with a teacher, and *PolarTREC*'s impact on their outreach activities is summarized below (Section 6).

Researcher Opinions

Researchers had favorable opinions of the program and shared them in surveys in 2012, 2013 and 2014. More than 89% of researchers agreed that their experience with *PolarTREC* was positive. Researchers were particularly positive about ARCUS and the support provided by ARCUS. All agreed that it was easy to communicate with ARCUS, and more than 90% agreed that ARCUS was responsive to the researcher's needs and provided needed technology to conduct outreach. The same number of researchers felt that the teacher's qualifications matched their research project and that the expectations of the program were clear. More than 80% of researchers agreed that the experience surpassed their expectations and stated that they would apply for another *PolarTREC* researcher and that the program was beneficial to the scientific process of their project.

Researcher comments echo survey results, with researchers stating that *PolarTREC* increased outreach for their project and created an opportunity to get to know and work with the teacher.

Teacher's Roles

Researchers unanimously agreed that they and their teachers had a clear understanding of the work that teachers would perform. More than three-quarters of researchers agreed that their teachers contributed positively to the expedition in the following ways: helping however needed in the field; being prepared physically for the demands of fieldwork; and helping with data collection. The same number of researchers also agreed that their teachers possessed the following positive qualities. These researchers stated that their teacher was: a good match for their project; a valuable member of the research team; and a quick learner. More than half of researchers agreed that their teacher was prepared academically for the demands of the project, was the main PR/outreach for the expedition, and learned to think like a scientist.

Researcher comments support the survey results above. In comments, researchers note that *PolarTREC* teachers were team members who provided data collection and project outreach.

Understanding of K-12 Education

PolarTREC increased researcher's understanding of K-12 education. All of the researchers surveyed agreed that because of their experience with *PolarTREC*, they had a better understanding of their teacher's knowledge of science. Ninety-five percent of researchers stated that *PolarTREC* increased their understanding of K-12 student engagement or interest in science. More than 75% of researchers increased their understanding of translating science to the K-12 classroom, the job of a teacher, what students do or do not know about science, and how to explain their work to a young audience. Fewer than half of researchers understood testing and curriculum requirements.

Comments by researchers support these results. Researchers expressed an awareness of the many time constraints and challenges faced by K-12 teachers who must juggle standardized testing requirements and time limitations with a need to create innovative lessons for a diverse student population. Most researcher comments voiced admiration for the difficulties that K-12 teachers face.

Impact on Outreach

Most researchers felt that *PolarTREC* had a positive impact on outreach during the expedition. Researchers unanimously agreed that *PolarTREC* expanded outreach on their project and reached a K-12 audience that otherwise wouldn't have been included. A large majority of researchers agreed that *PolarTREC* enhanced outreach through technology (websites, blogs, etc.) and helped articulate their project to the public.

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