PolarTREC Final Evaluation Report

Angela Larson, External Evaluator
Goldstream Group, Inc.

PO Box 83418
Fairbanks, Alaska 99708
www.goldstreamgroup.com

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Prepared By:
Angela Larson
External Evaluator

Goldstream Group, Inc.
PO Box 83418
Fairbanks, Alaska 99708
P 907.452.4365
F 907.452.4375

alarson@goldstreamgroup.com
www.goldstreamgroup.com

Prepared For:
Arctic Consortium of the United States
3535 College Road, Suite 101
Fairbanks, Alaska 99709-3710
P 907.474.1600
F 907.474.1604

www.arcus.org

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Introduction

PolarTREC Background and Program Description

While U.S. high-school students perform less well in science, technology, engineering, and math (STEM) than students in other economically advanced countries, knowledge of polar sciences and related environmental arctic change is particularly low among the U.S. students (Grigg, 2006; National Academy of Sciences, 2007; National Commission on Excellence in Education, 1983; National Commission of Teaching and the Future, 1996; U.S. Department of Education, 2005). The performance level of U.S. students and their lack of knowledge about polar sciences led the Arctic Consortium of the United States (ARCUS) to develop *PolarTREC* (Teachers and Researchers Exploring and Collaborating) to correspond with the International Polar Year. *PolarTREC* was funded with a National Science Foundation grant (grant #0632401) from 2007 to 2010. ARCUS received a second National Science Foundation grant in 2010 to continue *PolarTREC* for another four years.

PolarTREC, like other teacher research experiences, is based on the premise that experiences in the practice of science improve teaching and in so doing increase student interest and achievement in science. Teacher content knowledge is essential to student achievement of science (Darling-Hammond et al., 1995) and K-12 teacher quality is a major factor influencing students' decisions about pursuing STEM degrees and occupations (Ashby, 2005). Participation in teacher research experiences has been found to improve the quality and authenticity of science teaching (Silverstein, et al., 2009). In particular, these experiences improve teachers' ability to connect new research to their classroom curriculum (Glasson and Bently, 2000) and improve teachers' instructional practices by: encouraging the skills of scientific inquiry, curiosity, and openness to new ideas and data; incorporating technology; identifying and using resources outside the school; selecting and adapting curricula; and challenging students to accept and share responsibility for their own learning (Alters, 1998; Gilmer, 1999; Kielborn, 1999; Redfield, 2000).

PolarTREC differs significantly from most other teachers research experiences in that teacher participants conduct field research at remote research sites in the Arctic and Antarctic. These hands-on field experiences integrate research and education providing benefits to both K-12 teachers and scientists. Teachers learn the practices of field research, from travel and expedition logistical planning to the development of research questions and data collection methods, tools, and equipment. Teachers learn firsthand about Arctic and Antarctic science content like changes in the polar environment, glaciations, sea ice, atmospheric science, and polar animals and this firsthand experience is shared with students online and through live events from the field. Researchers expand their outreach and achieve broader impact goals when *PolarTREC* teachers receive media attention for their unique opportunity to work with scientists in remote parts of the world; when teachers use their research to develop and disseminate educational activities and products to students, educators, and the public; and when researchers develop a better understanding of translating their research for K-12 consumption.

Each year approximately 12 teachers are selected from a pool of 150-200 applicants which includes elementary, middle, high school, and informal educators. An intensive selection process includes a 20-member selection committee comprised of teachers, researchers, logistics providers, and other polar community members. Diverse participation in *PolarTREC* was an important project objective and one that ensures that underrepresented communities are engaged in polar science, STEM activities, and the International Polar Year (IPY). To help improve the program's diversity, applicants from underrepresented groups were closely tracked throughout the selection process to ensure that the committee selects a final pool (about 30-50 applicants) that represents diverse teacher backgrounds, diverse student populations, varying student abilities (special education, gifted, alternative schools), all types of communities (urban, rural, and suburban), and various school and community income levels. Although research teams make the final teacher selection, they often consult closely with the *PolarTREC* project managers in making the final decisions.

Accepted teachers receive extensive orientation to *PolarTREC*. They attend a two-week orientation covering a range of topics such as: the goals, purpose, and expectations of the *PolarTREC* project; program requirements and deliverables; education plan requirements; evaluation expectations; public outreach techniques and requirements; journaling techniques and requirements; life and work in the Arctic and Antarctic; using communication tools in the field; digital photography; and audio editing techniques. Past program participants also attend the orientation to provide their perspective on the field experience and how to bring the experience to their classrooms. *PolarTREC* teachers also participate in several webinars; a pre-field teleconference with ARCUS staff, logistics providers, and research team members; and one-on-one phone calls between ARCUS staff, teachers, and research team members prior to the field season. Teachers will sometimes meet the research team in person prior to their work in the field. Finally, teachers develop an education and outreach plan, a blueprint for transferring their *PolarTREC* research experience into the classroom and beyond. The plan includes a needs assessment, classroom implementation strategy, research experience reflection, and outreach strategy.

While in the field *PolarTREC* teachers work as members of their research team and, in addition, keep a daily online journal, capture their experience on film and audio recording, and facilitate an online *Live from the International Polar Year or Live from IPY!* events with their research team to students and other interested individuals from all over the world.

After *PolarTREC* teachers return from the field, they debrief with ARCUS staff, logistics providers, and their research team. They begin implementing their education and outreach plan, continue journaling, develop and submit two lessons plans to the *PolarTREC* learning resources database (http://www.*PolarTREC*.com/resources), and document their outreach activities. Many of the *PolarTREC* teachers also join the CARE (Connecting Arctic/Antarctic Researchers and Educators) Network, a professional development network managed by ARCUS that uses online web meetings to support the integration of science research experiences into classroom curriculum. CARE brings together teachers and researchers to discuss field experiences, current science issues, content, technology resources, and pedagogy.

The goal of *PolarTREC* is to invigorate polar science education by bringing K-12 educators and IPY researchers together through hands-on field experiences. The specific objectives of *PolarTREC* are to:

Objective 1: Improve teacher content knowledge of multidisciplinary polar science, with a focus on the three NSF IPY science emphasis areas—Ice Sheet History and Dynamics, Adaptations to

Life in Extreme Cold and Prolonged Darkness; and the Arctic Observing Network/Study of Environmental Arctic Change (SEARCH).

Objective 2: Improve teacher instructional practices, especially the use of inquiry-based learning to translate polar science to the classroom.

Objective 3: Improve polar researchers' understanding of and engagement in K-12 education to strengthen and enrich outreach and dissemination of their research.

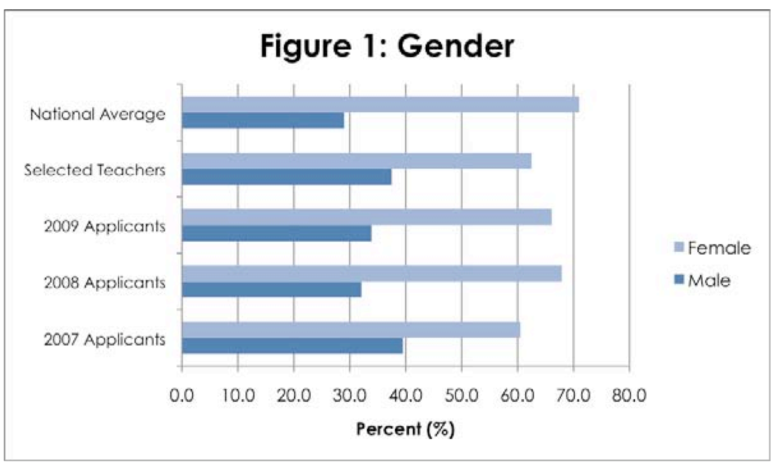
Objective 4: Increase students' understanding of and engagement in the polar regions and interest in science, technology, engineering, or mathematics (STEM) careers studying the Arctic and Antarctic.

PolarTREC Teacher, Student, and School Characteristics

From 2007 to 2010, 624 elementary-, middle-, and high-school teachers applied to participate in *PolarTREC*. Of the applicants, 48 (7.7%) elementary-, middle-, and high- school teachers were selected – 16 in 2007-2008; 13 in 2008-2009; and 19 in 2009-2010. The teachers represented 21 states and the District of Columbia.

Demographic data was collected from applicants to the program during the online application process. Although the application consisted of two parts, only teachers who submitted both parts—a full application—were included in the figures described. National teacher and student demographic data was derived from a 2003 article in USA Today *The Face of the American Teacher*[1].

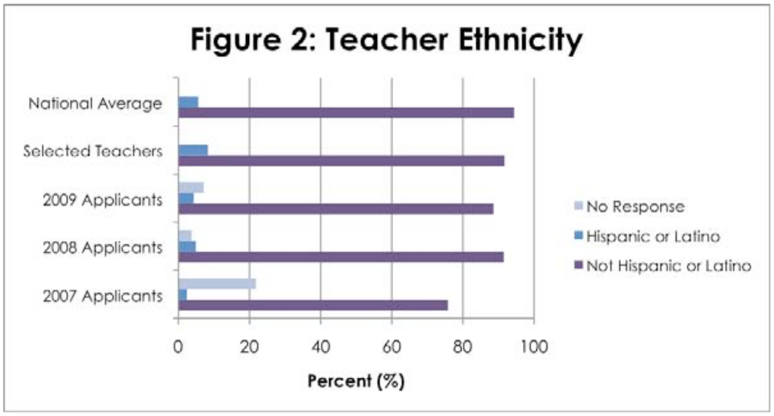
Teacher applicants to *PolarTREC* closely resembled the demographic percentages represented within the teaching profession. The total number of applicants to *PolarTREC* was approximately 30% male and 60% female, while nationally teachers are 29% male and 71 % female. From the pool of selected *PolarTREC* teachers, 36% were male and 62% were female (Figure 1).



It is worthwhile noting that although females are often underrepresented in STEM professions, men are often underrepresented in teaching professions.

1 At the time of this writing, a more recent breakdown of teacher and student ethnicity could not be found.

Approximately 2% to 5% of teacher applicants identified their ethnicity as Hispanic or Latino; the national average in the teaching profession is about 5%. Eight percent of 48 selected *PolarTREC* teachers identified themselves as Hispanic or Latino—3% greater than the national average in teaching (Figure 2).



Excluding Hispanic and Latino, approximately 15% of teachers nationwide identify their race as American Indian or Alaska Native, Asian, Black or African American, or Native Hawaiian or Pacific Islander. Approximately 10% of applicants to *PolarTREC* were from these groups, while about 90% of all applicants identified themselves as White. Approximately 6% of selected teachers identified their race as something other than White (Table 1).

Table 1: Teacher race by year

	2007 Applicants	2008 Applicants	2009 Applicants	*PolarTREC* Selected	National Average
	n= 124	n=246	n=254	n=48	n/a
American Indian or Native Alaskan	0.8 %	1.2 %	2.0 %	4.2 %	0.9 %
Asian	0.8 %	1.2 %	0.8 %	0.0%	1.6 %[2]
Black or African American	0.8 %	1.6 %	0.0%	2.1 %	7.6 %
Native Hawaiian or Other Pacific Islander	0.0%	0.0%	0.4 %	0.0%	
White	91.9 %	91.5 %	89.8 %	95.8 %	84.3 %
Other	0.8 %	2.4 %	2.4 %	0.0%	6.0 %
No Response	4.8 %	2.0 %	4.7 %		

While selected *PolarTREC* teachers represented slightly lower percentages of underrepresented groups (Hispanic or Latino, American Indian or Alaska Native, Asian, Black or African American, or Native Hawaiian or Pacific Islander) than the national average, the students they taught often represented near equal or greater average diversity than national averages (Table 4).

Table 2: Average student race & ethnicity by year

2 National data for Asian and Native Hawaiian/ Pacific Islander groups was combined.

	2007 Applicants	2008 Applicants	2009 Applicants	*PolarTREC* Selected	National Average
	n= 124	n=246	n=254	n=48	n/a
American Indian or Native Alaskan	4.1%	6.6 %	9.2 %	4.1 %	1.2 %
Asian	7.4 %	5.8 %	6.2 %	5.2 %	4.1 %[3]
Black or African American	14.9 %	14.2 %	12.8 %	11.0 %	17.2 %
Native Hawaiian or Other Pacific Islander	30.0 %[4]	2.8 %	1.0 %	5.2 %	-----[3]
White	59.0 %	59.9 %	62.4 %	63.0 %	61.2 %
Mixed Ethnicity	5.0 %	5.2 %	6.4 %	8.1 %	-----[3]
Hispanic or Latino	20.3 %	20.8 %	18.8 %	16.6 %	16.3

On the *PolarTREC* application, teachers were asked to specify what percentage of students in their schools made up the following ethnic groups: American Indian or Alaska Native, Asian, Black or African American, Native Hawaiian or Pacific Islander, and Hispanic or Latino. The teacher's responses were not always completely accurate (i.e. did not add up to 100%), but responses that came within 10% were accepted for this analysis. Incorrect data was removed (very high or very low percentage totals). One of the problems came from the fact that the "Asian" and "Hawaiian or Pacific Islander" groups were often combined in school district statistics, and instead of filling in one box the percentage was entered in both. In the future, ARCUS will streamline the application to make the collection of this data more accurate and applicable to the national baseline data used for comparison.

Schools of applicants to *PolarTREC* were 86-90% public and 8-10% private. Nearly 80% of selected teachers were from public schools and nearly 17% were from private schools. The remaining 4% of selected teachers were from informal education institutions such as museums or science centers. Schools of *PolarTREC* applicants had on average between 36-41% of students participating in the national free and reduced lunch program. The schools of selected *PolarTREC* teachers had an average participation around 33%, not far from the national average of 40%. Twenty-nine percent of selected teachers identified their schools and communities as rural, 25% identified them as suburban, and 45% identified them as urban. Additionally, several *PolarTREC* teachers were from schools that worked specifically with students in special education and/or alternative education with at-risk students.

PolarTREC Research Sites

Of the *PolarTREC* research sites, 57% were located in the Arctic and 43% were located in the Antarctic. The science topics covered by the expeditions ranged from studies of marine systems – a third of the projects, to space and physics – two percent of the projects. Table 3 lists each expedition by science topic area and project year.

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[3] National data for "Asian" and "Native Hawaiian/ Pacific Islander" groups was combined. The "Mixed Ethnicity" category did not exist in national data.

[4] One applicant in 2007 had 30% Native Hawaiian or Other Pacific Islander students, thus making this average percentage substantially greater than other years.

Table 3: *PolarTREC* expeditions by science category and year

Year	Science Topic Area	Expedition Name
2007-2008	Atmospheric Systems	Antarctic Weather Stations
		Greenland Snow Studies
		South Pole Ozone Changes
	Cryospheric Systems	Antarctic Ice Sheet Studies
		SEDNA Beaufort Sea Ice
	Ecology and Biotic Systems	Greenland Seabird Ecology
	Geology	Alaska Climate Variation
		Climate Change Svalbard
	Human and Social Systems	Kuril Islands Biocomplexity
	Long-Term Monitoring	Human Impacts in Antarctica
	Marine Systems	Antarctic Undersea ROV
		Bering Ecosystem Study
		Oden Antarctic Expedition 06
		Oden Antarctic Expedition 07
		SIMBA Antarctic Sea Ice
	Terrestrial Systems	Arctic Tundra Dynamics
2008-2009	Atmospheric Systems	Greenland Atmospheric Studies
	Cryospheric Systems	Ancient Buried Ice in Antarctica
	Geology	Erebus Volcano Antarctica
		High Arctic Change 08
	Human and Social Systems	Nuvuk Archaeology Studies
	Long-Term Monitoring	Lake Ecosystems in Antarctica
	Marine Systems	Antarctic Undersea ROV 08
		Bering Ecosystem Change
		Bering Ecosystem Study 08
		Drake Passage Opening
		Ocean Dynamics Beaufort Sea
		Oden Antarctic Expedition 08
	Terrestrial Systems	Arctic Tundra Dynamics 08
		Changing Tundra Landscapes
2009-2010	Cryospheric Systems	CreSIS Aerial Survey of the West Antarctic Ice Sheet
		CReSIS Greenland Ice Sheet Studies
		Greenland Education Tour 09
		Ocean, Atmosphere, Sea Ice, and Snowpack Interactions
	Ecology and Biotic Systems	Dissolved Organic Matter in Antarctica
		Microorganisms in Antarctic Glacier Ice
		Polar Bear Response to Sea Ice Loss
		Seabird Ecology in the Bering Sea
	Geology	Alaska Climate Variation 09
		Geologic Climate Research in Siberia
		High Arctic Change 09
	Human and Social Systems	Prehistoric Human Response to Climate Change
	Marine Systems	Early Spring Plankton and Benthos
		Spring Plankton and Changing Ice Cover

Year	Science Topic Area	Expedition Name
		Summer Ice Free Conditions
	Oceanic Systems	Antarctic Undersea ROV 09
	Space and Physics	IceCube In-Ice Antarctic Telescope

The research projects were primarily funded with National Science Foundation grants or were collaborations with other agencies, such as the National Oceanic and Atmospheric Administration (NOAA), the U.S. Geologic Survey (USGS), and the U.S. National Park Service. The principal investigators represented universities and agencies throughout the United States 33% of the principal investigators were women.

Organization of this Report

This final *PolarTREC* report presents the findings from the summative evaluation of the *PolarTREC* program funded by the National Science Foundation from 2007 to 2010 in four areas: 1) participant satisfaction with their *PolarTREC* experience; 2) teacher content knowledge and changes in instructional practices; 3) researcher understanding of and engagement in K-12 education; and 4) students understanding of and engagement in the Polar Regions and interest in science, technology, engineering, or mathematics (STEM) careers. Section 1 discusses the evaluation methodology, describing the evaluation design and data collection tools, samples, and analysis procedures. Section 2 summarizes the evaluation results for participating teachers. This section includes feedback about teacher satisfaction with their *PolarTREC* experience, teacher self-reported data about what they learned, and finally, teacher self-reported data about changes in their instructional practices after participating in *PolarTREC*. Section 3 looks at the outcomes for participating researchers and in particular at researcher satisfaction with their *PolarTREC* experience, and the extent to which they better understand and are engaged in K-12 education after working with a *PolarTREC* teacher. Next we look at the student outcomes in Section 4. This section details the results of the *PolarTREC* student pre/post survey which asked students to rate their interest in and knowledge about a range of polar issues, careers, and science topics. Finally, section 5 presents the evaluation's conclusions.

Section 1: Evaluation Methodology

Evaluation Design

The *PolarTREC* evaluation[5] uses a mixed method design incorporating descriptive components and a simple before/after design to measure what teachers and students learned over the course of teacher participation in the project. The use of a before/after design is likely to provide a reliable measure of the impact on teachers and students because knowledge of the Polar Regions is unlikely to change spontaneously over the program year (Rossi and Freeman, 1993). The evaluation questions are based on Guskey's (2000) five-level framework for evaluating teacher professional development. Guskey's (2000) framework includes five levels of assessment: 1) teachers' reactions to professional development experiences; 2) the knowledge and skills that educators gain from professional development experiences; 3) organizational support and change; 4) teachers' use of their new knowledge and skills; and 5) improvements in student learning.

Data Collection Tools, Sample, and Analysis

Teacher Pre-Post Survey

We developed a survey to assess changes in teacher knowledge and instructional practices before and after their *PolarTREC* experience. Teachers completed the pre-survey at the *PolarTREC* orientation and the post-survey at the end of the school year that corresponded with their *PolarTREC* field experience. Both the pre- and post-survey were completed using an online form.

The survey included three sections (survey is attached in Appendix A). The first section of the survey assessed the *PolarTREC* participants' self-reported use of science instructional methods that are characteristic of effective science instruction (National Science Education Standards, 1996). This list included specific skills, activities, and teaching strategies, such as using real-world contexts to teach concepts, encouraging students to explain concepts to one another, encouraging students to consider alternative explanations, and having students prepare laboratory or research projects. In addition, these include students activities, such as working with manipualtives, engaging in hands-on science activities, working on models and simulations, writing reflections in a notebook or a journal, and designing or implementing their own investigation. This section of the survey used the following scale:

1. Never
2. A few times a year
3. Once or twice a month
4. Once or twice a week
5. In all or almost all science lessons

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[5] The evaluation methodology was reviewed by the University of Alaska Institutional Review Board for ethical activities involving human subjects. The IRB determined that the *PolarTREC* project met the requirements for exempt status under the DHHS regulations.

The second section of the survey included questions assessing teachers' pre and post preparedness to teach about nine topics related to the Polar Regions and science processes: a historical overview of the global ice sheet; dynamics of ice sheets; adaptations of life in extreme cold; adaptations of life in prolonged darkness; issues involved with changes in the Arctic environment; issues involved with changes in the Antarctic environment; safety issues related to living in severe environments; scientific methods and inquiry skills: formulating hypotheses, drawing conclusions, making generalizations; describing, graphing, and interpreting data. The teachers were asked to rate their preparedness to teach these concepts to their students using the following scale:

1. Would find it difficult to teach even with resources
2. Would have to depend heavily on instructional resources
3. Would require moderate level of effort to get ready
4. Would feel confident teaching topic

In total 33 participants (70% of all of the *PolarTREC* participants) completed <u>sections one and two</u> of both the pre- and post-survey (Table 4).

Table 4: Number and percent of *PolarTREC* participants who completed <u>section one and two</u> of the survey of practices and polar knowledge

Cohort	Number (percent of participants)		
	Pre-Surveys	Post-Surveys	Both Pre and Post
2007-2008 (N=16)	10 (62.5%)	13 (81.3%)	9(56.3%)
2008-2009 (N=13)	11 (84.6%)	12 (92.3%)	11(84.6%)
2009-2010 (N=19)	14 (73.7%)	17 (89.5%)	13 (68.4%)
Total (N=48)	35 (72.9%)	42 (87.5%)	33 (68.8%)

For each teacher who completed both a pre- and post-test, we calculated the differences between the pre- and post-tests for each question and used a one-sample t-test to determine if the average difference in test scores was significantly different from zero. Detailed results of this analysis are included in Appendix B.

The third section of the survey included researcher-submitted facts, concepts, or skills specific to researchers' studies. We received a list of facts, concepts, or skills related to the following studies (some of the research projects did not submit questions). The projects that submitted questions are listed in Table 5 by year. A complete list of the facts, concepts, or skills is included in Appendix C.

Table 5: Projects with researcher-submitted facts, concepts, skills

2007-2008	2008-2009	2009-2010
Bering Ecosystem Study	Antarctic Undersea ROV 08	Alaska Climate Variation 09
Kuril Islands Biocomplexity	Arctic Tundra Dynamics 08	Antarctic Undersea ROV 09
Antarctic Ice Sheet Studies	Bering Ecosystem Study 08	Early Spring Plankton and Benthos

2007-2008	2008-2009	2009-2010
Alaska Climate Variation	Nuvuk Archaeology Studies	High Arctic Change 09
Greenland Seabird Ecology	Greenland Atmospheric Studies	Ice Cube In-Ice Antarctic Telescope
SEDNA Beaufort Sea Ice	High Arctic Change 08	Microorganisms in Antarctic Glacier Ice
	Ocean Dynamics Beaufort Sea	Ocean, Atmosphere, Sea Ice, and Snowpack Interactions
		Polar Bear Response to Sea Ice Loss
		Seabird Ecology in the Bering Sea
		Spring Plankton and Changing Ice Cover

The teachers were asked to rate their preparedness to teach these facts, concepts, or skills to their students using the following scale:

1. Would find it difficult to teach even with resources
2. Would have to depend heavily on instructional resources
3. Would require moderate level of effort to get ready
4. Would feel confident teaching topic

Of the 33 teachers who completed both a pre- and a post-survey, 23 (49% of all *PolarTREC* participants) responded to the section three questions generated by researchers (Table 6).

Table 6: Number and percent of *PolarTREC* participants who completed section three of the survey of practices and polar knowledge

Year	Number (percent of participants)		
	Pre-Surveys	Post-Surveys	Both Pre and Post
2007-2008 (N=16)	6 (37.5%)	6 (37.5%)	6 (37.5%)
2008-2009 (N=13)	7 (53.8%)	7 (53.8%)	7 (53.8%)
2009-2010 (N=19)	10 (52.6%)	10 (52.6%)	10 (52.6%)
Total (N=48)	23 (47.9%)	23 (47.9%)	23 (47.9%)

For each teacher who completed both a pre- and post-test, we calculated the differences between the pre- and post-tests for each question and used a one-sample t-test to determine if the average difference in test scores was significantly different from zero. Detailed results of this analysis are included in Appendix B.

Teacher Interviews

We interviewed teachers who participated during the 2007-2008 school year in May 2008; and teachers who participated during the 2008-2009 school year in May 2009. Teachers who participated during the 2009-2010 school year received a written survey in May 2010. The interview protocol is attached in Appendix D.

The interview had two sections. The first section related to *PolarTREC*'s impact on participating teachers' knowledge and instructional practices. This section asked participating teachers to describe the science content, processes, and other skills they learned from their field research experience as well as how their field experience changed their understanding of science careers. In addition, the interview asked teachers to describe how they connected their *PolarTREC* experience to their classroom instruction in terms of lessons, examples, talking to students about careers, and changes in the way they teach. The interview also asked participants to talk about changes they noted in their students' learning.

The second section related to teachers' experience in the field and their satisfaction with the overall *PolarTREC* program. This section asked teachers to describe in detail a typical day during their expedition, a task they spent a lot of time doing, and the extent to which they felt like an "active" part of the expedition's research team. The interview also asked teachers to suggest improvements to the *PolarTREC* program as well as aspects of the program that they would not change. Finally, the interview asked participants to describe the most significant part of their *PolarTREC* experience.

In total, 36 of the 48 *PolarTREC* teachers (75.0%) participated in an interview. We had the greatest interview participation during the first program year with 87.5% of the teachers participating in an interview. Participants were emailed to schedule a phone interview. Those who did not respond to email requests were directly phoned. In the third year we attempted to increase the number of respondents by providing a written survey asking the interview questions. However, only 68.4% of the participants responded (Table 7).

Table 7: Number and Percent of *PolarTREC* Participants Interviewed by Year

Year	Number	Percent
2007-2008 (N=16)	14	87.5%
2008-2009 (N=13)	9	69.2%
2009-2010 (N=19)	13	68.4%
Total (N=48)	36	75.0%

PolarTREC Teacher-Developed Lessons

As part of the *PolarTREC* program, participating teachers developed lessons based on their field experiences. The evaluation assessed the extent to which science lessons developed by participating *PolarTREC* teachers used science instructional methods that are characteristic of effective science instruction (National Science Education Standards, 1996). This list included specific skills, activities, and teaching strategies, such as using real-world contexts to teach concepts, encouraging students to explain concepts to one another, encouraging students to consider alternative explanations, and having students prepare laboratory or research projects. In addition, our criteria included students activities, such as working with manipualtives, engaging in hands-on science activities, working on models and simulations, writing reflections in a notebook or a journal, and designing or implementing their own investigation, and recording, representing and/or analyzing data (Appendix E).

The evaluators reviewed 18 randomly selected teacher lessons (from those available as of April 30, 2010) for their inclusion of these characteristics of an inquiry-based approach. The lesson evaluation protocol is attached in Appendix F.

Researcher Interviews

We interviewed researchers who participated during the 2007-2008 school year in May 2008; and researchers who participated during the 2008-2009 school year in May 2009. Researchers who participated during the 2009-2010 school year received a written survey asking them the same interview questions in May 2010.

The interview had four sections. The first section asked the researchers to comment on the teacher's role during the expedition. We were interested in knowing the teachers' primary roles, and how their roles were different than other members of the researcher team. We were also interested in understanding the impact the teacher may have had on the team's field research? The second section addressed the extent to which the researcher increased his or her understanding of K-12 education. The third section focused on the teacher's role conducting outreach. Finally, the interview asked researchers to discuss how they would change their *PolarTREC* experience, if at all. The researcher interview tool is attached in Appendix G.

In total, 21 researchers from 48 *PolarTREC* expeditions (43.8%) participated in an interview (Table 8). We had the greatest interview participation during the first program year with 56.3% of the teachers participating in an interview. Participants were emailed to schedule a phone interview. Those who did not respond to email requests were directly phoned. In the third year we attempted to increase the number of respondents by providing a written survey asking the interview questions. However, we had the lowest participation rate with the written survey (26.3%).

Table 8: Number and percent of *PolarTREC* researchers interviewed by year

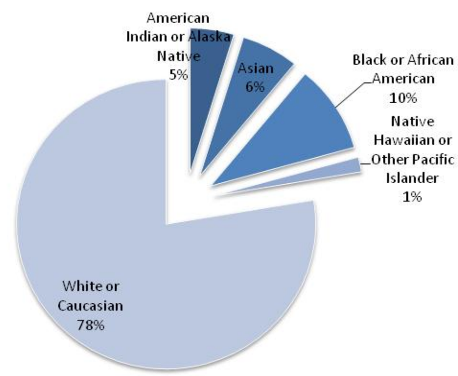
Year	Number	Percent
2007-2008 (N=16)	9	56.3%
2008-2009 (N=13)	7	53.8%
2009-2010 (N=19)	5	26.3%
Total (N=48)	21	43.8%

Student Survey

A student survey instrument was developed to gather the following information from students before and after their teachers participated in the *PolarTREC* project: 1) perceptions about the Polar Regions and science in general, 2) perceptions about STEM careers; and 3) knowledge of the Polar Regions. The survey was divided into three sections. First, students were asked background information, including their teacher's name, name of their school, name of the class they were in when completing the survey, their grade, their gender, their ethnicity, and their race. Second, students were asked to respond to questions related to their future, including their plans for after high school, jobs they were interested in pursuing in the future, and interest in specific STEM careers. Third, students were asked questions related to their general interest in science. Finally, students were asked specific questions about the Arctic and Antarctic. This section was divided into two question types: questions about the importance of understanding of the Polar

Regions, and questions asking the students to rate their content knowledge of various Polar topics, such as ice caps, weather, climate change, polar ecology, geography, and scientific equipment and technology. The student survey is included in Appendix H.

Figure 4: Race of student survey respondents (N=2,155)



Data Collection Method

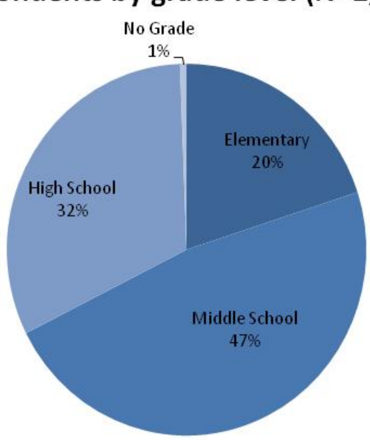
Survey Monkey was used to disseminate the student survey to students. Teachers were sent a web link to the student survey each fall and spring. Teachers facilitated their students' completion of the survey.

Sample

Over the three-year project period, 16 of the 48 participating teachers (33.3%) had their students complete both the pre- and post- student surveys. The 2,155 student surveys (862 pre-surveys and 1,294 post-surveys) of these 16 participating teachers were included in the final analysis. About half of the students who completed the student survey were in the middle- school grades (grades 7 and 8), another third were in high-school grades (grades 9, 10, 11 and 12), and 20% were in elementary-school (grades 5 and 6). Figure 3 shows the breakdown of surveys completed by grade level.

Approximately half of the student surveys were completed by girls and half the surveys were completed by boys. Only 12% of the student surveys were completed by students who identified themselves as Hispanic or Latino. More than 75% of the student surveys were completed by students who identified themselves as white or Caucasian. The majority of surveys were completed by students who planned to attend a four-year college or university after graduating from high school, with 56% of elementary students, 70% of middle school students, and 65% of high school students.

Figure 3: PolarTREC student survey respondents by grade level (N=2,155)



Analysis

For each student survey question the percentage of students' selection of each response (either 1-4 or 1-3 depending on the question) for both the pre-test and the post-test was calculated. Chi-square test of independence to test if the percent of students selecting the different responses were significantly different ($\alpha = 0.05$) between the pre-tests and the post-tests. Chi-square tests of independence were used to test for any significant differences ($P < 0.05$) in the pre and post responses to questions based on the following as well: students' grade level, gender of the student, and teacher. There were too few American

Indian or Alaska Native, Asian, Black or African American, or Native Hawaiian or Other Pacific Islander students to show significant changes between the pre and post-surveys.

Section 2: Teacher Outcomes

This section of the *PolarTREC* Final Evaluation Report discusses teacher-related *PolarTREC* outcomes, including teacher satisfaction with their *PolarTREC* experiences, participation as active members of their respective research teams; and the impact of *PolarTREC* on teachers' professional development both in terms of what they learned from their experiences and how they applied that learning to their classroom.

Teacher Satisfaction

PolarTREC teachers were extremely satisfied with their *PolarTREC* experience. Many said that they want to apply again or participate in a similar program. Others said that their experience was a "dream come true!" The majority of participants wished that their field experience had been longer. In particular, participants noted the important role that ARCUS staff played in coordinating their *PolarTREC* experience, the extent to which they were prepared for their field experience, and the successful relationships they developed with their research team.

> *It was everything that I expected, and it's always more, because it's just so much more intense than what you can imagine until you're there.*
>
> ***PolarTREC* Participant**

ARCUS provides extensive support to the teachers as they prepare for their field season, while they are in the field with the researchers, and when they return. Most of the participants noted this essential coordination role filled by the ARCUS staff. One participant said that ARCUS is "probably the most impressive group that I have ever worked with as an educator." Another said, "I have to say that the ARCUS people are the nicest and the most professional people that I have had the pleasure of working with in a long time...they were really good. They were helpful."

In particular, the participating teachers were pleased by the responsiveness of the ARCUS staff to their needs while in the field. For instance, one participant said, "They were there for us...and I could call anybody anytime." Another participant echoed this sentiment, "Even at weird hours, you know on the weekends and things like that I could go the ARCUS website and somebody would be there that I could contact."

ARCUS provides an extensive orientation, including a meeting in Fairbanks, a logistics phone call with the researcher, logistics coordinator, ARCUS staff, the evaluator, and a former *PolarTREC* teacher or teacher from a similar polar teacher research experience, and numerous emails and individual phone calls. All of the teachers were overwhelmingly positive about the extent of preparation they received from ARCUS. "ARCUS is doing an amazing job…. I have been involved with this TREC program since the first year, and each year the orientation and the pre-trip [preparation]…gets better. They are doing a really nice job of learning from what things they have done in the past and then improving it and what things they need to get teachers … to the point of…getting people to their computers early and practicing and setting up."

A few participants noted concerns about their preparation for their field experience. For instance, several of the participants felt that they brought the wrong clothing or too much clothing with them. This seems to be a personal issue and not one that ARCUS can address directly. A few participants also noted that they were not prepared for the impact of 24-hours of daylight. A handful of the participants noted that they were surprised by the physical requirements of the field work. One participant was unprepared to use a gun. And those that discussed not being prepared to use technology in the field often referred to their lack of practice (after the orientation) with the technology as the reason.

ARCUS uses a multi-layered selection process to match teachers and researchers, which provides opportunities for the researchers to make the final selection. This process resulted in highly successful relationships for the majority of teacher participants, which were essential to their success in the field and their ongoing outreach and collaboration. Several noted that the relationship they developed with their research team was the most significant part of their experience. "I think that the most significant thing...was having [a] developed relationship with the researchers." Many had a similar experience to the teacher who said, "I had an amazing team, especially [the researcher]. I would pretty much follow her to the ends of the earth. She is just fantastic. So I would definitely keep [the researcher] the same. I would go with her anywhere. I mean it. It was great."

These personal relationships have provided the participating teachers with a professional researcher or group of researchers with whom they can discuss science topics and continue to collaborate. And many have continued their relationship after the field season. "I would say probably the most significant was having the interaction with the scientists and the relationship built with those as well as other members of people that were on the Healy. [Another teacher] and I stayed in contact. I keep in contact probably once a month or so with [one of the researchers]; the grad student sometimes will give us information [about] what's part of [what] the scientists prove.… So I sort of keep an update [while] the science still continues."

> *He was always considered a member of the team who would be involved in all aspects of the field work. He jumped into that role without hesitation and quickly gained the full respect of everyone on the project. He was our communicator and he brought out the best in all of us when faced with a camera and microphone.*
>
> **PolarTREC Researcher**

The importance of successfully matching the researcher and teacher was raised by one of the researchers who had selected her participating teacher outside of the *PolarTREC* process. She noted that she selected her teacher prior to applying for the *PolarTREC* program and that while her project was by all measures "successful" next time she would like to go through the more formal selection process. Although she didn't elaborate, the teacher on this project found the post-field experience aspects of *PolarTREC* challenging, particularly lesson plan development, because the subject area he teaches is in one discipline (biology) and the research he participated in was in another (geosciences – engineering).

The participating *PolarTREC* teachers were, by several measures, active participants of the research teams. The teachers recorded daily activities in their journals and in interviews reported participating in research activities that mirrored those reported by researchers. All of the participating teachers described long, active days – they collected and recorded data, participated in planning meetings, operated machinery, made observations, worked in laboratories, and did manual labor. And at the end of the day, the teachers completed their *PolarTREC* journaling and posting requirements, answered student questions, and prepared for their *Live from IPY* events. During interviews 100.0% of the teachers and 85.7% of researchers interviewed described active participation in the research process. The majority of teachers (58.3%) also indicated that they felt like a member of the research team. Of the researcher interviewed, only 14.3% specifically described the teachers as part of their research team. Researchers were also more likely than teachers to describe the teacher's role in the field as conducting outreach. Of the researchers interviewed, 42.9% described the teacher's role as outreach. In comparison, 36.1% of teachers described their role this way (Table 9).

Table 9: Teacher and researcher interview responses related to teacher's role in the field

Response Theme	Teachers		Researchers	
	Number (N=36)	Percent	Number (N=21)	Percent
Description of active participation	36	100.0%	18	85.7%
Member of the team	21	58.3%	3	14.3%
Outreach	13	36.1%	9	42.9%

Teacher Content Knowledge

Participating *PolarTREC* teachers reported the most significant change in their knowledge, understanding, and preparedness to teach scientific methods and inquiry skills. They reported learning how scientists plan for data collection, take measurements, prepare samples, use a variety of tools, conduct observations, and adjust data collection as needed.

Participants also reported significant increases in their knowledge and understanding of numerous topics related to the Polar Regions, including adaptations of life in extreme colds and darkness, environmental changes in the Antarctic environment, and safety issues related to living in severe environments. Participating teachers also reported knowing more about topics related to researchers' specific fields of study, such as methods to gather seismic data to determine ice depth and the character of the ice bed, reasons why the Bering Sea is one of the most productive marine ecosystems in the world, and using an electronic Magnaprobe sampling device with 0.001 cm accuracy and what it measures.

Pre-Post Teacher Survey Results

Teachers reported significant increases in their knowledge of some topics related to the Polar Regions on the pre-post teacher survey. Participating teachers reported being significantly (α = 0.05) more prepared to teach six topic areas: adaptations of life in extreme cold and prolonged darkness; issues involved with changes in the Antarctic environment; safety issues related to living in severe environments, scientific methods and inquiry skills; and describing, graphing, and interpreting data. Of these topics, teachers reported the largest change in preparedness to teach about scientific methods and inquiry skills (t = 4.527; p = 0.000). Participating teachers did not report being significantly more prepared to teach three topic areas: historical overview of the global ice sheet, dynamics of ice sheets, and issues involved with changes in the Arctic environment (Table 10).

Table 10: Mean change in teachers' preparedness to teach general Polar Region topic areas

Topic Area	N	Mean Change	*t*	*P*-Value
Adaptations of life in extreme cold	32	.38	2.816	.008
Adaptations of life in prolonged darkness	32	.47	3.483	.002
Issues involved with changes in the Antarctic environment	31	.39	1.752	.012
Safety issues related to living in severe environments	31	.32	2.061	.048
Scientific methods and inquiry skills	32	.69	4.527	.000
Describing, graphing, and interpreting data	32	.25	2.784	.009
A historical overview of the global ice sheet	30	-.13	-.571	.573
Dynamics of ice sheets	32	.31	1.832	.077
Issues involved with changes in the Arctic environment	32	.22	1.752	.090

In addition, all but two of the 23 teachers who completed section 2 of the Teacher Survey increased their self-reported preparedness to teach the facts, concepts, or skills specific to researchers' studies (Table 11). The overall mean increase in preparedness was 1.024, a statistically significant difference (t =6.844; P-value = 0.000).

Table 11: Mean change in teachers' preparedness to teach about researcher topic areas related to the Polar Regions by year and expedition

Year and Expedition	n (N=23)	Mean Change
2007-2008	**6**	
Antarctic Ice Sheet Studies	1	0.900
Arctic Tundra Dynamics 07	1	1.375
Bering Ecosystem Study 07	1	1.667
Greenland Seabird Ecology	1	0.600
Kuril Islands Biocomplexity	1	0.300
SEDNA Beaufort Sea Ice	1	0.750
2008-2009	**7**	
Antarctic Undersea ROV 08	1	0.500
Arctic Tundra Dynamics 08	1	-0.375
Bering Ecosystem Study 08	1	1.111
Greenland Atmospheric Studies	1	2.571
High Arctic Change 08	1	0.000
Nuvuk Archaeology Studies	1	0.714
Ocean Dynamics Beaufort Sea	1	0.846
2009-2010	**10**	
Alaska Climate Variation 09	1	1.143
Antarctic Undersea ROV 09	1	0.714
Early Spring Plankton and Benthos	1	1.000
High Arctic Change 09	1	1.400
IceCube In-Ice Antarctic Telescope	1	1.200
Microorganisms in Antarctic Glacier Ice	1	1.143
Ocean, Atmosphere, Sea Ice, and Snowpack Interaction	1	2.889

Year and Expedition	n (N=23)	Mean Change
Polar Bear Response to Sea ice Loss	1	1.500
Seabird Ecology in the Bering Sea	1	1.000
Spring Plankton and Changing Ice Coverage	1	0.600

Teacher Interview Results

In interviews, participating teachers reported extensive learning about science content, scientific process and methods, research equipment, career options, and field work logistics. Three of these topics were discussed most often – scientific processes and methods (80% of teachers), science content (69% of teachers), and career options (61% of teachers) (Table 12).

Table 12: Teachers' self-reported knowledge gained while participating in *PolarTREC*

Teacher learning	Number (N=36)	Percent
Scientific process and methods	29	80.6%
Science content	25	69.4%
Career options	22	61.1%
Research equipment	21	58.3%
Field work logistics	7	19.4%
Science equipment	6	16.7%
Other outcomes	3	8.3%

Scientific Processes and Methods

More than 80% of the participating teachers reported learning about scientific processes and methods. Many specifically reported learning about data collection procedures. The following quotes in Table 13 are characteristic of teacher comments related to data collection:

Table 13: Illustrative teacher comments related to teacher learning about science processes and methods

*It was it was very interesting, **[learning about the scientific process**]. There were days when we got to work where some of our instruments weren't working right. You know we'd set out 30 or 40 of these geophone things and you know three quarters of them don't work so we'd move up and down the line and figure out which ones weren't working and try and figure out why they weren't working, reconnect them. You were going through the entire scientific process and if it didn't work then you try to fix it. If that didn't work then you went ahead and tried to do the best you could and ignore it. So I mean it was definitely a real life example of that whole process. PolarTREC* Teacher
*I learned a great deal about how **samples taken in this type of research are actually used**: what proxies are in general and how proxies are used in this research. I learned about how one sample can be used by a number of researchers on different projects to yield different types of information depending upon the proxies they are examining. I learned about linking current climate data to the record of the past to help understand events in the past. I learned that the work done in the field is sometimes a very small part of the actual research: what goes on back in the labs is at least as important, takes much longer, and makes the field research necessary and important. PolarTREC* Teacher
*I learned about the need to be **methodical in the collection of data**. The redundancies that are built into the steps that were taken to gather the samples were very important. Often we*

had one opportunity to collect our samples and if a step was forgotten, it was an opportunity that was completely lost. PolarTREC Teacher
*I was able to see how **oceanographic and field work is actually done**. Since my project generated so much data I have had to learn how to process so much information so that the data becomes useful. Also learned what constitutes good data and what doesn't. PolarTREC* Teacher
*It involved the **observation skills**, which is what the scientist needs to use in terms of observing, measuring, predicting, labeling… going through those types of processes as well as general archeological processes, in terms of how do you go and excavate in an efficient and timely manner, without disturbing objects, how do you record the objects, how do you take notes in terms of what is where and things like that so if the technology goes down you still have a digital record as well as a you know notes records of what is there. PolarTREC* Teacher
*I learned how the **water samples are processed** and all kinds of different parameters from nitrogen content to dissolved oxygen to temperature salinity. Data are collected from these water columns. PolarTREC* Teacher
*I learned a lot of **data collection techniques** both physical collecting so collecting samples out in the snow, snow samples, air samples...I also learned any number of different logging programs on computer that are hooked up to outside, how to log the data. PolarTREC* Teacher
*[I learned] **how to design a research project**, the grant applying process and NSF procedures, designing sampling techniques to get desired outcomes, and working as a team to accomplish individual and group goals**.** PolarTREC* Teacher
*[I learned about] **plankton towing, sediment sampling**, centrifuging, **sampling methods**, sorting and recording protocols. PolarTREC* Teacher

Scientific Content

Almost 70% of the participating teachers also discussed in great detail a range of topics they learned about while participating in *PolarTREC*, often listing numerous science concepts and emphasizing the tremendous gains in their knowledge (Table 14).

Table 14: Illustrative teacher comments related to teacher learning about science content

*The **learning curve was space shuttle blast off steep**! I learned specifics about under ice living organisms, how they feed, how they sense their food, how they move or respond to stress. PolarTREC* Teacher
*Wow... long list--**paleoclimatology, sedimentology, a little paleontology, limnology**, paleomagnetism, various aspects of mineralogy, All kinds of technical information about lake sediment drilling, impact science, lake ice platform and road engineering. PolarTREC* Teacher
*Specifically [I learned about] **phytoplankton and zooplankton and identifying different types of species** and not only their roles but also how they affect other species within the ecosystem and how they themselves are affected by changes possibly due to global*

climate change, receding sea ice and possible changes in the ocean dynamic and ocean temperature. PolarTREC Teacher

A lot of the science that we were doing, I did not have a lot of experience with. I knew what phyto and zooplankton were but I didn't have a lot of information about[things like] the ***lipids, and their eyeballs and how they can remove the lipids*** *from their eyeballs to assess the age of a krill and picking out the age of the krill will help you figure out when they reproduce. PolarTREC* Teacher

[I learned about science] ***processes, things like photosynthesis.*** *I am aware of lots of those basic scientific processes, [but] I think what this [experience] did was enhanced for me how those processes worked on an oceanic level versus the terrestrial level. I knew about phytoplankton before but I never really thought about the timing of the algae blooms in regards to the melting of the sea ice.* *PolarTREC* Teacher

I also learned more about the ***components, the chemical components of our oceanic ecosystem that I was careless to previously.*** *The role of carbon, the role of iron especially. The role of some of these basic elements that as a middle school science teacher, I can recognize and know kind of what they do on the terrestrial level but had no idea of the role that they played in oceanic level, especially iron. PolarTREC* Teacher

I learned more ***about relation ecosystem dynamics, specifically the relationship between the microscopic phyto/zooplankton communities*** *and those of the larger communities as well as the role of the benthic ecosystem in its role within the whole ecosystem dynamic. I had no concept at all about the role of the benthic plays. PolarTREC* Teacher

I learned all about the **different kinds of ice**. *I learned how to look down from above and estimate how old the ice is, whether it is multi-season ice or one-season ice by looking at its color. I learned about all kinds of different physical properties of ice and I learned the difference between a land ice, sea ice, glacier, iceberg...when you see it, you develop an appreciation for the differences rather than just being an abstract concept or something you can recite on the test. PolarTREC* Teacher

*I think the carbon…****the process of carbon and how it moves through our planet as carbon dioxide*** *and as methane and in to produce synthetic process. And in the process of potentially exponentially changing the planet just because as we open up the permafrost and how it start to melt because of global warming a little more, we are releasing carbon which is then created into an atmosphere and then heating it into I think that is one of the biggest processes in these areas that I learned about was we could be changing things in exponential rate as we start warming and melting this permafrost. PolarTREC* Teacher

Well I would say in the five weeks that I was up there, ***I learned more about atmospheric chemistry than I have in my entire life until that point****. PolarTREC* Teacher

[I learned about] ***lithic technology, Nordic prehistory, hunter-gatherer culture****, archaeology. PolarTREC* Teacher

Careers

More than 60% of the *PolarTREC* teachers also talked about having a better understanding of the skill set scientists bring to their work. They also stressed learning about other jobs required to carry out polar research, such as logistics support staff. Teachers also talked about the extensive opportunities they learned about for undergraduate or young adults to work in polar research (Table 15).

Table 15: Illustrative teacher comments related to teacher learning about science careers

*This field experience added an element of **excitement and dynamism to research careers** in this field that I did not see before. I have a clearer picture of the "think-on-you-feet" adaptability that is required for success. A strong independent spirit, stubborn nature, and ability to work with a team are critical for field work. The picture my students bring to the classroom of a scientist in a white lab coat working alone at a lab table was blown out of the water. I recognize that there is much of that in the laboratory side of science careers, but the in-the-field research was, in this case, very much a collaborative effort. We all needed good communications skills as well as having a solid science background and willingness to adapt. We had a "leader," but no boss. We were all involved in making important decisions and we all needed to be willing to accept the decision of the group. This is not a pursuit for mavericks. Science research can be hard work, physically and mentally. PolarTREC* Teacher
*I guess **problem solving** issue is what really awakened me to what scientists have to go through in the field. If you are out there, you better be prepared. You better have all your instruments and still things happen that no one could predict and you know, you still have to problem solve to get the task done maybe without the equipment you planned on and umm, so it highlights the fact that people need as many different kinds of skills and experiences they can have to help solve a problem that you do not know is coming. PolarTREC* Teacher
*It was also interesting to see… you know you think that a scientist is like walk up in a lab with white coats on which is pretty typical of what most stereotypes are. These guys were out there **in the field and you know blowing stuff up** and it was, it was kind of neat to see these, I mean these are super smart guys going for masters or PHD's and you know ice science, if you will I guess like glaciology and they were out there getting their hands dirty. Like these aren't people just sitting on computers analyzing data. PolarTREC Teacher*
*There is a lot more **diversity in science careers** and education than I was aware of -- we don't cover a lot of these in secondary education. PolarTREC Teacher*
*It helped me to realize the **multiple aspects that go into the field work of science**. Not only is there a deep understanding of the science concepts that are required, but also quite a bit of ingenuity to be able to adapt or create tools to fit a new purpose. There is also a need for understanding how to work in team with other scientists who may have different objectives for the same trip. Also, there was a need to work with media crews to report out the findings and the work that was being accomplished. PolarTREC* Teacher
[My experience] really humanized [the scientists]. PolarTREC Teacher
*Everybody thinks that the only people to go to Antarctica or to work for NASA or work or be scientists are crazy smart again glasses, white coat people. And that's not the case. If you **want to be part of NASA, if you want to be a part of Raytheon or work in Antarctica, you don't have to be a nerd scientist to do it**. You can go down and be a driller and drill an ice core. You can go down and you know work on maintenance. If you like working on cars and you want to be some place different then work on the trucks down in Antarctica. I mean whether it's with science or not. They need IT people, they need communications people. I mean everybody was down there to make it work. So they have to be there or it won't.*

PolarTREC Teacher
You do not have to have a PhD to do some really cool stuff. *In fact, you do not really have to have a college degree...but with all kinds of training, you can get involved in all kinds of different scientific research.* *PolarTREC* Teacher
I learned… ***[an ice specialist is the] coolest career***. *You cannot go to school to become an ice specialist. You major in geography. I never really knew you could even major in geography. Everyone knows you do with that, maybe you will become a mapmaker. I do not know, anyway she majored in geography and then answered an ad, something that was placed in some place in her hometown. She just thought it would be interesting, she got on the job training and now she is working on ice breakers as an ice specialist. That is cool.* *PolarTREC* Teacher
You know, the one thing that I really had not thought about until I went up there was that it ***takes a lot people to put a few people on the ice*** *and there are a lot of different careers that are sort of in the background.* *PolarTREC* Teacher
I think one of the things that I was impressed with and really wanted to share, ***[is the number of young people working in polar science].*** *There were 30 people there, 15 of them were 25 or younger and there were four or five who were 18, 19, 20 years old, nearly the same age as a lot of my students and they were getting paid to go up there and assist with all the science stuff. It was amazing to me to realize that there are opportunities for undergraduate students to do these amazing things. And then the other thing is over half of the people up there were ladies and a lot of times I think the perception is that it is gray-haired old men that are doing the science and coming up with all these science things when the pictures that I showed the students are there are these young ladies that are off on these wild expeditions that are coming up with these new creative experiments and they are getting funded and I think it is valuable for the ladies in my classes and the other classes I have talked to recognize that.* *PolarTREC* Teacher

Instructional Practices and Use of Inquiry in the Classroom

While *PolarTREC* teachers did not indicate any significant changes in their self-reported use of effective science instructional methods, they did report significant use of instructional practices characteristic of inquiry-based instruction in interviews and described the use of these instructional practices in the lessons they developed based on their *PolarTREC* experiences. The four primary instructional practices teachers reported were: 1) collect, record, represent, and/or analyze data; 2) engage in hands-on science activities – collect and identify samples, use microscope, build tools (ROV); 3) read other (non-textbook) science-related materials in class – including talking/writing to scientists, following *PolarTREC*, and reading science journals; and 4) using real-world contexts to teach concepts. These are closely aligned to the activities teachers participated in during their *PolarTREC* field work.

Pre-Post Teacher Survey Results

On the *PolarTREC* Pre/Post Teacher Survey of Practices and Polar Knowledge, participating teachers did not indicate any significant changes in their self-reported use of effective science instructional methods (Appendix B). The practices included in the survey were in general effective science instructional methods and not focused clearly on inquiry-based instruction. As a result, *PolarTREC* teachers, who were among the most highly qualified teachers in the United States rated their use of these instructional methods high on both the pre- and the post-survey.

Interview Results

During interviews *PolarTREC* teachers were asked to describe the ways they had applied their *PolarTREC* experience to their classroom. The four most common classroom applications described by teachers during interviews included 1) change in instructional practices (these are further described below), 2) sharing career options with students, 3) relating science topics to the Polar Regions, and 4) having a researcher visit their classroom (Table 16).

Table 16: Teacher reported applications of *PolarTREC* to the classroom

Application to the Classroom	Number (N=36)	Percent
Change in instructional practices	32	88.9%
Career options	18	50.0%
Relate science topics to the polar regions	17	47.2%
Researcher visit	8	22.2%
Developing lessons and other materials	5	13.9%
Covered science content in the classroom	3	8.3%
Easier to communicate science to students	3	8.3%

Change in Instructional Practices

PolarTREC teachers reported using a range of instructional practices characteristic of an inquiry-based approach, including having students design or implement their own investigation, conducting controlled experiments, encouraging students to explain concepts to one another, and working on models and simulations. The practices most commonly integrated by *PolarTREC* teachers, however, were collecting, recording, representing, and/or analyzing data; engaging in hands-on science activities; reading non-textbook science-related materials in class; and using real-world contexts to teach concepts (Table 17).

Table 17: Instructional practices reflected in teacher reported lessons/activities

Instructional Practices	Number (N=36)	Percent
Collect, record, represent, and/or analyze data	20	55.6%
Engage in hands-on science activities	10	27.8%
Read other (non-textbook) science-related materials in class	9	25.0%
Using real-world contexts to teach concepts	8	22.2%
Conducting controlled experiment/investigation	4	11.1%
Encourage students to explain concepts to one another	4	11.1%
Encourage students to consider alternative explanations	4	11.1%
Work with manipulatives – bones, materials, soils, etc.	3	8.3%
Write reflections in a notebook or a journal	3	8.3%
Design or implement own investigation -- determine research questions, design study	3	8.3%
Work on models and simulations	3	8.3%

Of the teachers interviewed 55.6% described specific ways in which their students collected, recorded, represented and/or analyzed data. Another 27.8% of *PolarTREC* teachers described hands-on science activities they had their student carry out, from collecting and identifying samples, to building remote operated vehicles. A quarter of the *PolarTREC* teachers also required their students to read non-textbook science-related materials in the classroom, such as talking or writing to scientists, following the *PolarTREC* journals, and reading science journals. Finally, almost 22.2% of the teachers also used real-world contexts extensively to teach concepts. Examples of these instructional practices are included in Table 18 below:

Table 18: Illustrative teacher comments related to instructional practices implemented after *PolarTREC* participation

*I was able to collect a bunch of the owl pellets and one of the lessons I will be teaching in the spring, the **kids will dissect the owl pellets and then put the whole relationship in that whole process in order of, if there is plenty of lemmings that year**, there is going to be hopefully, we would expect more owls, snowy owl babies because they have more to eat and as the lemming population goes down, then the snowy owl population increases. PolarTREC* Teacher
*I have really tried to make an effort to get **real time data when available especially on those topics where things change all the time from tracking hurricanes to current ones that are happening right now** to, you know plotting tornadoes where they are currently happening in areas to changes in temperature, over time or just plotting temperature data right here in Billings and then comparing it with what students have done in the past or historical records and things like that. So I think I have really tried to inject the applied science part of things to show that science is not in the book. It is these experiments. It is these collections of data and then analyzing that data and things like that. So it made me rethink some of the units and really step away from the mainstream teach them out of the book with those units. I think it also really made me question a lot of the topics that we are asked or we were told that we need to teach as part of the curriculum because there are a lot of these topics that are important, you know like climate change and some polar research and things that really affect everybody's lives but it is something that students in Montana are noticing that our winters they have not been around that long and they are noticing that the winters you know seem to be different from year to year or seems to get hot in the summer and those could be, you know, cyclic changes but they a e noticing those changes and I think it is beneficial to kind of foster that investigative, you know, ability in young people and I think the science part as a whole has been rethinking our curriculum because of a lot of those things and PolarTREC really caused me to rethink our curriculum. PolarTREC* Teacher
*There are also a series of **air sampling stations all over our town back in the late 90's we were identified as having some of the worst air quality** in the nation because of our industrial areas here in town and so the county set up air sampling, remote air sampling sites and I have worked with the county to get access to their data via the internet. It has kind of monitored, monitored some of that on days where there was not much of a breeze and we were kind of smogged in and we looked at how those numbers have changed based on weather conditions. PolarTREC* Teacher
*I'm taking **seismic data off of Dr. Kyle's Web site**. What we're going to do is we are going to look at the raw seismic data, and I guess in a nutshell, what I'm going to try to get them to do is look at the pattern in the volcanic activity. Then we're going to correlate those patterns with video, and photographs that I've got, as to what the actual volcano looks like as you're*

looking at those sorts of patterns and seismic waves. PolarTREC Teacher

Career Options

More than half of the participants specifically reported how they encourage science careers to their students. The following *PolarTREC* teacher descriptions of the ways they shared career options with their students are examples (Table 19).

Table 19: Illustrative teacher comments about encouraging science careers to their students

What I am doing is really you know planting seeds and tending the soil so that hopefully they see that it is fun. That it is exciting. That you can do cool stuff. ***They see themselves as scientists. We do a hawk watch in the fall and they were asked to draw a picture of themselves as the scientists that work****. W e continue to do open ended experiments in all areas, all types of science. PolarTREC* Teacher
One of the things, it's a little sidebar too…one of my students specifically chose a scientist not because of what the scientist was studying, ***he chose the scientist because the scientist was originally from Mexico****, immigrated to the United States and now is a US citizen and for my population, that was a huge deal. That gave a lot my students…that gave a lot of my students hope. I have a pretty high Hispanic population. PolarTREC* Teacher
[The students] had to ***research the different fields that are ocean science related fields****. We researched different Arizona science-type fields and then we compared them. We looked at who provided more, who provided more diversity, what the differences were, we then looked at all the "-ist" out there, the biologist, the entomologist, the "-ist" and then compared the "-ist" as far the variation in the different careers and how then they can, I guess, I am not sure if apply is better or whether or not they are they are interested in them. PolarTREC* Teacher
There were a lot of students on the boat...and I always thought that is was really interesting opportunity that I have not really thought about that was available. You can do this, five to eight weeks just on boat, you know, kind of manual student labor, lab rat sort of stuff. And I always thought that is a more accessible opportunity to the students I teach. I think sometimes careers is a lofty thing to tell the students about because they are really thinking about, you know, who they are going to sit next to at lunch and it is hard to get them motivated to think in long terms and if you could offer them stepping stones like "Hey you know, you can try to qualify as being a student intern in one of your programs by going on the boat and what you can learn about it" ***and I think that kind of stepping stone, career or job opportunity is important to show a student how to get from point A to point, you know F****. PolarTREC* Teacher
I started a career day years ago at my school and I invite people from all over the community and I am trying to get my researchers up from Miami to come this year but that is one thing that has already happened. ***Dr. Oberbauer was such a great thing that he is so close, came up last year and talked to them about his career and his life as a researcher...****priceless. Priceless because you never got the fact that you know, he has to write a little bit and he has to crunch these numbers but he travels a lot to Costa Rica and Barrow and he is always on the everglade. PolarTREC* Teacher
Well, we have actually a – ***I have a series that I picked up a while ago that is like entitled: "Science Careers."*** *It has little sections in there that I go over with the kids, and we've been*

focusing, obviously, more on polar types of careers, and geology types of careers. But we'll actually bring out some names of people that are working in the field, and then we will set up some questions for those people, and email those off periodically, and correspond with those people for at least once or twice. I offer to the kids at that point – and I also ask the people that we're corresponding with – that if the kids want to keep up some kind of contact with some of these researchers, that's a pretty good deal. PolarTREC Teacher

Relate Science Topics to the Polar Regions

When asked how they applied their *PolarTREC* experience to the classroom, more than 47% of the teachers spoke specifically about relating curricular topics directly to the Polar Regions (Table 20).

Table 20: Illustrative teacher comments about relating science topics to the Polar Regions

I connect what we are doing in science with the polar regions*. I try to expose the students to ongoing expeditions in the polar regions. I feel that my experience gives me a broader context to relate concepts to the students. They are able to make real connections to knowledge through my experience. PolarTREC* Teacher
I have just returned from the field, but I plan on using the ***content to create lessons around climate change*** *that revolve around the experience that I had. I plan on working with the research team to find articles and data to create a rich group work project. PolarTREC* Teacher
I'm currently working on a lesson related to ***flow of energy in food chains*** *that will be used by all fourth grade teachers in my home county. We will be using the ecology of the Bering Sea as a context for this unit. PolarTREC* Teacher
Just about every day I am able to say ..."when I was in Antarctica..*." There are so many examples and stories that I can tell my students that go along with every unit and every lesson we do in class. The students love the stories. PolarTREC* Teacher
Layered curriculum unit on Antarctica for my Intro to Science class*...we've focused on ways we can each minimize our impact on the environment with examples from Antarctica. Those examples have inspired my students to try some different things to "go green." PolarTREC* Teacher
I teach earth science. I teach about oceanography and astronomy and everything, so the ***biggest impact is that it is giving me authentic, anecdotal examples to use in class all the time.*** *I have a constant stream of examples where I can say, "Well, that's like the time that we were here and we were doing this, and we had to solve this problem," so that's a powerful tool. PolarTREC* Teacher
Yes- all of the time. During warm-ups — ***I can relate what we are learning to my field experience.*** *For example, when we were learning about the water cycle, I showed picture of glaciers, water vapor rising off of the Bering sea....PolarTREC* Teacher

Researcher Visits

About a quarter of the teachers interviewed reported that a researcher had visited his or her classroom. Researchers shared aspects of their research with students, discussed science topics, brought instruments used in the field for students to see, answered student questions, and participated in science fairs and expos and career fairs. Some researchers participated in classroom visits through video telecommunications.

PolarTREC Teacher-Developed Lessons

PolarTREC teachers developed more than 58 lessons related to the Arctic and Antarctic after they returned from their field experience. Eighteen of these lessons were randomly selected (from those available as of April 30, 2010) for analysis of the instructional practices used in the lessons.   The 18 lessons are summarized in Table 21.

Table 21: Summary of *PolarTREC* teacher lessons reviewed

Recess at 20 Below: This lesson uses a children's book to compare climates. The teacher will read the book, *Recess at 20 Below* (Cindy Aillaud) to class; students will dress paper dolls for cold and tropical climates and compare what students in a tropical climate do to prepare for recess with students who live in the interior of Alaska. Students will learn several consequences caused by sub-zero temperatures. Students will gain awareness that people are able to prepare for a cold environment by adding layers of clothes. The lesson provides an introduction to static electricity being enhanced by colder temperatures.
Science in Antarctica: Students investigate different science projects in Antarctica through the *PolarTREC* and the USAP websites. They will then make a short PowerPoint (or similar) presentation to the rest of the class.
Staying Warm in Antarctica: Two lessons are offered. Lesson 1: Students compare how a layer of blubber can help to keep you warm. Students place one bare hand and one hand with a "blubber glove" into an ice bath, predict which hand will be able to withstand the water longer. Lesson 2: Students use various lab materials to cool one can down as much as possible, while keeping the other as warm as possible. Students develop a data table to record temperature and time for this experiment, as well as design what lab materials are used to cool the cans in the experiment.
Shrunken Spotted Seal Measurement Fun: Students use "Susea" the seal—a seal toy that grows in water—to discover the scientific process. Submerge the shrunken seal toy in water where everyone in the class can watch the changes that take place in the seal daily. Be prepared to transfer the seal to new containers as it grows. Over 3-4 week period, periodically measure and weigh the seal. Revisit the "Shrunken Seal Inquiry" worksheet to reevaluate student hypothesis, experiment, and conclusions. Use the "Susea the Seal Contest" worksheet to make predictions about the seal's growth.
Bedroom Archaeology: The Surface Archaeology Activity allows students to develop some of the knowledge and skills that archaeologists use to do their work while also getting a chore done at home. Students mark objects "discovered" on a map they made of the room to be cleaned. Then students assign a label to each object and record the "find" on a chart.
Little Auk Survival Challenge: Dividing the class into little auks and predators (1 glaucous gull and 1 arctic fox per 30 little auks), students complete a survival game for several seasons. After tallying up total volume of food collected, survival rates of the chicks can be graphed and analyzed.

Geologists in Training: Students make models representing several layers sediment in order to determine the relative ages of sediment layers, practice describing the features of the sediment and drawings the geologic cross-section.

Drawing Diatoms like Ernst Haeckel: Using an online PowerPoint developed by the Smithsonian Institution, students compare and contrast scientific illustrations by Beatrice Potter and Ernst Haeckel. Students draw organism/water microbes from the PowerPoint examples. Students use computer stations and look and draw Hawaii water microbes and contrast them to computer copies of microbes from Hawaii's near shore. Students write in their journal reflecting on what they learned and what they still have questions about.

Asking Significant Questions: An important science skill that needs to be developed is asking significant questions that advance knowledge. This activity helps students to understand the difference between significant and trivial questions.

Properties of Heat Transfer: We all know that Antarctica is a very cold place, and the scientists who work there are not the only ones who have to worry about staying warm. The animals that live in Antarctica have to protect themselves from the frigid conditions on a year-round basis. In order to keep heat they produce from escaping into the environment, these animals are typically well insulated.

Frozen fish? Unique adaptations of Antarctic fish: Students will learn about adaptations that allow fish to survive the frigid waters of Antarctica and will make calculations to demonstrate how they survive these conditions.

Playground Profiling – Topographic Profile Mapping: Students become familiar with topography, while practicing skills in data collection, mapping, and graphing.

Global Snow Cover Changes: This lesson allows students to use online mapping tools to investigate global snow cover changes. Students develop a problem statement about global snow cover and then use mapping tools to investigate their problem or question.

Arctic Animals: How do they measure up? This lesson is intended to have the students think about the animals of the Arctic and which ones they think are the largest. This will help with misconceptions of some animals being smaller than they think and you sneak in the scientific method and measuring skills while doing this lesson. Students will love actively participating and comparing themselves to see where they measure up.

Technology Enhances KWL: The objective of this lesson is for students to utilize recording devices (audio with or without video) and podcasts while learning about the polar regions. After students have written a baseline for what they want to record and have developed questions for their podcast they will interview other students and create at least 3 podcasts under the umbrella of What I Know, What I Want to Know and What I learned about Polar Regions. Students will then burn a CD to share and/ or upload their project to iTunes. This lesson plan can also be used with an entire school during a thematic year.

Puffin Patrol: Students will become familiar with the anatomy/physiology, habitat and lifestyle of puffins. On the 2009 Healy Icebreaker expedition the wildlife survey team was primarily interested in bird diversity and population in the Bering Sea. Puffins were spotted during the cruise, especially feeding in and around Dutch Harbor, Alaska.

Bering Sea Fabulous Food Chain Game: Students will sort organisms found in the Bering Sea into food chains and gain an awareness of the flow of energy and nutrients in the Bering Sea Ecosystem. To play the game: 1. Shuffle the cards. Deal five cards to each player. Place the rest of the cards face down on the table. 2. The player on the dealer's left selects a card from his/her hand. This card serves as the 'start' point for the game. 3. The second player selects a card from his/her hand and builds to the left OR right of the start card. A card representing an organism eaten by the organism on the start card is placed to the left. A card representing an organism that eats the organisms on the start card is placed to the right. 4. If a player cannot place a card down, the player must draw from the deck until a card can be played. If no cards are left on the table, the player must pass. Play continues until a food chain is completed. The winner is the player with no cards remaining or the fewest cards remaining when the food chain is completed. 5. Before you play again, list organisms in the data table that made up your food chain. Play the game 4 or 5 times to build up several food chains.

Why Can't I Eat this Fish? Students will discover how a simple action such as turning on a television will lead to toxins in our food supply. Many of these toxins concentrate in the Arctic because of long-range transport of pollutants in the atmosphere. Scientists in the OASIS project (http://www.*PolarTREC*.com/ocean-atmosphere-sea-ice-and-snowpack-interacti...) study these pollutants in the Arctic. Students will learn about actions that they can take to reduce these pollutants.

On average these lessons included 15 of the specific skills, activities, or teaching strategies characteristic of an inquiry approach. These skills, activities, and teaching strategies aligned with those that teachers described during interviews. More than 40% of the lessons required students to collect, record, represent, and/or analyze data; 56% required hands-on science activities; 33% required students to read non-textbook science-related materials in the classroom, and 72% used real-world contexts to teach concepts. In addition, the lessons used effective instructional practices, such as cooperative learning groups, working with manipulatives, and explaining concept to one another. Almost half of the lessons required students to construct or draw physical models to explain scientific phenomena. Table 22 summarizes the number and percent of lessons that used each skill, activity or strategy. The bolded criteria are those that teachers most often reported using during interviews.

Table 22: Skills, activities, and strategies emphasized in *PolarTREC* teacher-developed lessons

Area	Criteria	Number	Percent
Skills and Activities emphasized	Learning scientific vocabulary	12	66.7%
	Learning specific information about Polar Regions	10	55.6%
	Constructing or drawing physical models to explain scientific phenomena	8	44.4%
	Learning about the contribution of science to everyday life	6	33.3%
	Learning the useful and limiting attributes of models	5	27.8%
	Collect, record, represent, and/or analyze data	**8**	**44.4%**
	Conducting a controlled investigation,	3	16.7%

Area	Criteria	Number	Percent
	manipulating one variable		
	Identifying independent and dependent variables in an investigation	2	11.1%
	Carrying out a planned experiment	2	11.1%
Teaching Strategies Emphasized	Have students work in cooperative learning groups	14	77.8%
	Using real-world contexts to teach concepts	**13**	**72.2%**
	Use of open-ended questions	12	66.7%
	Encourage students to explain concepts to one another	10	55.6%
	Help students see connections between science and other disciplines	8	44.4%
	Provide concrete experience before abstract concepts	8	44.4%
	Require students to supply evidence to support their claims	7	38.9%
	Encourage students to consider alternative explanations	7	38.9%
	Having students prepare/project/laboratory/research projects	2	11.1%
	Specifically encourage participation of females/minorities in science	2	11.1%
Student Activities Emphasized	Work with manipulatives	11	61.1%
	Work in cooperative learning groups	11	61.1%
	Engage in hands-on science activities.	**10**	**55.6%**
	Work on models and simulations	9	50.0%
	Reflect on readings, activities, or problems in groups	8	44.4%
	Reflect on readings, activities, or problems individually	7	38.9%
	Play a game to build or review knowledge/ skills	6	33.3%
	Read other (non-textbook) science-related materials in class	**6**	**33.3%**
	Write reflections in a notebook or a journal	5	27.8%
	Participate in discussions with the teacher to further science understanding	4	22.2%
	Design or implement own investigation	3	16.7%
	Evaluate the validity of arguments or claims	3	16.7%

Area	Criteria	Number	Percent
	Write a description of a plan, procedure, or problem-solving process	3	16.7%
	Participate in student-led discussions	3	16.7%
	Make formal presentations to the class	3	16.7%
	Work on solving real-world problems	3	16.7%
	Share ideas or solve problems with each other in small groups	3	16.7%
	Prepare written science reports	2	11.1%
	Take short- answer question tests (e.g. multiple choice, true/false, fill in the blank)	2	11.1%
	Engage in performance tasks for assessment purposes	2	11.1%

Section 3: Researcher Outcomes

In this section we summarize the evaluation's findings about the *PolarTREC* researchers' experiences collaborating with a teacher both in the field and before and after the field research experience. We used data gathered from interviews with researchers completed after the researchers had been involved with *PolarTREC* for at least one year.

> *I think pairing teachers with researchers as they do their field work is a great model and could be expanded to all sorts of fields in all parts of the world.*
>
> **PolarTREC Researcher**

The findings are organized by evaluation question. First we consider the extent to which researchers were satisfied with their *PolarTREC* experience. Next we look at what researchers learned about K-12 education from their experience with *PolarTREC*. Finally, we discuss the extent to which researchers view *PolarTREC* as an outreach activity.

Researcher Satisfaction

Interviewed researchers were overwhelmingly positive about their *PolarTREC* experience. Almost half of the interviewed researchers indicated that they would, or already had, applied for another *PolarTREC* teacher or funded a teacher through their own grant. More than 40% shared a general positive comment about their *PolarTREC* teacher and 38% described *PolarTREC*'s impact on their outreach efforts (Table 23).

Table 23: Positive researcher responses related to program satisfaction

	Number (N=21)	Percent
ARCUS role essential	11	52.4%
Applied for another teacher/funded own teacher/wants to repeat experience	10	47.6%
Positive comment about the teacher	9	42.9%
Positive comment in general	6	28.6%
Benefits scientific process	4	19.0%

ARCUS's Role Essential

Interviewed researchers reported that ARCUS's role in providing research experiences for K-12 teachers was essential for several reasons, including matching the right teachers with the right expeditions, facilitating the logistics, and managing and delivering the public communications between the teacher/researcher and classrooms around the United States. Almost half of the researchers interviewed indicated that they had, or would apply for another teacher to join their research team. Most of those who indicated they would apply for another teacher noted the many positive aspects of having a teacher on the research team and the ease of including a teacher on the research team. Table 24 lists sample comments illustrating ARCUS's essential role.

Table 24: Illustrative researcher comments about ARCUS's role

*ARCUS is **phenomenal at finding the people**, getting the applications, and getting the logistics in place. So we could then focus on the experience in the field. PolarTREC* Researcher
*Yeah I mean, it is **electronic logistics and it is field logistics** and it is travel logistics and it is safety logistics and all that so…I think they do a great job and I was really pleased when they got renewed again because they, they deserved it. PolarTREC* Researcher
*Having the whole ability to **host Web sites is fantastic**, because that's something that not every – certainly not any high school can usually handle, and it's not something that people here at the Institute for Geophysics want to expend a huge amount of energy on. PolarTREC* Researcher
*The **Polar TREC site really worked out well from a variety of viewpoints**, you know just for people other than students I think, like our families who were able to follow the trip. I am sure [our teacher] used it very extensively. I do not have any, I have not asked that question of her but I am positive that she did. PolarTREC* Researcher
*So I think it's really **important to have organizations like PolarTREC** that can set these things up and vet teachers, and have a group of people that can make some sort of comprehensive decision about whether or not somebody is even going to survive in on a shipboard or a field situation. PolarTREC* Researcher
***I have another PolarTREC teacher for this coming year**, and we had to really struggle because there were some issues with the original teacher that I selected and his school district, and so it was kind of this on again/off again, on again/off again, reorganize, ask for more money sort of thing, and PolarTREC was awesome throughout the whole thing. And so the willingness of Kristin and Janet to step up and say, "No, we're gonna make this work," is what really makes this program fantastic. It's not the sort of thing that would work if you had people who were like, "Yeah, we're just gonna plug this one to that one, and then whatever." They're really, really intensely interested in everybody having a really successful experience, and I think that's incredibly valuable. So, making sure you get the right people in the right place is something that's really important, and those two are great to work with. They've just been really kind, and they do a lot. **I'm impressed**. PolarTREC* Researcher
*Probably the best indication [of our support for programs like PolarTREC] is that if we were not supported by PolarTREC to take a teacher we would probably try to take a teacher anyway because we feel very strongly about it. Because our program is all about education, education research, and so we really want to get as much out of it as we can and do as much with the program as we can. **The thing that PolarTREC does is that they make it really easy to identify a good teacher to take** and to actually make it happen and make it happen in an effective and productive way. PolarTREC* Researcher
*Overall **I was really pleased** and I can see that [PolarTREC is] really trying to tie in the latest technology that can be done and it really is a help to the scientists to have this venue because the teachers benefit so much for the position they are in. It takes a lot of that kind of task off the burden of the scientists so they can do their science, translate it with the teacher into a language that makes sense and then we are getting it out to the public. It was very nice when we held our live from IPY presentation. It was one of the last days we were on the ice and somebody had prepared slides for us and cooked it down and condensed it and all*

we had to do was comment from the ice. It was just like "boy, can I hire you for my day job." I was so pleased with that because I know how much effort it takes to do outreach and when you are on the ice you can only do so many things. You are out there under very difficult conditions so having that land base coordination, you guys really thought that through very, very carefully. PolarTREC Researcher
***They have access to teachers, high quality professionals** a pool of them...the infrastructure that is needed for the webcasts. It would be expensive to set it up...the advertising, helping getting the research, the linking with other outreach, they were networked. When I was Antarctica, there was an ice sheet day...She was in the audience. I was calling in from the field. It is hard to get people in their offices; homes can log in and interact. PolarTREC* Researcher
*It is amazing. **I have seen the entire process and the only complaint I have is that the government needs to give you all more money so you can get more teachers**. That is my one certifiable complaint because I could not be more pleased—the training they received. He had zero understanding—never owned a laptop in his life and by the end [of the field season] was transmitting, web sites with compressed images, and I was able to call my family on Easter Sunday, which I had never been able to do in the field before. So you guys were able to bring us a whole [new] level of technology. PolarTREC* Researcher

Positive Comments about Teachers

Almost half of the researchers interviewed specifically talked about their *PolarTREC* teacher. The researchers were impressed with the teachers' ability to perform physically and mentally in the field. They used words like, positive attitude, independent, bright, self-motivated, interested, hard working, and enthusiastic to describe their *PolarTREC* teacher. Some illustrative comments are included in Table 25.

Table 25: Researcher comments about *PolarTREC* teachers

***Having a teacher along was absolutely the best thing we did for the project**....he was an essential element! PolarTREC* Researcher
***We were really happy with him by far**. There is not too much I would change about him specifically or the role he took as a science teacher. He had some experience out in the field previously from living in Alaska which was really helpful. PolarTREC* Researcher
*And he was not so shocked by it. **He had obviously done some background research and he lives in Vermont, off the grid so it was not, you know as much of a shock for him** I think coming up here although this may be colder and just imagine it being in the summer, not that it was colder where he used to working at by any means… PolarTREC* Researcher
***She was very independent when she has some ideas**, she went in and who should I talk this or that, and I would say well go out check with the chief, and she would go off on her own and take care of the tasks, you know, as opposed to like I didn't have to just hold her hand and walk her around. PolarTREC* Researcher
*You know she was great. **She was fit and she was strong and she was determined and made the best out of the situation**, even the bad weather situation and she was great. She is just a wonderful person to have along with us. PolarTREC* Researcher

It was a wicked steep learning curve. I have to give him a lot of credit. *He was basically going "they should have a kid out here doing this." I was supporting him and he was supporting me because I would have my bad days too. It all worked out in the end but he really earned his stripes on that one. There is a lot of stuff you teach those teachers. PolarTREC* Researcher
It was really fantastic. ***She was so enthusiastic and picked up so much***. *I think part of the learning experience for me is learning what teachers know and do not know. PolarTREC* Researcher
Most of the experiences I've had with teachers, they've been ***very self-motivated,*** *and where certainly they've asked questions about what we're doing and stuff. They've been essentially designing their own way of interacting with the whole thing. PolarTREC* Researcher
She's also very bright, *so I mean, there was nothing like she had to be hand-held or anything like that. PolarTREC* Researcher
His presence was nothing but positive. *He interviewed everyone and their part in the project. So that made everyone feel included and important! This works in all sorts of positive ways in a remote field camp. Plus he has such a positive but realistic attitude to all that he was very easy to like and share in his ideas for educational communications. He was a totally positive element in the field campaign***.** *PolarTREC* Researcher
Very positively. It provided a new dimension. *There were times when the research had to be shortly interrupted for him to perform his functions but the gains were far greater than the costs. PolarTREC* Researcher

Benefits to Scientific Process

The researchers also found that their research benefited from the inclusion of a teacher on their research team. More than half of the researchers specifically noted that one of the strengths of the *PolarTREC* project is its benefit to the scientific process. They noted that the researchers were asked by the teachers and their students to explain the science and data collection that was occurring and to "boil it down to the raw essence." This interaction helped the research teams see how their research fits into the bigger world picture (Table 24).

Table 26: Researcher comments about benefits to science

A positive. We certainly do more describing of what is going on. We have done this for so many years you kind of get in a routine. Like ***a teacher actually kind of reminds you why you are there***, *what you are trying to do and you explain stuff in a way we would not normally do. In terms of the negatives, we do what we do. There is really no negative impact at all having a teacher there. PolarTREC* Researcher
I think it was enhanced because ***he always had a lot of questions and it is good that it requires you to think about what you are doing instead of just doing it.*** *If we were, maybe we would be putting a sensor out at a station at a certain height or something and he might ask why. Things like that make you think about it a little bit more when you have somebody asking you questions. As far as a distraction, I suppose it can be a distraction to ask a lot of questions because it gets away from your work but we never really felt that way about it. PolarTREC*

Researcher

*I think that the **scientific process itself benefits enormously from having a high school teacher embedded in there**. We have to drop any fancy lingo we may have. We have to cook things down to the raw essence and we have to work with the teachers to try to find out how I get this across to the general public. You could not find a better group of people to put in the field with scientists than high school teachers—or just teachers in general. PolarTREC* Researcher

*...**we would explain what we were doing and that would actually help us structure things a lot better**...by asking questions we had to reassess why we do things and often we might change something like "well maybe we should go and get this…download all this information first and then look at it." PolarTREC* Researcher

Areas for Improvement

The researchers also noted a few areas for improvement. Several of the researchers said that they would have liked to have more time face-to-face with their teacher prior to the field season, including time to visit the classroom. Researchers who were able to meet their teacher before the expedition noted this time as a strength that improved the field season and clarified expectations for the work in the field and for continuation of the researcher-teacher relationship and outreach after the field season. Several also noted that ongoing collaboration with teachers after the field season was difficult. Table 27 summarizes these responses.

Table 27: Researcher reported areas for improvement

	Number (N=21)	Percent
More time with teacher before field season	8	38.1%
Teacher selection	5	23.8%
Ongoing collaboration with teacher difficult	4	19.0%
Process was time consuming	3	14.3%
Local to increase collaboration between teacher and researcher	2	9.5%
Technology problem	2	9.5%
Better defined expectations	1	4.8%
Length of field season	1	4.8%

One researcher particularly recommended better defined expectations for follow-up and outreach after the teachers' field experiences. He felt that the teacher did not incorporate the field research experience into her classroom or successfully facilitate researcher visits to her school. When the researchers did visit the teachers' school, turnout was low.

This researcher's experience however, was not echoed by any of the others interviewed and should not necessarily be a poor reflection on *PolarTREC* overall. Nonetheless, the expectations for outreach may have been better communicated between teachers and researchers who were able to meet prior to their field season. One researcher in particular said that he was able to meet with his project's *PolarTREC* teacher soon after the project began, and together they defined each partner's outreach roles and responsibilities.

One additional area that the researchers talked about was teacher selection. Although no general theme about teacher selection criteria was raised during the interviews, we have listed the individual concerns researchers raised here to think about during continued program implementation.

- The physical aspects of the field work should not be overlooked in the assessment and applicants need to be made aware of the physical challenges they may face
- The teachers selected have had a lot of experiences like *PolarTREC,* and ARCUS might want to spread out the "wealth a bit". One of the researchers said, "If teachers have 8 or 10 different types of experiences like this I am not quite sure how it influences the decision making because obviously previous experience prepares the teachers to be able to participate, particularly when they are in the field in such a remote location as Antarctica. But, again, if the teacher has already done six of these I sort of wonder if it would be better that a teacher who had no previous experience in this might be selected versus the sort of professional teacher that does a lot of these."
- Another researcher echoed the observation that many of the selected teachers had significant experience with special projects like *PolarTREC* and noted that his teacher's additional experiences may have made her too busy to prioritize *PolarTREC*.

Researcher Learning About K-12 Education

The majority of researchers interviewed reported learning about one or more specific aspects of K-12 education. Although few of the researchers commented specifically on the same aspect, their comments fell into two areas: 1) teachers' knowledge, understanding, and challenges; and 2) students understanding (Table 28).

Table 28: Researcher reported learning about K-12 education

	Number (N=21)	Percent
Better understanding of translating science to classroom	7	33.3%
Job of the teacher	7	33.3%
What students know or don't know about science	5	23.8%
Testing requirements	4	19.0%
Student engagement or interest in science	2	9.5%
Didn't learn anything new about K-12	1	4.8%
Non-traditional education	1	4.8%
Teachers knowledge of science	1	4.8%

Those who spoke about teacher knowledge, understanding and the challenges teachers face commented specifically that the *PolarTREC* project helped them to understand what teachers know and do not know about science and that teachers do not always have time to gather the scientific background information they need to teach a given topic. They also noted learning about the many hurdles teachers face in their day-to-day work, like testing, curriculum requirements, school politics, policies, standards, and leaving the classroom to do the field work. Finally, the researchers noted that teachers look at the world in a conceptually different way than scientists do and it is not always easy to get teachers to think like a scientist (Table 29).

Table 29: Researcher comments about teacher knowledge, understanding, and challenges

*It was very **interesting to hear [the teachers] describe the kinds of work that they do**. Whether it's the impact teaching or the activities that they use in the classroom we're always interested to what kinds of things that they do with their students. PolarTREC* Researcher
*Well, I know that **secondary school teachers work a lot harder than University professors**...there is a lot of commonality. Granted my students are older and there are [fewer discipline problems] and [university students] are more self selecting, but a lot of the conversations we had were just sort of education conversations in general. You know, what do you, what do you find works in the classroom or what do you think is effective or how do you think we could do this or do you think students of this age will be able to handle these data sets or make this project… PolarTREC* Researcher
*[I was] continually r**eminded of all the hurdles [K-12 teachers] have [to jump through]**actually just deliver their own content, let along try to think about bringing in the scientific standpoint. You just kind of realize that teachers have been trained differently than scientists have throughout their educational program. PolarTREC* Researcher
*One thing that I was reminded of with the Polar TREC teachers this year, **they conceptually view the world quite differently than a scientist.** One of the things that is frustrating in any of these teacher education programs, what we strive to do is to actually get the teacher to think like a scientist and that is not always easy. When you work with them for a month straight you kind of realize how different a world you come from. PolarTREC* Researcher
*I think it is always a learning experience when you take the teachers out. I would say **we still have a lot of work to go to try to actually get teachers to think more like scientists**. If this is any indication on Polar TREC it is always one thing that comes up in every educational thing I work with teachers is that it is a very hard bridge to make and to actually figure out how you can actually get teachers to understand science in the way that we as scientists view it so that can be passed on to their kids. I do not have an answer to it but it is the one thing that I took away from last year's experience. PolarTREC* Researcher
*One thing that I learned from this is that the **teachers do not always have the time to do the background research that gets done,** not up to speed, but gets the in depth understanding that kind of leads to the point there the science project is at. There is a lot---science processes are at this pretty high level and there are a lot of steps that have head up to that. Sometimes I would present something or come up with some concept for sharing with the students and I did give her enough background information or enough resources to be able to understand what led up to that—what the nuggets were—what the building blocks were. It was just a thing that was too big. PolarTREC* Researcher
*Again, you gain **new respect for all the things teachers have to deal with that we as scientists do not have to.** You have a much better perception of the hurdles and difficulties of implementing more, say inquiry based activities or other things in the classroom. You try to gain a better perspective of how teachers think about science versus how you as a scientist do. PolarTREC* Researcher
*I learned that every teacher is different and the standards they are required to teach to, which I wasn't really aware of how strict the standards are and there is really a **limited amount***

***of flexibility within those standards**. PolarTREC* Researcher
*So just the whole complexity of you have these incredibly creative human beings who are **really service oriented trying to teach kids and the struggles they have to go through with the bureaucracy of this system**. PolarTREC* Researcher
*Well, I think that the structure of the current system—it is a good way of measuring progress—but perhaps not the best way of making progress. [PolarTREC teacher] is working with students who are artistic rather than scientific so their learning styles are not necessarily the learning styles that are traditionally taught to in our school system. **So I saw her struggling with trying to make things relevant to her students and the interest of her students and to their strengths.** They all had incredible strengths but they maybe are not necessarily the kind of students who are going to sit down and take a test really well. PolarTREC* Researcher
*The real struggle [for teachers] is to **take these real world experiences and then relate them to standards** so that they are still addressing the standards and yet they are also making it exciting and relevant for the students. [I have a better] understanding of the struggles that the teachers are going through to try and meet these kind of demands. PolarTREC* Researcher

Researchers also noted that because of their one-on-one experience with a teacher they had a better understanding of how to break their research down for a K-12 audience and how this would look in the classroom (Table 30).

Table 30: Researcher comments translating science to K-12 audience

*I knew but it was reinforced that there are not only skills involved but that there is a particular **outlook that is necessary to reinterpret science** for the k-12 levels. PolarTREC* Researcher
*I think it's been helpful, as I said before, because it gives me the idea that having a product, **such as something that's solid and hands-on, really makes the kids motivated and makes them proud**. So, when they're producing something like an ROV that they can hold in their hands and show people at the end of the time, that's a really good motivation and a good teaching tool. PolarTREC* Researcher
*From [the PolarTREC teacher] I learned there is **no need to water things down** if you approach the subject in the right way and gather in the audience. PolarTREC* Researcher
*Tons!! He **forced me to simplify and also to think about my audience more**. I also learned more about how to take a difficult topic and lead into it with a ramp up of info. It was just great...it was also helpful that I visited his school before the trip so I had a sense of how to communicate with them from that experience also. This instantly communicates to all of my outreach. PolarTREC* Researcher
*I think I will turn this around a little bit and say that some of the experiences I had were – well, all of them were very good, but some of the ones that sort of opened my eyes to the importance of having teachers out on board, particularly either a Coast Guard ship (which is one of the places where I've been involved with teachers), is that they say, quite frankly, that obviously it's just like not every basketball player's going to be in the MBA, n**ot every good or even every student taking science in high school, or whatever, is going to wind up being a research scientist.** But they found that it was really nice to be able to see there were all sorts*

of other ways that they could go back and have their students get excited about learning about the world, and not necessarily being a scientist, and one of the things is having them go into the Coast Guard, and experience things like that. PolarTREC Researcher

Those who spoke about having a better understanding of K-12 students noted several changes. Several of the researchers said that they learned that elementary-aged students were able to understand the scientific content of their research, even the technical aspects (Table 31).

Table 31: Researcher comments about K-12 students

[The students] seem to be ***interested in science*** *assuming that you make it interesting to them. I think that would be, not that it is hard to make science interesting, but you can make it boring if you really try. PolarTREC* Researcher
They wanted to know these questions about climate change. ***They asked questions*** *that my undergraduates and undergraduate and graduate school would ask. They were very carefully, well thought out questions. We explained everything from the social life to the scientific life on this floating ice. PolarTREC* Researcher
I learned that the kids have a real ***wide range of familiarity*** *or lack of with the science; some kids aren't aware that climate change is a hot topic...PolarTREC* Researcher
I learned that the ***students can accomplish a great deal,*** *and then I think that the separating it out is that it really takes dedication on the part of the teacher. PolarTREC* Researcher
The kids were sharp*, really picked up a lot and I think it reflected well ultimately in their standardized testing, too, because they did a lot of extra reading and all that sort of thing. PolarTREC* Researcher
I was really impressed *when we went out to visit the elementary school class. They treated [their assignment to follow their teacher's PolarTREC expedition] like they were the scientists on the expedition. I thought that was really a tremendous experience for the kids to have a virtual expedition... [They did] all sorts of mapping, figuring out where we were. You know you are talking about second and third grade bilingual students. They could go right to the globe and figure out where we were, knew about latitude and longitude so I think it was really a tremendous learning vehicle for the kids and for them in that respect. It was more like they were the scientists who participated in the trip. PolarTREC* Researcher
It was really a good feeling because the teacher and the kids seemed to ***really get into the expedition and really enjoyed it*** *a great deal as well. It seemed like a terrific learning experience. PolarTREC* Researcher

PolarTREC as an Outreach Activity

The researchers viewed *PolarTREC* as an essential outreach activity for their research project. Many of the researchers also noted that their outreach through *PolarTREC* was "easy." One researcher specifically noted that *PolarTREC* "takes a lot of [the outreach tasks] of the burden of the scientists so they can do their science." And another said that "I've got two big projects going on at the same time now. So having somebody who is a specialist and an expert in that [communicating with students] and having *PolarTREC* as a medium for getting this out and doing the public relations and so on is fantastic…. It's the kind of collaboration that is necessary to do this well and some research institutes have their own sort of ways of doing public relations and education and they [have a] whole staff dedicated to it. We don't. So it really is a win-win situation." Table 32 summarizes the researcher reported impact on outreach themes that emerged from the interviews.

Table 32: Researcher reported impact on outreach

	Number (N=21)	Percent
Expanded outreach	11	52.4%
Articulate to the public	8	38.1%
Reached K-12 audience	6	28.6%
Good for outreach and awareness	1	4.8%

Other researchers said that the outreach provided by their teacher also improved the research project's public image and articulated complex ideas to the public at large. One of the interviewed researchers explained the impact of the Live from IPY events this way: "We are used to justifying ourselves, rationalizing ourselves, explaining ourselves to other scientists. What about the guy at the gas station, the people whose taxes pay for our science? How do we explain to them why what we are doing is important?"

Another explained that the teacher was able to capture the public's interest and create a bridge between the scientists and the public at large. "It was really considered unique that a teacher could go on this [expedition to Antarctica] so it really enhanced our project and its presentation to the public at large. [With the teacher], we participated in a couple TV interviews. And a couple of newspaper articles in the local paper really talked more about the teacher and her experience. Along with that we get a lot of visibility within the community for the type of science that we are involved in and doing. She was almost like the public relations arm of the project. I think it really went over well that a teacher was involved in this kind of effort. It really increased our [public image and bridged the] separation between science and the public at large."

One of the researchers also explained how his collaboration with the *PolarTREC* teacher significantly expanded his outreach. "We have a rich experiment menu that we use in K-12 outreach, and he has exported those into his classrooms. Certainly he has developed some other activities that we will take advantage of as we expand our menu of things to do in schools for outreach, but the one thing I think he did was that he challenged us to think bigger. For a Center of our magnitude we ought to be thinking big anyway. He and I sat down one afternoon, the first time we met, and he said he was challenged to have a big idea by Polar TREC. As a result of that he and I concocted this concept we called Climate Pathfinders, which was the notion that we would attempt to provide a million school children internationally some common baseline of understanding about climate change science. That is actually starting to unfold, and we have just recently completed a pilot program in the Topeka Public Schools that is called Climate Pathfinders [simply] as a result of he and I sitting around the table. Again, Topeka Public Schools [is] a school district with a higher percentage of under-represented minority school children at the middle school level, [one] that we hope to grow into a national outreach effort. That is really in my judgment the best result of what we have gotten with him."

Section 4: Student Outcomes

This section discusses the impact of *PolarTREC* on student interest and knowledge about the Polar Regions. We used data gathered from the student Polar region interest and knowledge survey. The survey asked students about five factors that contribute to students' pursuit of STEM careers (Dorsen, et. al. 2006): career awareness and decision to pursue a STEM career; academic preparation and achievement; identification with STEM careers; self-efficacy to do science; and interest, enjoyment and motivation. In addition the survey asked students to rate their knowledge of the Polar Regions.

Student Pre/Post Survey Results

The results of the pre and post survey administrations are summarized by question. Appendix I includes detailed tables showing the pre, post, difference between pre and post, and chi-square results for each question part. The results described below and in Appendix I are based on 2,155 student surveys -- 862 pre-surveys and 1,294 post-surveys.

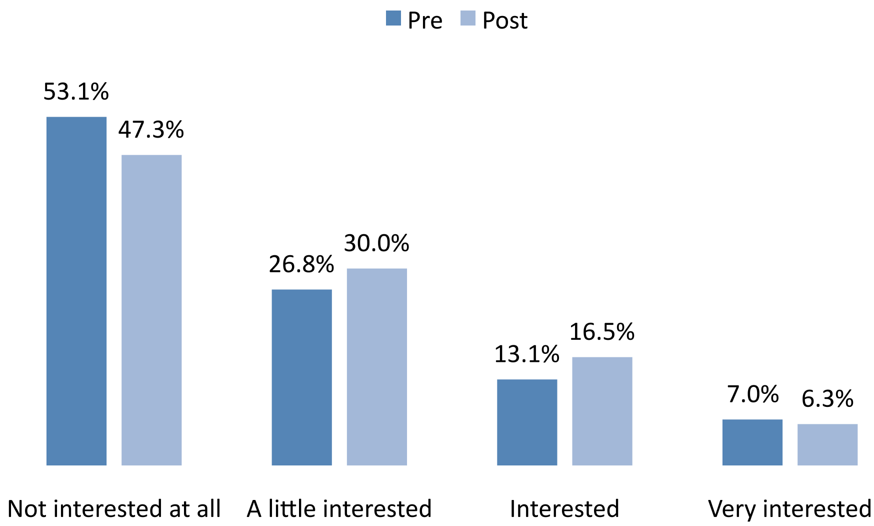
Results Related to Students Interest in STEM Careers

Question 13 asked students to report how interested they were in 14 STEM careers – not interested at all; a little interested; interested; or very interested:

- Engineer
- Mathematician
- Botanist
- Geologist
- High School Science Teacher
- Chemist
- Seismologist
- Marine biologist
- Volcanologist
- Atmospheric Scientist
- **Biologist**
- Elementary School Teacher
- Middle School Teacher
- Zoologist

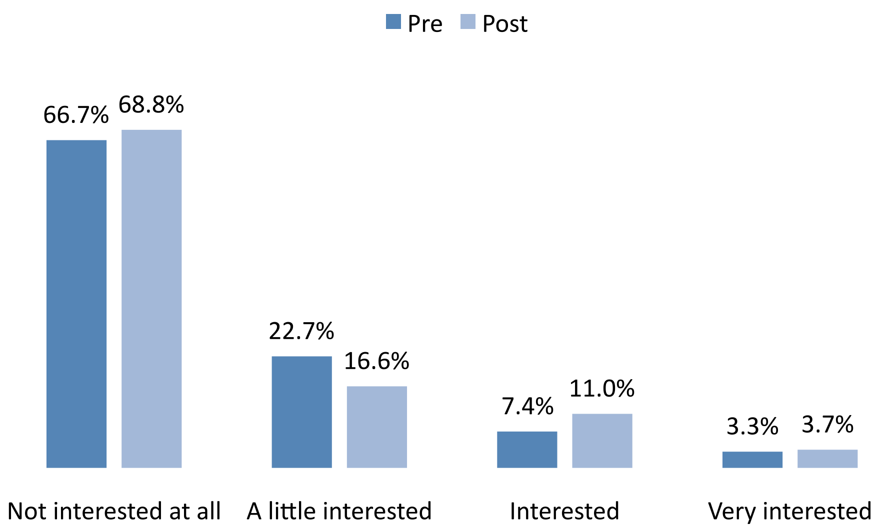
There were no significant differences between the pre- and post-administrations of the student survey to the career choices except biologist. More students reported being *a little interested* or *interested* in biologist as a possible future career and less students reported *not interested at all* in a future career as a biologist (Figure 5). These were statistically significant differences (X^2 = 9.250; P-value = 0.026).

Figure 5: Percent of students interested in being a biologist



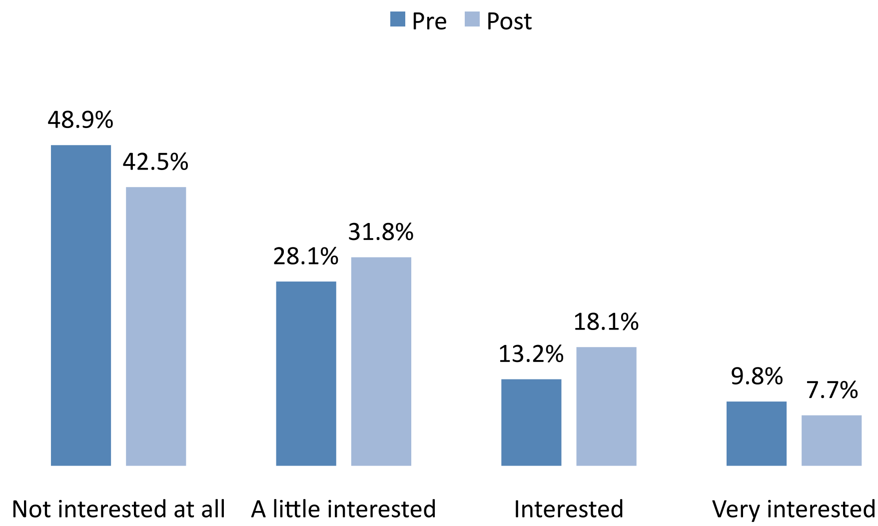
There were no significant differences in the responses to "*How interested are you in each of the jobs below as possible future careers?*" by grade level. However, the results showed significant differences in the responses of girls and boys. Girls reported significant increases in their interest in three future careers: mathematician (X^2 = 8.772 *P*-value = 0.032), biologist (X^2 = 8.748; *P*-value = 0.033), and high school science teacher (X^2 = 11.312; *P*-value = 0.010). The percent of girls who reported being *interested or very interested* in being a mathematician increased 4.0%; however the percent who were not interested at all increased slightly (Figure 6).

Figure 6: Percent of girls interested in being a mathematician



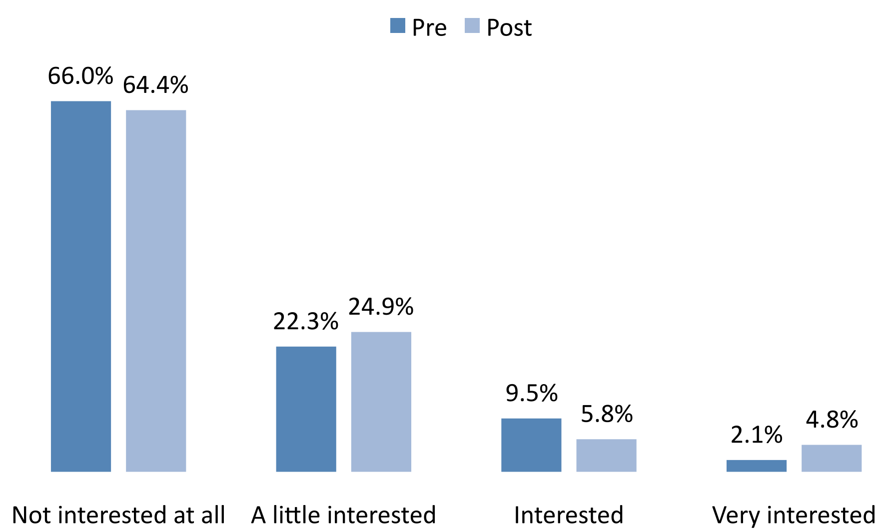
The percent of girls who reported being *interested or very interested* in being a biologist increased 2.8%. However, the percent of girls *not interested at all* decreased by 6.4% (Figure 7)

Figure 7: Percent of girls interested in being a biologist



The percent of girls who reported being *interested or very interested* in being a high school science teacher decreased by only one percent, but the percent of girls who reported being *very interested* increased by 2.7%, and the percent of girls who reported being *not interested at all* decreased by almost two percent (Figure 8).

Figure 8: Percent of girls interested in being a high school teacher



Results Related to Attitudes about Science

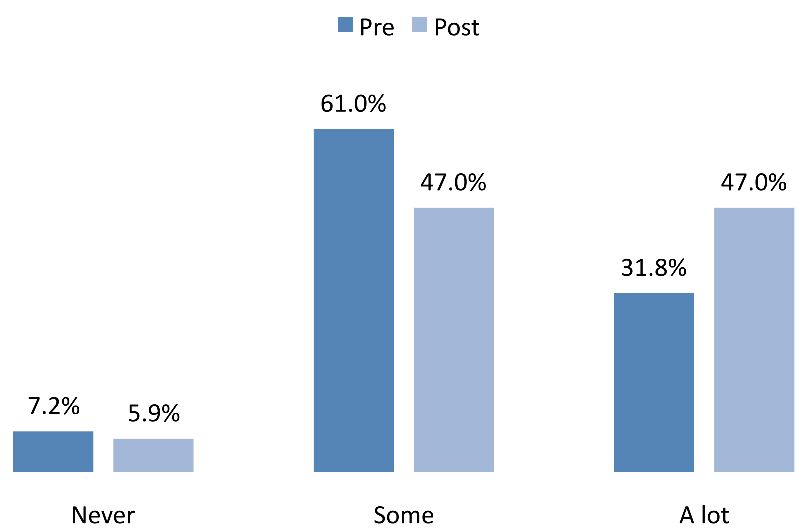
Four questions related to student attitudes about science:

1. How often have you explored science research activities at a special camp in the summer?
2. How often have you explore science research activities in school?

3. How often have you explored science research activities on your own time?
4. Below are statements about science. Please select the response that reflects your level of agreement with each statement – this is not like me at all; this is kind of like me; this is like me; or this is totally like me.

Overall, the student responses to three questions changed significantly from the pre-survey to the post –survey. First, more students reported that they explore science research activities in school. On the pre-survey, 31.8% of the students reported exploring science research activities *a lot*. On the post-survey 47.0% of students reported exploring science research activities *a lot* (Figure 9). This was a significant increase (X^2 = 49.542; *P*-value = 0.000). There was not a significant change in percent of students who reported that they explored science research activities at a special camp or on their own.

Figure 9: Percent of students exploring science research activities in school



Second, more students reported that they could handle more difficult science. On the pre-survey 8.7% of students reported that *this is totally like me* in comparison to 13.1% on the post-survey; a significant difference (X^2 = 12.787; *P*-value = 0.005). Third, more students reported that they will need a good understanding of science for their future work. On the pre-survey 18.0% of students reported that *this is like me* in comparison to 22.9% of students on the post-survey; a significant difference (X^2 = 7.912; *P*-value = 0.048).

When the results were analyzed by grade level, there were several significant differences. Elementary and middle school students reported at significantly higher rates of exploring science research activities in school, whereas high school students did not (Figures 10 and 11).

Figure 10: Percent of elementary students who report exploring science research activities in school

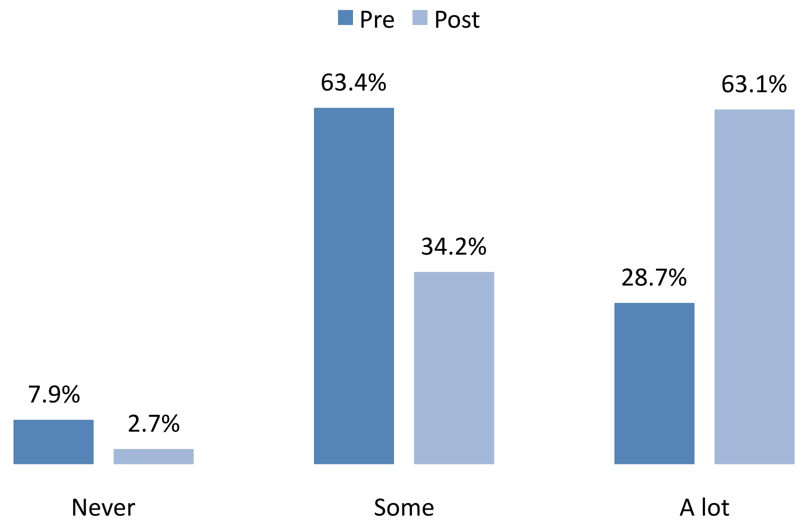
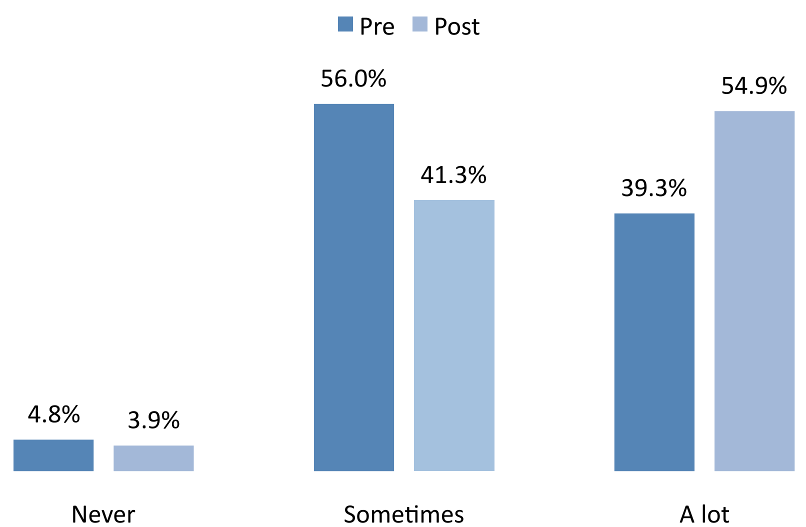
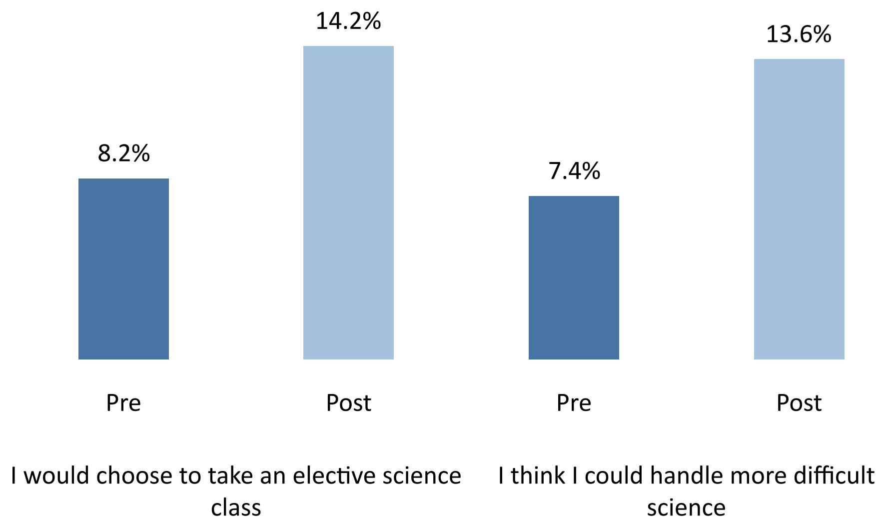


Figure 11: Percent of middle school students who report exploring science research activities in school



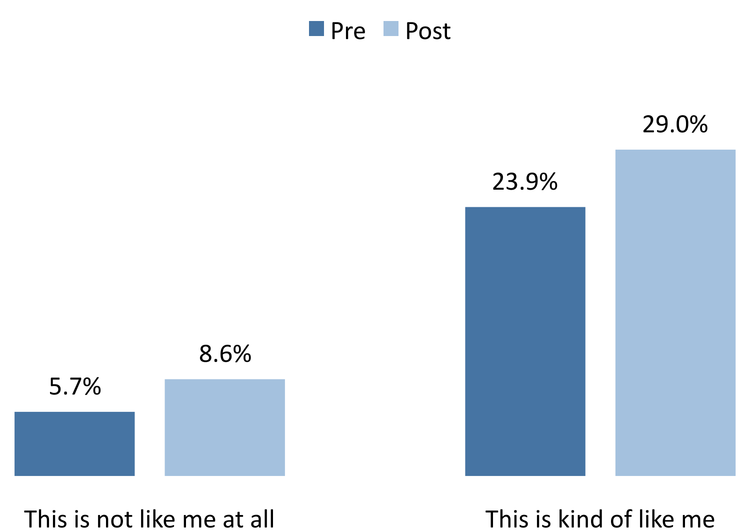
Significantly more middle school students also reported *this is totally like me* for two questions on the post-survey: "*I would choose to take an elective class"* (X^2 = 12.758; *P*-value = 0.005) and "*I think I could handle more difficult science*" (X^2 = 12.178; *P*-value = 0.007). Neither elementary nor high school students reported significant increases or decreases on these questions (Figure 12).

Figure 12: Percent of middle school students who would choose to take an elective science class and could handle more difficult science



Significantly fewer middle school students reported on the post-survey that they have fun in their science class. The percent of students who reported *this is not like me at all* increased by 2.9% and the percent of students who reported *this is kind of like me* increased 5.1% (Figure 13). These were significant decreases (X^2 = 8.941 *P*-value = 0.030). The percent of students who reported that *this is like me* and *this is totally like me* both decreased.

Figure 13: Percent of middle school students who reported having fun in their science classes



Girls seemed to be more interested in science on the post-survey. Significantly more girls reported on the post-survey that they could handle more difficult science(X^2 = 18.022 *P*-value =

0.000). The percent of girls who reported *this is not like me at all* decreased from 41.3% on the pre-survey to 30.3% on the post-survey. Boys seemed to be less interested in science on the post-survey. Significantly more boys reported on the post-survey that *science is boring to me* (X^2 = 10.109 *P*-value = 0.018). On the pre-survey 64.5% of boys reported *this is not like me at all*. On the post-survey 55.9% of boys reported *this is not like me at all* and 8.9% reported *this is totally like me*.

Significantly fewer boys also reported on the post-survey that they have fun in their science classes. In response to "*I have fun in my science classes*", 32.8% of boys reported *this in not like me or this is kind of like me*. On the post-survey the *this is not like me or this is kind of like me* responses increased to 42.8%; a significant difference (X^2 = 10.224 *P*-value = 0.017).
Six of the 17 (35.3%) teachers whose students completed the pre- and post-survey showed significant increases in the percent of students who reported that they explored science research activities in school *a lot.* The largest increase was 59.6% from 34.8% on the pre-survey to 94.4% on the post-survey. The smallest increase was 11.6% from 27.5% on the pre-survey to 39.1% on the post-survey.

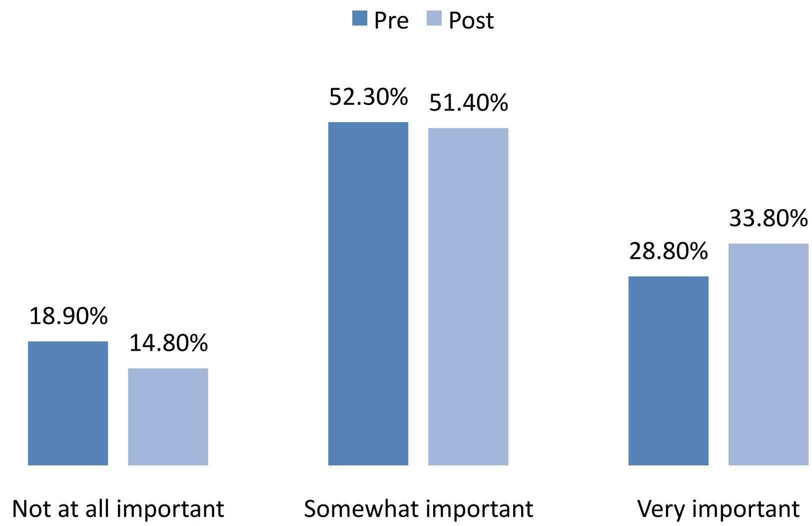
Results Related to Attitudes about the Polar Regions

Four questions related to student attitudes about science:

1. As a person living in today's world, how important is it to you, to have an understanding of the Polar Regions – the Arctic and Antarctic?
2. As a person living in today's world, how important is it to you, to have an understanding of issues involved with changes in the Arctic and Antarctic?
3. As a person living in today's world, how important is it to you, to have an understanding of natural and physical sciences (geology, biology, botany, etc.)?

Overall, only one of the questions had an increase in the percent of students reporting *very important*: As a person living in today's world, how important is it to you to have an understanding of the natural and physical sciences? On the pre-survey, 28.8% of the students reported it is *very important* to have an understanding of the natural and physical sciences. On the post-survey 33.8% of students reported it is *very important* to have an understanding of the natural and physical sciences (Figure 14). This was a significant increase (X^2 =8.458; *P*-value = 0.015).

Figure 14: Student report of importance of understanding of natural and physical sciences



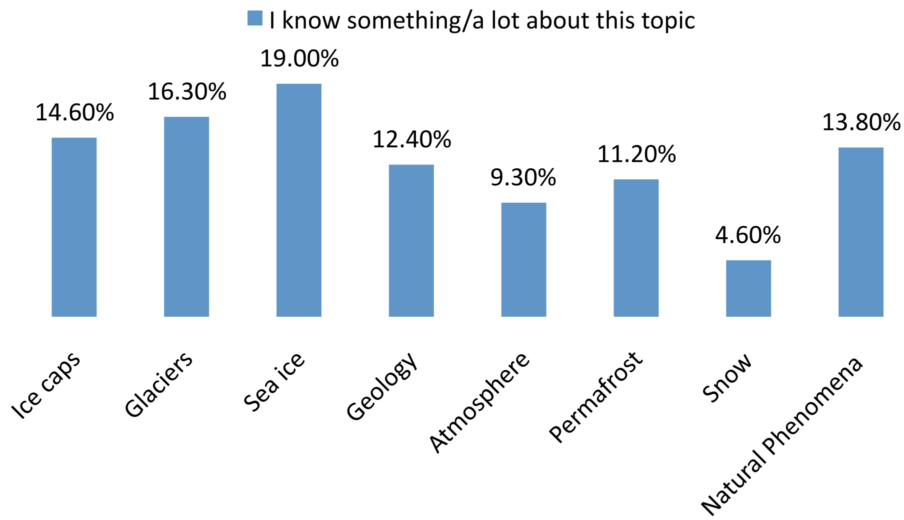
Significantly more girls reported on the post-survey that it is important to have an understanding of the natural and physical sciences ($X^2 = 10.724$; P-value = 0.005). The percent of girls who reported that understanding of the natural and physical sciences is *very important* increased from 32.1% on the pre-survey to 39.0% on the post-survey. There were no significant differences by grade level or teacher.

Results Related to Knowledge about the Polar Regions

Students were asked to rate their familiarity with several physical science topics, including ice caps, glaciers, sea ice, geology, atmosphere, permafrost, snow, and natural phenomena (earthquakes, landslides, tsunamis).

Physical Science Topics: Overall students made significant gains in their familiarity with all the physical science topic areas, with the largest gains in familiarity with sea ice, glaciers, and ice caps (Figure 15). There were no differences among the groups by gender.

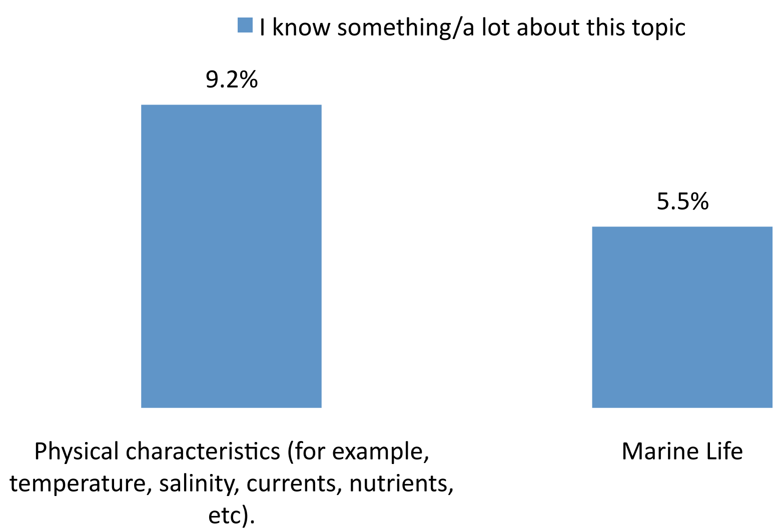
Figure 15: Percent pre- to post-change in student familiarity with physical science topic areas



There were some differences among the grade level groups. Elementary students did not report significant gains in their familiarity with: geology, atmosphere, snow, or natural phenomena. High school students did not report significant gains in their familiarity with permafrost, snow, or atmosphere. Middle school grade students reported significant gains in their familiarity with all of the physical science topics.

Ocean Topics: Overall students made significant gains in their familiarity with both of the ocean topic areas, with the largest gains in familiarity with physical characteristics of oceans (Figure 16).

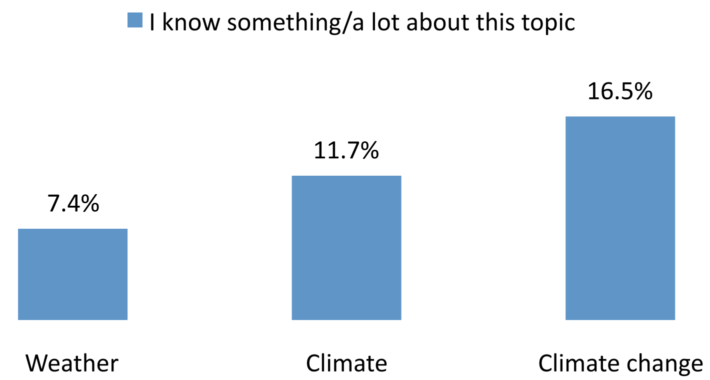
Figure16: Percent pre- to post-change in student familiarity with ocean topic



There was one difference by gender: girls showed a significant increase in their familiarity with marine life (X^2 = 10.260; P-value = 0.016); boys did not. There were also some differences by grade level. Elementary student results showed significant gains in physical characteristics, but not oceans. Middle school student results showed significant gains in physical characteristics, but not oceans. High school student results did not show significant gains in physical characteristics, but did show gains in oceans.

Polar Weather and Climate Topics: Overall students made significant gains in their familiarity with the polar weather and climate topics, with the largest gains in climate change (Figure 17).

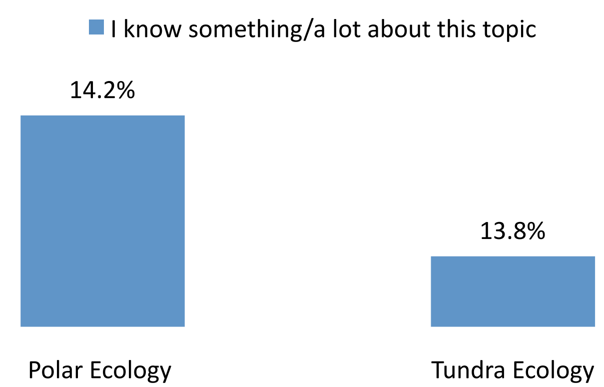
Figure 17: Percent pre- to post-change in student familiarity with polar weather and climate topics



There were no differences by gender, but there were several differences by grade level. Elementary student results showed significant gains in climate change, but not weather or climate. Middle school student results showed significant all three areas: climate change, weather and climate. High school student results showed significant gains in climate change, but not weather or climate.

Polar Biology and Ecology: Overall students made significant gains in their familiarity with the polar biology and ecology topics, with the largest gains in polar ecology (Figure 18).

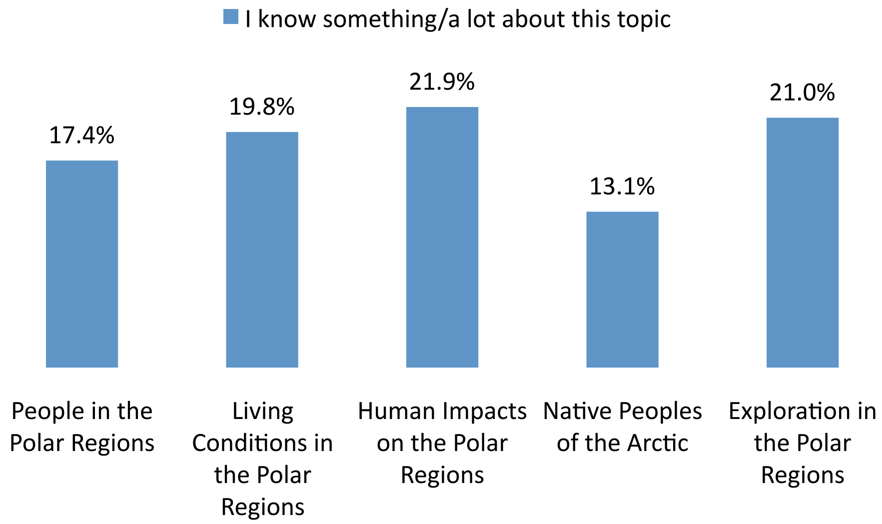
Figure18: Percent pre- to post-change in student familiarity with polar weather and climate topics



Only middle school student results showed significant differences between the pre and post tests. There were no differences between the results by gender.

Human Dimensions in the Polar Regions: Overall students made significant gains in their familiarity with the human dimension topics, with the largest gains in human impacts on the Polar Regions and exploration in the Polar Regions (Figure 19).

Figure19: Percent pre- to post-change in student familiarity with polar weather and climate topics

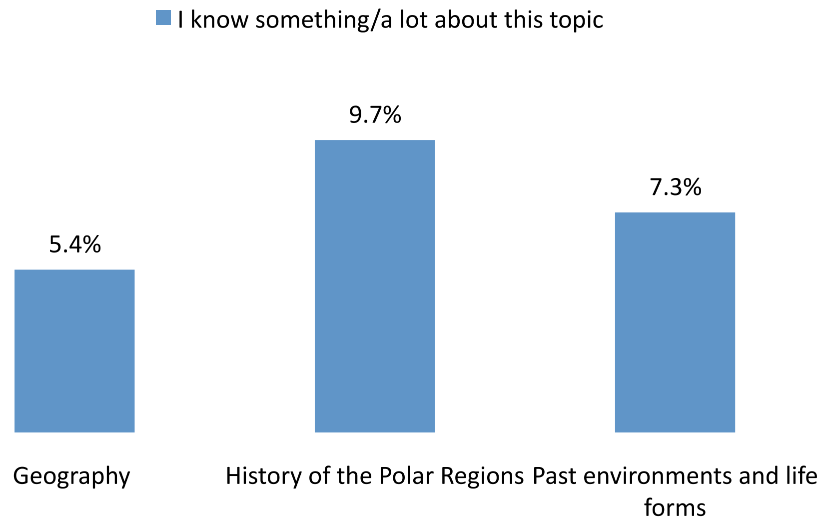


Both middle and high school student results showed significant increases in all five human dimension topics. Elementary student results showed significant increases in all of the topics except Native peoples of the Arctic. There were no differences in the results by gender.

Polar Geography and History: Overall students made significant gains in their familiarity with Polar geography and history topics, with the largest gains in human impacts on the Polar Regions and exploration in the Polar Regions (Figure 20).

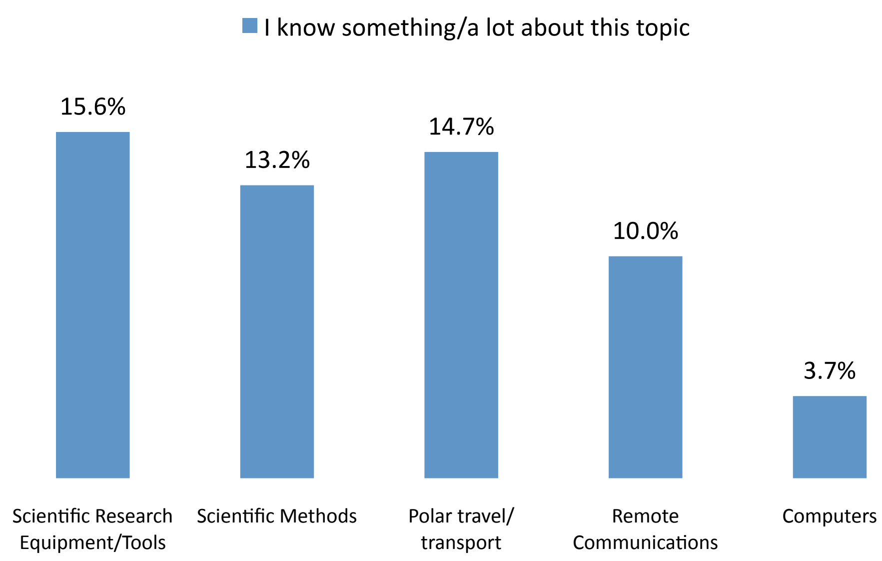
Middle school student results showed significant increases in all three geography and history topics. Elementary student results showed significant increases only in the history topic. High school student results did not show any significant increases. There were not any differences by gender.

Figure 20: Percent pre- to post-change in student familiarity with Polar geography and history topics



Technology and Research Topics: Overall students made significant gains in their familiarity with all of the technology and research topics, except computers, with the largest gains in scientific research equipment and tools and the smallest gains in computers (Figure 21).

Figure 21: Percent pre- to post-change in student familiarity with Polar geography and history topics



Elementary student results showed significant increases in familiarity with scientific research equipment and tools, scientific methods, and Polar travel, but not with remote communications or computers. Middle school student results showed significant increases in all five areas. High school student results show significant increases only in scientific research equipment and tools. More boys, but not girls, reported more familiarity with computers on the post-survey than on the pre-survey.

Section 5: Conclusions

With *PolarTREC* the Arctic Consortium of the United States (ARCUS) hoped to invigorate polar science education by bringing K-12 educators and IPY researchers together through hands-on field experiences in the Arctic and Antarctic. ARCUS believed that by providing this unique teacher research experience, teachers would increase their content knowledge of multidisciplinary polar science, increase teachers' use of the practices of science (inquiry-based learning) in the classroom, improve polar researchers' understanding of and engagement in K-12 education to enrich outreach and dissemination of their researcher, and ultimately increase students' understanding of and engagement in the polar regions and interest in STEM careers.

By numerous measures *PolarTREC* has successfully met its objectives. Over the last three years, *PolarTREC* has provided teacher research experiences in the Arctic and Antarctic for 48 elementary-, middle-, and high-school teachers. *PolarTREC* successfully built on previous research experience programs (Russell and Hancock, 2005; Silverstein, Dubner, et.al, 2009; Snowcroft and Knowlton, 2005) and significantly expanded best practices in the field of teacher professional development (Loucks-Horsley, et.al, 2003). Selected teachers were carefully matched with leading polar researchers based on teachers' topic area selections, which increased the relevancy for teachers and the likelihood that participants would be able to use what they learned in the classroom. Participating teachers received an extensive orientation where they met previous *PolarTREC* teachers and learned about the program's expectations. In teleconferences, participating teachers met their research teams and received logistical information prior to departing for their research site. Participants then spent two to eight weeks as members of research teams working in remote Arctic and Antarctic sites and aboard research vessels. While in the field they conducted field research, captured their experiences in a daily online journal, and facilitated online presentations with their research team to students all over the world. When they returned from the field, the participating teachers brought their experiences to their students and to their communities. Many continued to work with their research team to develop classroom projects and materials and facilitate scientist classroom visits. Others joined Connecting Arctic/Antarctic Researchers and Educators (CARE), a professional development network to support the integration of science research experiences into classroom curriculum.

These experiences have significantly increased the *PolarTREC* teachers' self-reported knowledge and ability to teach about the Polar Regions and the practices of science. After their *PolarTREC* participation, teachers reported knowing more about various broad topics related to the Polar Regions, such as adaptations of life in extreme cold and darkness and environmental changes in the Antarctic environment than before. Their experiences resulted in a broader understanding of the multiple diverse careers available to students who might be interested in working in the Arctic or Antarctic. Finally, they better understood scientific processes and methods, like designing research studies, collecting data, designing sampling methods, preparing samples for analysis, conducting observations, and processing data, among other topics.

PolarTREC teachers brought this learning into their classrooms. Most frequently teachers integrated the scientific processes and methods they learned in the field into their instructional practices, reflecting the work of real scientists and increasing the authenticity of their science teaching. Over the three-year project students of *PolarTREC* teachers engaged in numerous science practices – they collected, recorded, and analyzed scientific data; collected and identified plant and animal samples; built remote operated vehicles to collect samples; conducted controlled experiments; discussed science concepts with one another; designed and implemented their own investigations; learned to ask significant questions; created models to understand natural processes; and used technology, such as online mapping tools to investigate scientific questions. The increase in teachers' use of scientific processes was also noted by students, especially by elementary and middle school students, who reported exploring science research activities in school "a lot" when asked at the end of the school year.

PolarTREC teachers also used their new knowledge to connect polar research and science content to their required curriculum in countless ways. For example, teacher-developed materials included a lesson on the food chain that used organisms found in Bering Sea to illustrate the flow of energy and nutrients in an ecosystem. Another drew on the life cycle of the Little Auk, an Arctic bird to demonstrate the food chain and survival rates. In other lessons students learned about the properties of heat transfer, evolutionary adaptations, and anatomy/physiology and habitat by studying the animals and fish that live in the Arctic and Antarctica.

Polar science careers was also a topic *PolarTREC* teachers brought into their classroom after their field experiences. Some teachers held careers fairs. Others asked their students to research different science jobs by discipline (e.g., biologist, entomologist). Still others had researchers visit their classrooms to talk about their research and the job of a scientist. Many teachers simply encouraged their students to see themselves as scientists or to explore the countless jobs that support to polar research.

Together, the 48 teachers who participated in the *PolarTREC* teacher research experience taught approximately 5,000 students during the three-year project period. These students, like their teachers, learned about the Polar Regions, the practices of science, and science careers during the past three years. They reported significant increases in their knowledge of a range of polar topics, including physical science topics, such as sea ice, glaciers, and ice caps; physical characteristics of oceans and marine life; polar weather, climate, and climate change topics; polar biology and tundra ecology; human dimensions in the Polar Regions; and technology and research topics.

There were several significant differences in the student data by grade level. For instance, elementary students reported significant gains in their familiarity with Native peoples of the Arctic. But, did not report significant gains in their familiarly with geology, atmosphere, snow, or natural phenomena. These significant differences in student knowledge by grade level indicate the changes measured are a direct reflection of teachers' instruction, if not increases in knowledge about the Polar Regions. To further explore this connection between what the teacher taught and what students learned further evaluation will explicitly ask *PolarTREC* teachers to report the extent to which they teach various topics and ask students the extent to which they are knowledgeable about those topics.

In general, students also seemed to increase their interest in science, although the results are not conclusive or consistent across groups. Only middle school students were more likely to report increased interest in science – in particular they were more likely to choose a science elective class and believe that they could handle more difficult science. However, middle school students were less likely to report that their science class is fun after their teacher participated in *PolarTREC*. Girls also seemed to be more interested in science after their teachers' *PolarTREC* experience than boys were. More girls indicated that they could handle more difficult science and that science class was not boring.

With a few exceptions, teachers' *PolarTREC* experience did not increase their students' interest in STEM careers. One exception was students' interest in a career as a biologist – more students reported being interested in biologist as a possible future career after their teacher participated in the *PolarTREC* project. While the evaluation did not include an analysis of student data by the topics teachers studied or taught, teachers frequently reported implementing lessons related to biology, indicating that there may be a relationship between the topics teachers taught and their students' interest in careers in those fields. In the continuing evaluation of *PolarTREC,* this relationship will be further explored by asking teachers to explicitly report the extent to which they teach various topic areas.

Another exception was girls' interest in various STEM careers. Girls were significantly more likely to increase their interest in a career as a biologist, mathematician, or high school science teacher. Of the *PolarTREC* teacher participants, more than 60% were women and of the researchers more than 30% of the research project principal investigators were women. Although the evaluation data does not provide conclusive evidence that the girls were influenced by these female participants, it is a reasonable conclusion and one that the evaluation will continue to explore.

The *PolarTREC* project also had significant benefits to researchers, particularly in terms of outreach and in terms of bridging the cultural gap between education and science professions (Snowcroft and Knowlton, 2005). Researchers saw *PolarTREC* as an essential vehicle for ensuring that their research had broader impacts. By capturing the public's interest and translating polar science for a general audience, many of the teachers significantly expanded their research team's outreach. Teachers also helped researchers understand how to translate their subject area for a K-12 audience. Researchers also gained a better understanding of the teaching profession, including the needs, standards, and policies of K-12 science, a result consistent with teacher research experience research findings (Chennel, 1999). This understanding made many of the researchers willing and excited to include another teacher in their field research in the future.

PolarTREC has clearly invigorated polar science education. Research shows that science curricula are still generally centered on teachers' lectures, textbooks, and student memorization of voluminous facts (Fischer-Mueller and Zeidler, 2002). This pedagogical style is contrary to the way science is practiced. *PolarTREC* teachers in comparison engaged their students in the practices of sciences. A task they were able to do because they themselves had been immersed into the inquiry of science and learned first-hand how science practices are put into action. Importantly, for the long-term impact, *PolarTREC* has bridged the education and research fields so that researchers have continued working with *PolarTREC* teachers both through the program and outside of it. These relationships will continue to impact polar science education and ensure that student practice science long beyond the *PolarTREC* program.

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