An Exploratory Study of Science Teacher Professional Development for Climate Change Education with a Focus on the Polar Regions and Real Time Data

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Introduction

Climate change has become a pressing and widespread concern with consensus among climate scientists that the earth is experiencing human-caused global warming (Cook et al., 2016). Changes associated with a warming earth are especially visible in the polar regions, where increasing temperatures are resulting in ice melt and changes to ecosystems.

Previous studies on teacher professional development in climate change have been conducted and reported by our research team (Hestness, McDonald, Breslyn, McGinnis, Mouza, 2014, Hestness, McDonald, Breslyn, McGinnis, Mouza 2017, McGinnis, McDonald, Hestness, Breslyn, 2016). In this report a new focus for teacher professional development in climate change is examined. A focus on the polar regions in teacher professional development for climate change education may offer a potentially new and engaging context to develop an understanding of the causes, mechanisms, and impacts of climate change. Students are often least minimally familiar with the polar regions, and they are increasingly aware of some of the major effects of climate change, such as ice melt, and its negative impact on the charismatic megafauna, such as polar bears and penguins.

Linking teachers and students to practicing researchers in the polar regions may have potential for effective and meaningful teacher professional development in climate change education. Through real-time interactions, such as video conferencing and access to data, as well as via asynchronous communication such as email and blog postings, teachers and their students can engage in climate change related to disciplinary core ideas and scientific practices stated in the Next Generation Science Standards (NGSS).

The NGSS is the first U.S. standards that explicitly address climate change at the middle and high school levels (NGSS Lead States, 2013). Within the standards there are multiple instances of climate change and climate change related content across the grade bands (McGinnis, et al., 2013). Consequently, there is a need for the implementation and study of professional development (PD) programs that help science educators align their science teaching practices with NGSS in novel ways, such as teacher interactions with practicing researchers.

Situated within the **Ma**ryland **De**laware **Cl**imate Change **E**ducation, **A**ssessment, and **R**esearch (MADE CLEAR), a NSF CCEP II grant and involving researchers at Palmer Station, Antarctica, this exploratory study seeks to address the research question, "*How do teachers consider using real-time polar research to inform their climate change education pedagogy?*"

Context of the Professional Development and Study

During this study, Natalie H. Ylizarde was a doctoral student in Science Education at the University of Maryland (UMD) and a Research Assistant (RA) for the National Science Foundation funded MADE CLEAR-UMD learning sciences research team (UMD PI, Dr. J. Randy McGinnis). This work has resulted in multiple publications on climate change education (see www.ClimateEdResearch.org). She was also a third-year member of a three- time funded National Science Foundation project in Antarctica (PI, Dr. Richard E. Lee, Jr.). According to A Fly on the Pole (2017), Lee has included a K-12 teacher on his team for the past eight field seasons to help conduct fieldwork on "the wingless fly" (*Belgica antarctica),* and spearhead outreach to US classrooms. This work has resulted in multiple articles and books (See Miami University, 2009), including

in science education (Betteley, Harr, & Lee, 2013; Constible, Sandro, & Lee, 2008; Harr, Doneyko, & Lee, 2012; Harr & Lee, 2010, 2011; Spring & Harr, 2014).

During the last two years, Natalie developed the educational outreach program called *A Fly on the Pole* (www.aflyonthepole.com). In her work with these two research teams, Natalie brought the two NSF studies she is involved in together by leading a yearlong exploratory study (utilizing real-time polar research at Palmer Station as a vehicle to teach climate change in classrooms, grades 4-12). The ultimate goal of the study was to explore a teacher professional development model on climate change education through case study analysis involving MADE CLEAR teacher participants. Situated within Dr. Lee's broader outreach efforts, the MADE CLEAR PD study focused on exploring a polar focus on teacher climate change education professional development.

The outreach efforts for the 2017 Antarctic field season were twofold: (1) to connect the science activities of Lee's Antarctic research team and other research projects at Palmer Station, Antarctica with teachers and their students, and (2) to synergistically partner with education researchers from the MADE CLEAR grant. MADE CLEAR brings together science educators, learning scientists, schools, climate scientists, and the broader community to address comprehensive climate change education in Delaware and Maryland (See Maryland and Delaware Climate Change Education Assessment and Research, no date).

Located on the Antarctic Peninsula, Palmer Station is one of three US Antarctic research stations funded by the National Science Foundation. According to the Long Term Ecological Research Network (no date), the area around Palmer Station is

experiencing the "most rapid climate warming on the planet." As one of 26 Long Term Ecological Research Sites, Palmer Station is part of the longest running US ecological research network as well as the largest. Since rigorous education and outreach are a major component for NSF grants as well as the LTER program, connecting teachers with real-time polar research at Palmer Station has the potential to inform teacher pedagogy, provide real-time educational opportunities for classrooms, support researchers' broader impacts, and foster a better understanding of the link between scientific discovery and societal benefits.

The overarching research question for the study was: *How do teachers consider using real-time polar research to inform their climate change education pedagogy?* We defined "real-time polar research" as current or ongoing scientific research taking place at a designated research station (land based on maritime) in the Arctic or Antarctic.

Summary of the Professional Development

Table 1 provides an outline of the three phases of the Polar MADE CLEAR study and data collected. All instruments are provided in the Appendix.

Table 1: *Overview of Polar MADE CLEAR Study Phases*

Study Phase	**Timeline**	**Description**	**Participants**	**Data Collection Method**	**Appendix**
I	Summer 2016	MADE CLEAR Summer Teacher Academy: Polar PD	31 Maryland and Delaware informal and formal teachers (grades 4-12)	Pre-Academy Registration Survey (electronic) Pre- Polar PD Survey (electronic) Polar Graphical Organizer Post-Polar PD Survey (hard copy)	**A** **B** **C** **D**

II	Fall 2016	Polar Case Study	6 formal Maryland and Delaware teachers (grades 4-12)	Polar Prompt Response #1 (via email)	**E**
III	Spring 2017	Polar Case Study (continued)	6 formal Maryland and Delaware teachers, grades 4-12	Polar Prompt #2 (via email) Polar MADE CLEAR Final Survey (via Google Forms)	**F** **G**

During Phase I of the study, Natalie worked with 31 teacher-participants (i.e., grades 4-12, informal education) during the 2016 MADE CLEAR Climate Change Teacher Academy held at Chesapeake College in Maryland. As an instructor during this weeklong summer workshop, Natalie implemented three professional development (PD) interventions to highlight the effects of climate change in the polar regions, especially Antarctica. In addition, these PD interventions provided the teacher-participants with an introduction to the polar regions, an overview of Lee's research on the Antarctic fly, insights on what it is like to live and work at Palmer Station, and how to get involved with *A Fly on the Pole*. The teacher-participants also got to try on polar-issued gear and take home a variety of polar educational resources for use in their classrooms as a form of reciprocity.

Phase II of the Polar MADE CLEAR study took a qualitative approach and followed 6 teacher-participants (Grades 4-12) from the MADE CLEAR Climate Change Teacher Academy to study their climate change education pedagogy. In the late fall and winter, each teacher-participant received three additional polar PD interventions for use in their classrooms: 1) access to polar-related educational resources at

www.aflyonthepole.com, 2) a blog that chronicled Natalie's experiences on the 2017 Antarctic expedition from December to March, and 3) a live 30-minute video teleconference (VTC) with Natalie in January from Palmer Station, Antarctica. These interventions were designed to help teachers and their students engage with real-time research at Palmer Station using technology.

As these interventions were rolled out, the MADE CLEAR UMD learning sciences research team gathered qualitative data from the teacher-participants via email prompts, email correspondences, and a culminating electronic survey to understand how, if at all, the polar PD interventions were shaping their climate change education pedagogy. Four of six teacher-participants engaged with their students in the video teleconference (VTC), which included a walking tour of Palmer Station, anecdotes of what it's like to live and work there, and a discussion (with the receding Marr Ice Piedmont glacier as the backdrop) on the climate change happening in this particular location. By partnering with the Palmer-LTER (Long Term Ecological Research) project's educational outreach coordinator, Natalie was able to video-teleconference with multiple classrooms using Zoom software as a hosting platform, and to digitally archive these video sessions for use as a pedagogical tool (with edits) in classrooms.

During Phase III of the study, Natalie and the MADE CLEAR UMD learning sciences team created 3-5 minute educational videos using interviews she had conducted with Palmer scientists and staff during the field season. Using "critical pedagogy of place" (Gruenewald, 2014, p. 149) as a conceptual framework, the videos highlighted the five dimensions of a place, including the ecological, political, perceptual, ideological, and sociological dimensions (Gruenewald, 2003) to help students and their teachers better

connect with this remote polar region, especially in regards to climate change. Other videos captured the human experience of being in Antarctica as well as evidence of the climate change occurring at Palmer Station. The team collected qualitative data on how the six teacher-participants used these videos to help teach about climate change in their classrooms (Appendix G). A compilation of the teacher resources that were developed specifically for this study (i.e., PowerPoint presentations, websites, and movies) can be found at Climate Change and the Polar Regions: Teacher Resources and Research.

Methodology, Study Context, and Participants

Polar Study: Phase I

Prior to attending the MADE CLEAR Summer Teacher Academy, the teacher-participants completed an electronic pre-academy survey (See Appendix A) as part of their application to the workshop, describing their school demographics, teaching experiences, relevant professional development experiences, availability of Internet-enabled computers at their school, and ways to modify their school year to include climate change instruction. This data was archived for later use in the study.

At the end of the MADE CLEAR Summer Teacher Academy (Day #1), the teacher-participants responded to an electronic pre-polar PD survey (See Appendix B) as a form of daily reflection. This pre-survey prompted the teacher-participants to describe their previous ways of teaching climate change and whether the polar regions had been included as part of their past climate change instruction. This data (See Table 2) provided insights into each teacher-participants' experience level with teaching these topics.

Table 2: *Pre-Polar Professional Development Data*

Teacher-Participant's Level	Experience Teaching Climate Change	Experience Including the Polar Regions when Teaching Climate Change
Experienced	11	6
Somewhat Experienced	9	6
No Experience at All	7	12
No Answer (left blank)	2	1
Not Applicable (n/a)	2	6

Using inductive analysis, eleven teacher-participants were classified as "experienced" in teaching climate change, since their data described ways they incorporated climate change topics or lessons into their instruction, usually more than one lesson.

For instance, a teacher-participant stated:

This past year I tried to teach about climate change more to mirror the new NGSS standards. My students looked at climate data for four cities and discussed what factors influence local climates. My students analyzed data about rising sea levels and discussed the possible causes for the change in climate.

Ten teacher-participants were classified as "somewhat experienced" by describing how they "touched on" or "mentioned" climate change during their previous instruction. Some of these teachers mentioned teaching a lesson about climate change or bringing it up informally during instruction. The remaining 10 teacher-participants had either no experience teaching climate change previously, left the prompt unanswered, or replied "not applicable" to them. Out of the eleven teacher-participants who were classified as "experienced" with teaching climate change, only six had included instruction on the

polar regions. Out of the twelve teacher-participants who were labeled as "experienced" or "somewhat experienced" in regards to including the polar regions, eight teacher-participants made reference to the decreasing ice in these regions (e.g., melting polar ice caps, receding glaciers, or decreasing sea ice) and four of these teacher-participants referenced sea level rise as a resulting phenomena. This data was used for Phase II of the study in order to inform the development of interventions and in the selection of case study participants.

During Day #2 of the MADE CLEAR Summer Teacher Academy at the start of the polar intervention, Natalie randomly divided the teacher-participants into groups of 4-5 to create a graphic organizer (See Appendix C) using large chart paper and blue markers for the following three minute prompt, "What do you know about the polar regions?" (See Fig. 1 and 2).

During Natalie's introduction to the polar regions, she used the data as a baseline for what the teacher-participants collectively knew about the polar regions and referred to them throughout the three polar PD sessions. The graphical organizers were revisited by the teacher-participants at the end of the day, and responded to a post-activity prompt using a green marker: "What have you learned about the polar regions?" (See Fig. 1 and 2). These graphic organizers were photographed and archived as data.

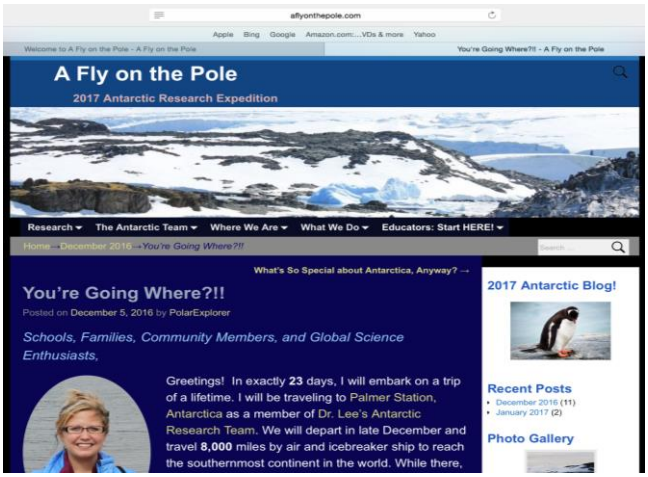
Of the data collected from the Teacher Academy, the post-polar survey data were examined first with the goal of identifying prominent themes that would shape the creation of upcoming instruments and to identify potential case study participants who would be considered a rich data source. Two raters (Natalie and Emily) began by each independently coding the first five teacher-participant responses using NVivo software as

an analytic tool to establish an initial coding scheme. They came to a consensus after sharing results.

In all, the post-polar PD survey findings informed the compilation of polar educational resources found on *A Fly on the Pole* for Phase II of the study. Within the "Educators Start Here!" dropdown tab (See Fig. 3) on www.aflyonthepole.com, three distinct web pages were created to help address the benefits and challenges that teachers face when using real-time polar research as a vehicle to teach about climate change. The Climate Change and the Polar Regions page provides teachers with videos, websites, and lesson plans to help bring the polar regions and climate change into their science curriculum. Comparing the Polar Regions webpage showcases a variety of educational resources for comparing the Arctic and Antarctic, including the PD intervention (a PowerPoint) used with teachers at the MADE CLEAR Teacher Academy. Integrating Climate Change across the Curriculum provides resources to help teachers create cross-curricular climate change lessons plans (i.e., science, art, history, social studies connections) with a polar region focus. Maps, visualizations, and data sets were embedded throughout various components of the *A Fly on the Pole* website. The 2017 Antarctic Research Expedition blog was also designed to chronicle Natalie's experiences preparing, traveling, and working in Antarctica.

Fig 3: Climate Change Educational Resources Informed by Post-Polar Professional Development Survey Data

Fig 4: A Screenshot of the 2017 Antarctic Research Expedition Blog Informed by Post-Polar Professional Development Survey Data



Polar Study: Phase II

To select the case study participants for the study, Natalie and Emily examined the post-polar survey data using an inductive approach. First, they narrowed down the participants who expressed interest in participating in the Palmer video-teleconference (VTC) session with Natalie as a case study participant. From the 12 participants who expressed a "yes" response, the team then examined their pre and post polar data. Since this is an exploratory study, the team specifically looked for rich data sources. Participants who did not complete or answer all the questions, were not considered a rich

data source. However, they did consider one participant who was unable to attend the MADE CLEAR follow-up summer workshop, since she personally contacted Natalie via email to express her interest in participating in the study. Although, they were missing her post-polar survey responses, all of her other data sources were considered of potential value. They eliminated one participant since she worked in informal education and was not associated with a school district.

The process helped the team to narrow down the selection to eight case study candidates. Gender, teaching experience, and school demographics were mediating factors in deciding our top six participants and two alternatives from our candidate pool. All six of our participants, spanning 4-12 grades with varying teaching responsibilities and degrees of experiences, expressed an interest in continuing the polar-region aspect of the MADE CLEAR Climate Change Professional Development program for the remainder of their school year.

Table 6: *Demographic Information on Case Study Teacher-Participants*

Participant ID Number and State	**Gender**	**Teaching Experience**	**School Setting**	**Percent Free and Reduced Meal**	**Current Teaching Assignment**
Participant 1 DE	Female	17 years (1st, 6th, 9th grade)	Urban/ Suburban	(data not available)	Middle School, STEM/environmental sciences
Participant 2 DE	Male	+20 years	Urban	12%	8-9th grade science
Participant 3 MD	Male	16 years	Rural	30%	Environmental and agricultural sciences, 9-12th

Participant 4 MD	Female	1st year	Rural	40%	9-12 earth/space, environmental
Participant 5 MD	Female	20 years	Suburban	Not sure	9-12 Biology, into the environmental
Participant 6 DE	Female	14 years	Suburban	0%	Science, SS, math 4-5 grade
Participant 7 MD	Female	13 years High school, chem, bio, science research	Rural	16.2%	8th grade earth /space sciences
Participant 8 DE	Female	10 years Earth sci, chem, alchemy, ELA, Spanish	Suburban	90%	All sciences, except physics year-round

In Phase II each of the six case study participants were asked to complete Polar Prompt #1 via email (Appendix E). The prompt asked participants to review a list of PD experiences and describe what would be of interest/benefit and why. The PD experiences included access to polar-related education resources, a blog, and a live video-teleconference from Palmer Station, Antarctica.

Polar Study: Phase III

Building on data collected from the six case study participants in Phase II, Phase III consisted of exploring participants' perceptions of the program at the end of the school year, after taking part in real-time video conference with researchers at Palmer Station in Antarctica. Of the six participants in Phase II, five completed the Polar MADE CLEAR Case Study: Final Survey (Appendix G) for Phase III. Data relevant to the research question is synthesized for each question in the Final Survey.

Insights

Together, the three phases of the study provided some initial insights on how a focus on the polar regions, particularly Antarctica, may impact teachers professional development growth in climate change education. Because of the small sample size, especially in Phase II and III, insights in this report of an exploratory study should be viewed as tentative. Due to growing importance of climate change education, and the highly visible nature of its impact on the polar region, the insights contribute as a first step to the emerging body of literature on teacher professional development on climate change education.

Phase One

Data collected from the graphic organizers generated by teachers (Figures 1 and 2) indicates that teachers came in with some understanding of the polar regions.

Figure 1: Teacher Generated Graphic Organizer of Polar Regions

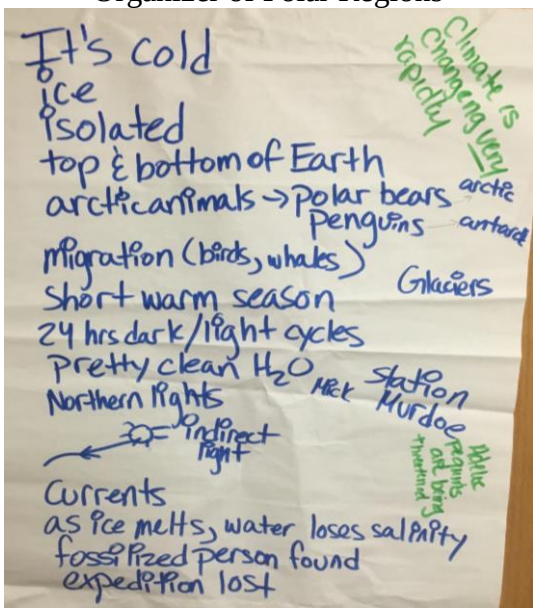
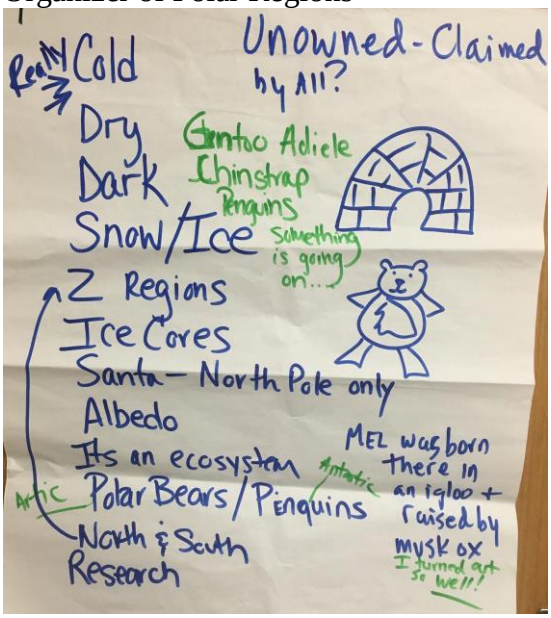


Figure 2: Teacher Generated Graphic Organizer of Polar Regions



Pre-knowledge included extreme climate (e.g., icy, dry, cold, pristine, and remote), landscape features (e.g., glaciers, sea ice, and landmasses), natural phenomena (e.g., seasonal light variations, Auroras Borealis or Northern Lights, Auroras Australis), wildlife (e.g., penguins, polar bears), and historical facts (i.e., a health rescue at the South Pole research station, the discovery of frozen artifacts and fossils, and infamous polar explorers). The teacher-participants also demonstrated some knowledge of climate change in these regions, by including terminology such as sea level rise, habitat loss, decreasing sea ice, glacial melt, and oceanic conveyor belts. As evidenced by the graphic organizers (See Fig. 1 and 2), participants demonstrated some growth in their understanding of the polar regions as two geographically distinct regions with unique fauna and challenges with climate change.

Two weeks later, the teacher-participants attended a MADE CLEAR Summer Teacher Academy follow-up workshop held at Fort DuPont State Park, Delaware City, Delaware. During the daylong workshop, the teacher-participants were asked to respond to three written prompts, or a post-polar survey, regarding their participation in the polar PD two weeks earlier. A total of 23 teacher-participants completed the survey in order to gather data on how the teacher-participants considered using the polar regions and real-time research to teach about climate change in their classrooms, the possible benefits and challenges in doing so, and whether they were interested in being a case study participant in the next step of our study, which featured a live video-teleconference (VTC) with Natalie from Palmer Station, Antarctica.

Post-Polar Survey

When asked how the professional development (PD) on the polar regions and

real-time polar research may be used to help teach climate change in their classrooms, two themes emerged from the data (See Table 3). The first theme, adding something new to the curriculum, was referred to by a total of eleven participants. Six of these participants made references to incorporating data or visualizations while five participants described adding a comparison activity for the polar regions to help teach about climate change. As part of the second theme, integrating into the existing curriculum, participants most frequently referenced connecting the polar PD to science topics in the curriculum (14 participants), such as ice cores, evolution, food webs, climate change, sea level rise, carbon cycle, water cycle ecology, and albedo. For non-science related topics, four participants mentioned making connections to reading, history, geography, or social studies. Four participants provided minimal information and two others mentioned interacting with scientists via video-teleconference or following a research blog, such as *A Fly on the Pole*.

Table 3: *Emerging Themes in Post-Polar Professional Development Survey Data*

Emerging Theme	Teacher Response Example 1	Teacher Response Example 2
1) Adding to the curriculum	-Compare and Contrast "I will be incorporating the data on the amount of polar ice in the Arctic and Antarctic since 1979."	-Visualizations and Data "I plan to use the model ice cores to promote questioning and a combination of satellite photos, graphs, and raw data to expose students to various pieces of evidence."
2) Integrating into the curriculum	-To other science topics	-To non-science topics

	"I plan on introducing polar region information in evolution section. I got the idea from a participant today to include it in food webs as well."	"...potentially in my social studies unit on geography - humans interact with environment."

The post-polar PD survey (See Appendix D) also asked participants to describe some of the benefits and challenges to using the polar regions and real-time research as a vehicle to teach climate change in their classroom (See Tables 4 and 5). This question was divided into two parts (benefits and challenges). Natalie and Emily independently coded each response, created a new coding system, and discussed any discrepancies between their analyses until a consensus was reached. Some participants only stated benefits or challenges, so blanks were left for non-responses. If the responses were lumped together or indistinct, the response was included in both benefits and challenges. The creation of a new coding system informed the content for Tables 4 and 5.

The ultimate benefit for using information on the polar regions and real-time research in teaching about climate change as reported by the participants is student interest. One participant described polar fauna as "eye candy" that provides "context to explain ramifications of climate change" with her students. One stated, *"*Students know about the plight of polar bears and I could generate interest with this tie-in.*"* Another participant reported that students are "usually interested in this and more apt to gain something from it and become concerned, activist, adults." Other benefits reported by the participants include new learning opportunities that broaden and deepen students' understanding of science and climate change by enabling them to "look larger… and see

more of the world." Another participant described how a polar region focus helps to "build awareness that (climate change) is here for a long time" and bring students' attention to global issues associated with climate change, such as human health impacts. The real-time experience of using current data sets, visualizations, and video-teleconferences were also found to be beneficial by "making (climate change) relevant to my students" by experiencing "...data collection...and sampling techniques" being conducted in the moment by scientists. The "possibility of coordinating with Natalie...to do web meetings from the pole" was also highlighted as a real-time benefit.

Table 4: *Benefits for Including the Polar Regions and Real-Time Research into Climate Change Instruction*

Benefits	**Number of References**	**Examples**
Student interest	10	-Creating student interest in climate change with new information -Peaking existing interest/frame of reference (polar bears and other polar animals)
New learning	6	-Providing a global perspective, an understanding of scientific practices (i.e., data collection) -Using unknown information serves as a catalyst for learning -Enhancing diversified thinking, such as perspectives on long term climate change impacts and connections to human health
Real-time experience	5	-Using current data sets, visualizations, and real life/real world/current events
Climate change connections	4	-Providing context for ecological ramifications (i.e., species) -Making global connections to sea level rise -Deepening student understanding of climate change
Cross-curricular	1	-Enhancing curriculum (i.e., planetary science unit)
No response	3	(blank)

Not Sure	1	Not sure

The most referenced challenge by the participants for using information on the polar regions and real-time research in teaching about climate change is that the topic is difficult to relate to on many levels. Participants noted it being "hard to bring the polar experience to the classroom" and "making it relevant" since it is "far away, unconnected from the students in many ways." This "personal separation from the topic" was reported by nearly half of the participants who completed the survey. Other challenges were related to a lack of teacher resources, time and support.

Table 5: *Challenges for Including the Polar Regions and Real-Time Research into Climate Change Instruction*

Challenges	**# of References**	**Examples**
Hard to relate to	12	-No personal experience or frame of reference to draw on -A very distant concept that seems difficult to model; too abstract or multidimensional
Teacher Resources	4	-Lack of teacher knowledge -Lack of tangible or age appropriate materials -Difficult to model for students by teachers
Time	3	-Curricular constraints -Lack of time to bring in outside resources (i.e, a video-teleconference with scientists) - Lack of time in general
Not sure	1	Not sure
No response	4	(blank)

By administering a follow up survey during Phase I of the study, the UMD MADE CLEAR learning sciences research team found that when considering how to

teach climate change, many teacher-participants preferred to integrate the polar regions into current topics in their curriculum rather than adding it as a new topic. When asked to describe the potential benefits for using the polar regions to teach climate change, the teacher-participants cited many reasons, including it being a novel learning opportunity, a real-time experience (i.e., connecting with current science), and a way to build on students' interests, especially with polar fauna (e.g., penguins, whales, and seals). The most cited challenges for using the polar regions to teach climate change were that the polar regions are hard for learners to relate (i.e., remote, far away, a foreign environment), that few educational resources exist on the topic, and the perceived constraints of existing curriculum (i.e., time and space). Finally, the team found that many teachers were interested in participating in a live video-teleconference (VTC) with their students from Palmer Station, Antarctica.

Polar Study: Phase II

In Phase II the case study teachers were asked to review a list of professional development experiences (informed by the Phase I data) and to describe what would interest/benefit them and why. Table 7 is a synthesis of participant responses to Polar Prompt #1 (Appendix E).

Table 7: *Teacher Reported Benefits for Polar Professional Development Experiences*

Type of Polar Professional Development	**Teacher Reported Benefits**
Access to polar-related educational resources at www.aflyonthepole.com	- Student engagement with topic (PowerPoints, photos of Natalie near penguins) - Time saver/a centralized resource for teachers - A resource to narrow ideas for student research projects

	- Readily available lesson plans arranged by grade level and science topics "I like the HS lesson plans, especially the one using beets. Very relevant to biology content and gives a great visual as well as a way to bring climate change into the content - easily understandable." "It saves me the time necessary to research and find information myself." "My students were interested in the Powerpoint information. The 'largest land animal blew their mind.'"
An interactive blog that chronicles Natalie's Antarctic expedition from December to March	- Access to educational resources "You said that I will be able to have contact with the research team! I'm excited about that!"
A live 30-minute video-teleconference session from Palmer Station, Antarctica	"The live skype session is looked forward to although the students don't know what to expect from that experience."

The primary themes that emerged from examination of the data were student engagement and access to resources.

In Polar Prompt #2 (Appendix F) teachers were asked how the pre-resources prepared them and their students for the video-teleconference session. Three of the four teachers who responded reported that they used the pre-resources, however, they did not specify direct connections between the pre-resources and preparation for the video-teleconference. Pre-resources, such as photo galleries and blog entries helped teachers conceptualize what was considered a remote and disorienting place. One teacher stated, "*A Fly on the Pole* was fun to flick onto and see what was going on, to read the blogs,

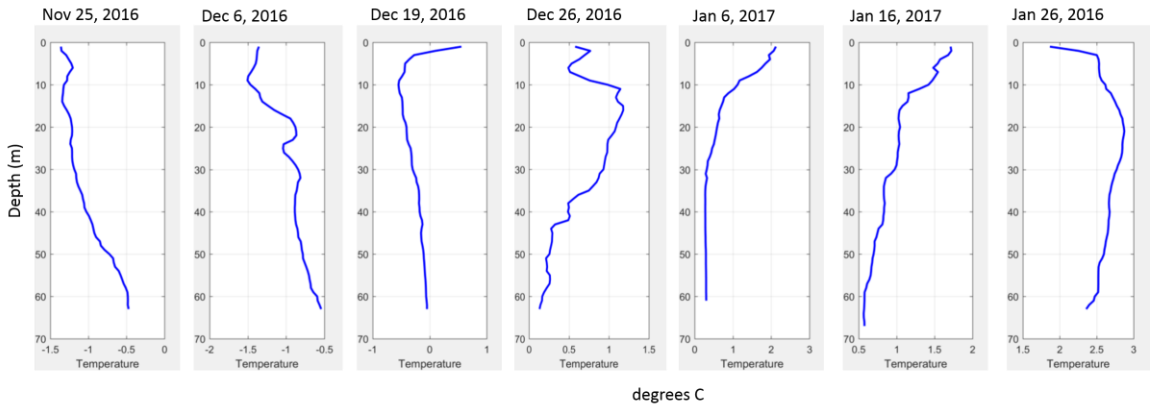
and check out the pictures. It was informative for the students to see real results and people doing real research." The pre-resources helped another teacher make a "scary topic" such as ocean acidification more approachable. Due to time and curricular constraints, one teacher described minimal use of the pre-resources, but still described the VTC as being a useful pedagogical tool for introducing climate change in the polar regions.

Polar Prompt #2 also asked how the video-teleconference experience assisted the teachers in teaching about climate change. Teachers highlighted discussions sparked by the experience as an important outcome. This is evident by a follow up email received after a VTC, which contained 10 student-generated questions. Although these were not climate change specific questions, they did probe for rich information regarding Natalie's lived experiences working in a polar region, such as her personal well-being (i.e., *Is it difficult being away from your family so long? Do you have to share a room? What exactly are you allowed to eat?*), safety concerns (i.e., *has anyone ever died at your research station?*), and specifics about the VTC (i.e., *Is there are reason that you were only able to talk for 30 minutes*?). Most notably, four of the questions inquired about the real-time research taking place at Palmer Station. One question asked, "Have you or the researchers, tried to isolate and recreate the gene that allows the flies to survive 7 days without oxygen?" With the help of her fellow teammate, Natalie wrote back, "...it's likely a combination of altered gene expression and other biochemical factors that prevent damage due to lack of oxygen." Since another question probed about the water temperature at Palmer Station, Natalie conferred with a phytoplankton researcher at

Palmer Station, and emailed the class the following response accompanied with a real-time graph provided by the researcher (See Fig. 3):

...the surface temperature (of the water) varies throughout the season. On average, the surface temperature ranges between 0.5 - 2.5 degrees Celsius. The temperature at the bottom of the ocean fluctuates between the same range. Below (See Fig. 3) is some data...recently collected using a CTD (conductivity, temperature, and depth) instrument. Station B is a specific location of water near Palmer Station. The researchers who study the phytoplankton travel by zodiac boat and use a GPS to pinpoint the exact location and collect the data.

Figure 3: Real Time Data on Water Temperature at Palmer Station, Antarctica



One teacher reported that students utilized the information learned from the VTC session to form arguments when speaking with students who expressed "doubts or questions" about climate change. Two teachers described the VTC as a pedagogical tool that "opened a different door" and generated new conversations about climate change. For instance, after a VTC session with a high school classroom, Natalie followed up a student's question about ocean acidification at Palmer Station with additional information

provided by another research team at Palmer Station for the teacher to further delve into the topic with students (see Project Parka: Planting AntaRctica in KAnsas, 2017; Smithsonian National Museum of History, no date).

In line with responses regarding the pre-resources, "the true value of the VTC was just seeing you in person" and "the mini-tour of the facility was the next best thing to being there." The sole elementary participant did not believe that the VTC assisted with her students' learning of climate change but noted that "the students were amazed" by the live feed which enabled them to experience what life what like on the station and to virtually ask questions in real-time. Throughout Polar Prompt #2, teachers did not discuss their own PD but instead focused on student engagement.

Polar Study: Phase III

Participants responded to four questions in Phase III of the study with the goal of determining how they *consider using real-time polar research to inform their climate change education pedagogy*.

Question One: *How has your participation in the polar-region focused PD, if at all, assisted you in teaching climate change this year to your learners?*

Teachers' responses addressed either how PD supported their students learning or how it supported their own professional development. The teachers stated that student learning was supported by creating excitement through the live sessions with Palmer scientists and the penguin webcam. For example, one teacher stated it provided "real world examples" of climate change. Another teacher explained that the PD provided a:

> "*learning opportunity for the students because they could compare places they knew about to a place they previously knew little about.*"

Other teachers described the PD as giving them access to "real data" and helping them build their understanding of the impacts of climate change in the polar regions, stating that the PD assisted their teaching climate change "*by giving me a visual of how climate change is affecting other parts of the world and the animals who live in it*."

Question Two: *"In which ways, if any, did a focus on Antarctica (a polar region) assist your students in learning about climate change?"*

Teachers' responses to Question Two were similar to the previous question. The value of having contact with "live individuals" and being able to "see changes first hand" were perceived to be valuable for students. Two teachers responded of the importance of being able to make comparisons between the polar regions and their own community. One teacher evaluated the experience as engaging for students but challenging to work into the curriculum, which did not focus on climate change or the polar regions. Another teacher, however, was able to relate climate change to their current science topic, explaining:

> "*Focusing on Antarctica helped with climate change because we as a class focused on the polar regions and how climate change was affecting the food changes/ webs."*

Thus for two teachers, their curriculum was a central feature in their teaching about climate change but for the others it was not.

Question Three: *In what ways has each of the five components below assisted you, at all, to teach about climate change to your learners?*

Of the five components, Component 1, which asked about the 2016 Summer Made Clear Teacher Academy's polar region PD sessions, was most relevant to the primary research question for this project studying teacher PD. Three of the five teachers

found the PD session to have increased their interest and motivation to teach about climate change. For example, one teacher stated that the summer PD "hooks the teacher … the teacher is invigorated" and "made me even more passionate about teaching CC than I already had been."

Three teachers also stated the value of the PD providing background knowledge. For example one teacher stated,

> "*The summer session gave me information and knowledge to bring back to the classroom and share with my students. The polar region PD opened my eyes to what is happening in other parts of the world and how they can effect us here in Delaware."*

Finally, one teacher found the examples and activities they could use in their teaching to be of value.

Overall, the teacher responses indicated they were supportive of the blog, educational resources, and live video conference. However, the responses did not address how these components contributed to their professional development, and therefore did not directly inform the study's central research question.

Informed by Polar Prompts 1 and 2, five 3-4 minute educational videos (Component 5) were developed as a follow-up resource to the VTC. Teachers described them as "short and sweet" and helped to reinforce "what students have learned." Teachers received the follow-up videos near the end of the school year and discussed the possibilities of utilizing them in the future.

Question Four: *What do you think, if anything, your learners may have gained of special value in your teaching of climate change by including attention on the polar regions,*

especially Antarctica?

Four teachers indicated that their students learned that climate change is a serious global issue, and two teachers noted the value of learning about research.

Discussion

Findings from our exploratory study with a small sample of teachers suggest that teachers may find a focus on the polar regions as a helpful feature in their professional development and subsequent instruction of climate change. Specifically, since there is a noticeable and extreme nature of change in the poles, they can serve both as a starting point for teaching and learning about climate change as well as an opportunity to compare and contrast climate change in learners own communities. Connecting teachers to researchers in the poles additionally supports teacher PD efforts and the instruction of climate change to their students.

In this exploratory study two themes emerged and provide insight into teacher PD involving climate change and the polar regions. It was found teachers often described the polar regions as providing students with an opportunity to compare climate change in an extreme environment to their own communities. Additionally, the participating teachers were drawn more to discussing student engagement rather than their own teaching and professional growth. While our primary research question centers on how teachers consider using real-time polar research to inform their climate change education pedagogy, when asked about their Polar Region Climate Change PD, especially teachers involved in the video conference with Palmar Station, teachers frequently discussed student engagement.

Three of the six case study teachers in Phase II and III stated that being able to

compare the polar regions with their own communities was valuable. In addition, in Phase I, about a third of the teachers comments cited student interest as a benefit of studying the polar regions. However, in discussing the challenges of teaching with the polar regions, many of their comments stated that the polar regions were too distant and there was no frame of reference for students to draw upon. Further research is needed to understand how PD can better draw on student interest in the polar regions and/or how to connect the polar regions with learners' own communities to enhance their understanding of climate change. Moreover, exploration of how technology, especially technology that is already in use at US research stations (e.g., live webcams, video teleconferencing technology, email, satellite-connected telephones) and/or by Antarctic research teams (e.g., educational outreach websites, blogs, videos, podcasts) may help mediate the learning of extremely remote but geographically significant places for teachers and their students is also warranted.

It is noteworthy to mention that the Palmer Station researchers who contributed to this study were especially enthusiastic and appreciative of the opportunity to share their work with students and teachers. More ways to tap into Antarctic researchers' eagerness to participate in educational endeavors like this is yet another direction to take future research. It is also important to explore how having a teacher/educational researcher at a US research station in a polar region can impact the design of teacher professional development models on climate change. Although some programs exist for teachers to travel to a polar research station to participate and support real-time research, there is a lack of opportunities for educational researchers to design polar PD opportunities using real-time polar research to inform climate change education

pedagogy.

To conclude, finding from this study suggest that continued research in including a polar region focus in climate change education with use of real time data is warranted. Future research, with a larger sample, which consists of a wider range of teacher interest and experience, could build upon these initial findings and offer further insights towards incorporating the polar regions in climate education.

Limitations

While this exploratory study offers insights to how PD for teachers in climate change education that includes a polar region focus with use of real time data may influence their instruction there are limitations. Due to these limitations, findings in this report are not generalizable to other contexts with different populations, professional development experiences, or teaching other climate change topics.

Researcher objectivity may have been impacted in this project as the primary researcher was embedded in the research community at Palmer Station, developed the resources used in the PD, and took part in video conferences with the teachers and their students. That is, while multiple researchers on the MADE CLEAR team participated in analysis of the data and engaged actively in their interpretation, the degree of involvement of the primary researcher should be considered. Additionally, the small sample size and the self-selected nature of participants, particularly in the Phase II and III of the study, limit the depth and potential scope of the findings.

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Appendix A: Pre-Academy Survey Instrument

1. Last Name
2. First Name
3. For what school district do you work? (N/A for not applicable)
4. What subject(s) do you teach?
5. Tell us a little about your teaching experience, as well as your relevant professional development experiences.
6. What grades do you expect to teach in 2016-17?
7. Briefly discuss how you could modify your school year to include climate change.
8. What is your current assignment? (highlight all that apply)
    a. K-12 Teacher
    b. Science Supervisor
    c. Department Chair
    d. School-based resource teacher
    e. Team leader
    f. Informal Educator
9. Would you consider your school setting to be...
    a. urban
    b. rural
    c. suburban
10. What percentage of the students in your school qualify for Free and Reduced Price School Meals?
11. Please describe the availability of internet-enabled computers to your students while at school.

Appendix B: Polar Pre-Survey Questions

Individual Writing Activity

Name:

1.) *How have you taught about climate change in your teaching practice?"*

2.) If you have taught about climate change in your teaching practice, how have you included instruction about Polar Regions when you have taught about climate change?

Appendix C: Polar Graphic Organizer

Group Activity One (Pre-Academy Instruction)

Names of Group Members:

Part I: Using the material provided, please create a graphic organizer for the following prompt:

What do you know about the Polar Regions?

Group Activity Two (Post-Academy Instruction)

Names of Group Members:

Part II: Please revisit your graphic organizer to respond to following prompt:

What have you learned about the Polar Regions?

Appendix D: Post- Polar PD Survey Questions

Individual Writing Activity

Name:

Now that you have experienced instruction on the Polar Regions and real-time polar research,

1) How do you see yourself using it in your classroom to help teach about climate

change?

2.) *What do you see as some of the possible benefits and challenges to using it in your classroom?*

3) Would you be interested in a follow up session with Natalie during the school year, including a live Skype session from Palmer Station, Antarctica?

Appendix E: Case Study Polar Prompt #1

What would interest/benefit you and your students from the provided list of professional development experiences, and why?

List of professional development experiences:

- Access to polar-related educational resources at www.aflyonthepole.com
- A blog that chronicles my Antarctic expedition from December to March
- A live Skype session from Palmer Station, Antarctica

Appendix F: Case Study Polar Prompt #2

How did the pre-resources, if at all, prepare you and your students for the video teleconference (VTC) session?

How did the video teleconference (VTC) experience assist you, if at all, on how to teach about climate change?

Appendix G: Polar MADE CLEAR Case Study: Final Survey

(Section 1 of 7)

Dear _____,

We have reached the end of our Polar MADE CLEAR Study! Below is our final (and

most important) data collection from you as a participant of our study. It only consists of 4 items and might only take about 20 minutes. Please be as descriptive as possible as you fill out this short survey. We would like to receive your response by May 31st, so that we have sufficient time to write up our final report for the study.

Once completed, we will mail you a signed copy of the NSTA Press Book called Climate Change from Pole to Pole (2008). Dr. Richard Lee, an author of the book and chief scientist at Palmer Station, will personalize your book with a handwritten message to you and your students!

We can't thank you enough for your efforts to bring the polar sciences into your classrooms by participating in this study. We hope you find this personalized book useful in incorporating the polar regions in your climate change lessons in the future.

(Section 2 of 7)

Please consider your participation in the following PD opportunities when answering the

question below:

-Summer Made Clear Teacher Academy polar sessions
-2017 Antarctic Research Team's blog
-A Fly on the Pole educational resources
-the live Palmer video teleconference (VTC) session
-Follow- up polar videos

Question 1: *How has your participation in the polar-region focused PD, if at all, assisted you in teaching climate change this year to your learners?*

[text box for response]

(Section 3 of 7)

Question 2: *In which ways, if any, did a focus on Antarctica (a polar region) assist your students in learning about climate change?*

[text box for response]

(Section 4 of 7)

Question #3*: In what ways has each of the five components below assisted you, at all, to*

teach about climate change to your learners?

Component 1: 2016 Summer Made Clear Teacher Academy's polar-region PD sessions

[text box for response]

Component 2: 2017 Antarctic Expedition Blog (www.aflyonthepole.com)

[text box for response]

Component 3: Additional educational resources found on A Fly on a Pole website

[text box for response]

Component 4: The live Video teleconference (VTC) from Palmer Station

[text box for response]

Component 5: The five Follow-Up Polar Videos (see below)

Note: Four videos were embedded into the Google Form here for easy reference:

(Section 5 of 7)

Question 4: *What do you think, if anything, your learners may have gained of special value in your teaching of climate change by including attention on the Polar Regions, especially Antarctica?*

(Section 6 of 7)

Almost Done...

Provide your full name and address to receive your personalized NSTA Press book called "Climate Change from Pole to Pole" as a token of appreciation as a participant of this study!

(Section 7 of 7)

Thank you!