

# Climate Change as an Integrating Context for Learning

## **MEGHAN E. MARRERO**

U.S. Satellite Laboratory, Inc.; Email: [mmarrero@us-satellite.net](mailto:mmarrero@us-satellite.net)

## **BRADFORD T. DAVEY**

Technology for Learning Consortium, Inc.

## **HILARIE B. DAVIS**

Technology for Learning Consortium, Inc.

## **GLEN S. SCHUSTER**

U.S. Satellite Laboratory, Inc.

### **Responses**

Please consider writing a response to this paper in the WePaste forum for JASTE 3.1 ([www.wepaste.org](http://www.wepaste.org))

### **Abstract**

As the effects of global climate change are being observed but not yet fully understood, how can we best teach our K-12 students to examine and respond to this planet-sized problem? This research report describes evaluation results from the National Science Foundation- sponsored SPRINTT [Student Polar Research with National [and International] Teacher Training project, administered by U.S. Satellite Laboratory, Inc. In SPRINTT, students study standards-based science concepts in the context of Earth's Polar Regions and conduct their own research projects in which they analyze authentic data, collected by both western and indigenous scientists, and present their findings in the form of an online research paper. A random sample of research papers from more than 1000 students was analyzed using the program rubric to examine students' understanding of science concepts (e.g., adaptations of organisms, weather and climate); demonstration of process skills (e.g., citing evidence, drawing conclusions); and making connections to indigenous scientific knowledge and Native peoples of the Arctic. Students at the upper elementary, middle, and high school levels illustrated strong evidence of understandings of polar concepts and science process skills. These understandings and skills may help students as they become voters and decision-makers faced with socioscientific issues such as climate change.

### **Introduction**

Students of the 21<sup>st</sup> Century are facing many environmental issues—from oil spills to toxic sludge, acidifying ocean waters to mass extinctions in the rainforest. The defining issue of their time may be global climate change, but this important subject has become a highly politicized hotbed rather than a scientific

subject to be studied. We believe that In order to prepare students to be activists in responding to climate change, we need to prepare students to appropriately analyze and interpret real data, and make decisions based on science, not politics. This research report shares some of the evaluation results of a climate change research program for K-12 students, in which students studied science in the context of Earth's Polar Regions, Earth system science, and the issue of global climate change.

## **NSF-sponsored SPRINTT**

The years of 2007-09 were designated the “International Polar Year,” or IPY, by the International Council for Science and the World Meteorological Association. It was actually the fourth IPY; the first was held in 1882-83. This IPY lasted two full years to allow two cycles of research in both the Arctic and Antarctic. The purpose of this global scientific effort was to increase research and awareness of Earth's poles. In the most recent IPY, the urgency of observable effects of climate change triggered great global cooperation in both science and educational efforts (IPY International Programme Office, 2010).

In the United States, the National Science Foundation (NSF) funded several education projects to increase awareness of IPY and climate change. One such project was the SPRINTT [Student Polar Research for IPY with National (and International) Teacher Training] project, administered by U.S. Satellite Laboratory, Inc., an education technology group in Rye, NY. In SPRINTT, students in grades 6-12 study engaging topics including walrus movement and migration, ice and sediment cores, and glacial movement as they learn standards-based concepts including food webs, needs of living things, the phases of water, and erosion and deposition. The students access and interpret authentic data, collected by scientists around the world and shared with the SPRINTT team. As a capstone project, students report their findings in an online “Build-Your-Own Research Paper,” which presents as a web page that can be shared with parents, administrators, and other members of the school community.

The SPRINTT program is divided into three phases. In Phase I, students use hands-on and technology-based activities to make connections between their own lives and Earth's Polar Regions. The Phase is divided into three content themes: Frozen Water, Frozen Land, and Food. Phase I includes many scientific content-based connections to Alaska Native ways of knowing. Students watch videos in which Native elders describe the environmental changes that are occurring in the North. They read stories about Indigenous Scientific Knowledge of weather and ice changes and compare their own diets to those of traditional rural Alaskans. Students also interpret examples of Western Scientific Knowledge including satellite images of sea ice and temperature graphs generated from permafrost cores. Through these activities, students learn the value of both Indigenous and Western Scientific Knowledge. They begin to study concepts such as glaciers and sea ice, permafrost, and food webs and spend about 3 weeks on Phase I activities.

Phase II is an *optional* curriculum segment, comprised of standards-based lessons on a variety of topics in polar science, including the electromagnetic spectrum, albedo, ocean currents, penguin populations, and more. Phase III is the crux of the SPRINTT program; this is where student research projects take flight. In this Phase students are introduced to the process of scientific inquiry and use elements of Traditional

Knowledge and Western Science to conduct their own polar research. Custom-designed curricular materials and web tools scaffold the inquiry process, leading students through making observations, asking questions, analyzing data, drawing conclusions, and asking more questions. Students choose from many investigation topics, including studies of paleoclimatology, analyzing ice core data; biological change using tree line or reindeer data; changes in sea ice using satellite imagery, weather and climate, permafrost, and food webs and pollutants using an Alaska Native online database. Students write a hypothesis in response to a climate change-related research question, and analyze data to support or refute their hypothesis, communicating their findings in their web-based research paper.

Hundreds of teachers from across the United States, including villages in Alaska, as well as from Greenland and Denmark, were invited to participate in online and onsite teacher trainings. During these workshops, teachers learned about the educational philosophies inherent in the SPRINTT curriculum design, as well as how to facilitate student research projects using the Phase III tools. Each teacher also worked through their own research project, modeling what his or her students would do in the classroom. Teachers received ongoing phone and email-based support from program staff during implementation.

## **Theoretical Frameworks**

The instructional design of SPRINTT and methods of this study are based on the theoretical frameworks of contextual learning and social constructivism. Both of these frameworks are supported as students use technological tools to learn about Earth's poles through inquiry and through the lenses of Western and Indigenous Science.

**Contextual Learning.** Specifically, the instructional design of SPRINTT uses the environment as an integrating context (EIC) for learning. Research on EIC's notes that teaching science and other subjects using environmental context will lead to greater student engagement and performance (Lieberman & Hoody, 1998) and can be used as a way for students to learn the Nature of Science (NOS) (Khishfe & Lederman, 2006). In this case, students studied several scientific disciplines (physical, Earth and life science) in the context of Earth's poles and climate change. Students learn traditional science concepts, but the concepts are authentically integrated, providing students with a unified conceptual understanding and increasingly sophisticated content, instead of the rote memorization of isolated facts or cookbook activities, with which students have no personal connection. Research supports both achievement and affective gains for using an integrated approach (Czerniak, 2007). Hull (1993) explains that:

“According to contextual learning theory, learning occurs when students process new information or in such a way that it makes sense to them in their frame of reference (their own inner world of memory, experience, and response). This approach to learning and teaching assumes that the mind naturally seeks meaning in context--that is, in the environment where the person is located--and that it does so through searching for relationships that make sense and appear useful.” (p. 41).

As an example, in SPRINTT, students connect their own experiences to those of the Alaska Native peoples and their environments relating to content in the context of Frozen Water, Frozen Land and Food.

They build problem-solving skills by performing research and examining the evidence for and impacts of past, present and future changes in climate. In her comprehensive review of the relevant literature, Czerniak (2007) found “A number of K-12 studies sustain the notion that integration helps students learn, motivates students, and helps build problem solving skills” (p. 545). Learning science in an integrated context help to empower students toward active decision making, particularly for environmental and social problems such as global climate change (Bybee, 1993). The National Research Council (NRC) drafted the *National Science Education Standards*, “Standards,” in 1996. The *Standards* defined “scientific literacy” as “the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity” (National Research Council, 1996, p. 22). The *Standards* document explains that students should be active participants in their learning; they do not learn best from teachers simply presenting topics or by reading vocabulary-dense textbooks. In the SPRINTT program, students are using interactive, simple-to-use digital resources and tools to engage in science learning activities such as those advocated for by the NRC.

**Constructivism.** From a constructivist perspective, “learning is not viewed as transfer of knowledge but the learner actively constructing, or even creating, his or her knowledge on the basis of the knowledge already held” (Duit & Treagust, 1998, p. 8). John Dewey (1915) noted that, “[Learning] involves organic assimilation starting from within” (1915, p. 108); we begin with what we know from the world around us, and build upon that knowledge. The social constructivist design supports students as they work through the inquiry cycle. For example, in SPRINTT, students work in teams to access and analyze authentic data sets and use data (e.g., sea surface ice coverage, gas concentrations in ice cores) to make connections to the larger issue of global climate change. Technological tools support student teams as they make observations, ask questions, collect and analyze data, draw conclusions and suggest ideas for further investigation.

In SPRINTT, the constructivist design is supported in part by utilizing the “5E” model for inquiry-based science lessons: *Engage, Explore, Explain, Elaborate* and *Evaluate* (BSCS & IBM, 1989). In an *Engage* part of a classroom lesson, students connect to their prior knowledge and pique their interest in a new topic as they connect it to their previous understandings, e.g., considering the foods they eat during different seasons and comparing these foods to traditional seasonal foods and food-gathering practices of Alaska Natives. The *Explore* section allows students to work with new content, for example, by constructing an Arctic Ocean Food Web, before they *Explain* what they have learned through oral and written activities. In the *Elaborate* section, students can extend their new understandings to a new context, such as examining the biomagnification of pollutants and high levels observed in top-level predators. Finally, students demonstrate what they have learned in the *Evaluate* section.

**Using technology as a tool for inquiry.** Technological tools, including visualizations of data, animations, and “fly throughs” of faraway places can help students to make connections between their local setting and global environments and issues (Marrero & Schuster, 2010). In SPRINTT, students use visualizations of data, including sea ice and glacier coverage, air temperature and more to make comparisons between the Arctic and Antarctic. They watch animations of glacier formation and movement, and videos of tundra and taiga biomes to understand polar habitats.

In SPRINTT, students model what scientists do by accessing data and sharing collaborative ideas online (Hawkins and Pea, 1987). Inquiry-based learning is central to the development for students’ scientific literacy (AAAS, 1989; National Research Council, 1996). Even as U.S. schools are essentially all online (U.S.

Department of Education, 2004), studies are finding that computers are not often used in ways that promote student scientific literacy, and, in fact, digital tools and resources are being underutilized, particularly in science classrooms (Songer, 2007). SPRINTT gives teachers a way to use technology to scaffold learning experiences, allowing students to extend beyond their capabilities in terms of conceptual understanding, critical thinking skills and data analysis, as suggested as a best practice for inquiry-based science learning by Songer, Lee, & McDonald (2003).

**Indigenous Science.** An important component of SPRINTT was the infusion of Alaska Native resources and ways of knowing. Indigenous peoples of the circumpolar North have been successfully living in the Arctic, relying on its resources in a sustainable way, for thousands of years. These peoples, and other indigenous groups around the world, have their own body of knowledge and ways of knowing which allow them to observe and analyze their environments, manage their resources, and react to changes (Kimmerer, 2002; Lambert, 2003; Snively & Corsiglia, 2001). Through generations of close relationships with the land and sea, indigenous peoples have built a body of knowledge known as “traditional ecological knowledge.” In SPRINTT, we referred to this type of knowledge as “Indigenous Science,” and asked students to consider the similarities and differences between Indigenous Science and Western Science. For example, both Indigenous and Western Science practices are based on much careful observation. In Indigenous Science, however, explanations of these data often include ideas that are based on cultural values (Kimmerer, 2002). Understanding the ways in which the two perspectives complement each other and the relevance of each in terms of scientific thinking is a recommended approach for developing scientific literacy (Snively & Corsiglia, 2001).

SPRINTT students are asked to consider both Indigenous and Western perspectives on the same information. For example, they watch videos of Alaska Native elders describing the changes in weather patterns that they have experienced in recent decades. Then, students use visualization tools to see the same observations from a Western perspective.

## Research Aim

The aim of this research was to evaluate the effects of participation in the research project modules on students’ understanding of investigations, hypothesis development and testing, collection and use of evidence, how to draw conclusions, and western and indigenous content. Students engaged in SPRINTT had a unique opportunity to study science in the context of the Earth system, the poles and global climate change. They were introduced to Indigenous and Western science perspectives, accessed and analyzed their own data, and communicated their findings. They designed, conducted and reported their investigations. These group investigations were analyzed for effects on student understanding using a rubric. As researchers, we were interested in learning how students were able to demonstrate scientific thinking and understanding of polar science through their work products.

At the time of this study, the five investigation modules were:

- Alaska Native Reindeer Herding: Will climate change affect the plants reindeer eat?
- Paleo-Ice: What can ancient atmospheres on Earth tell us about Earth’s future atmosphere?

- Walrus: How will changes in sea ice affect walrus populations?
- Treeline: Movement of the Arctic Treeline
- Greenland: Is the Greenland ice sheet growing or shrinking, thickening or thinning?

At the end of the module, students use a database-driven research tool that creates a web page of their work with the following parts:

- Introduction
- Results (3 pieces of evidence)
- Methods
- Discussion

## Methods

To evaluate the effects of the SPRINTT student research studies on student content knowledge and scientific thinking, we analyzed a random sample of student research papers using the rubric provided to the teachers and students on the website. A stratified random sample (10% by grade) of student research papers was analyzed using the rubric provided to students and teachers to guide their investigations. Two researchers practiced scoring with the rubric until inter-rater reliability was achieved (Moskal & Leydens, 2000). Then one researcher scored all 89 papers, 10 or fewer at a time to preserve intra-rater reliability. The second researcher scored a 10% random sample of each grade level set of papers.

**Sample.** A total of 852 student groups completed research papers; 1166 completed some part(s). A random sample from elementary (45), middle (399) and high school (408) was chosen. The resulting sample consisted of eight elementary student research papers (18%), 40 middle school student research papers (10%), and 41 high school student research papers (10%). The total number of samples analyzed was 89 representing 10.4% of the total completed. A larger sample was analyzed at the elementary level to be sure the sample was representative of the small population (45). Table 1 shows that the random sample came from the different levels for each module. A breakdown of the sample by module and grade level is shown in Table 2 below.

**Table 1: *Sample Size***

Level	Population	Random Sample	% Of Total
Elementary School	45	8	18%
Middle School	399	40	10%
High School	408	41	10%
Totals	852	89	10%

**Table 2: *Breakdown of sample by module and grade level***

Topic	% Total by Module	Level	Number completed	Random Sample	% Total by Level
Walrus	12%	Elementary	11	2	18%
		Middle	65	11	17%

		High	112	10	9%
Paleo-ice	9%	Elementary	7	1	14%
		Middle	69	4	6%
		High	60	7	12%
Greenland	7%	Elementary	9	1	11%
		Middle	75	3	4%
		High	66	6	9%
Treeline	11%	Elementary	8	2	25%
		Middle	98	11	11%
		High	96	9	9%
Reindeer	14%	Elementary	9	2	22%
		Middle	82	11	13%
		High	70	9	13%

**Scoring with the Rubric.** The Student Research Paper Rubric, provided in the SPRINTT curricular materials (Figure 1), was used to score the sample of student research papers. Each student research paper was evaluated for how successful it was in meeting each criterion on a scale of 1-4. The rubric focused on the application of the content knowledge that was learned to develop a hypothesis, collect evidence to support or refute it, and discuss the conclusions. To score highly (3 or 4) students must have given background information about the topic and its importance, clearly stated an investigation question and justified their hypothesis, analyzed evidence supporting or refuting the hypothesis including knowledge from indigenous people, and given at least three pieces of evidence that supported their conclusions. Scores of at least three provide good evidence that students had learned the content and were able to apply it to draw evidence-based conclusions. The rubric appears below as Figure 1.

Introduction	4	3	2	1
Background	Gives in-depth background information about the topic (several paragraphs) including why the topic is important. Background information is in student's own words and includes pictures and/or other resources.	Gives background information about the topic (at least 1 paragraph), including its importance. Background information is in your student's words and may include pictures and other resources.	Background information is less than 1 paragraph or does not include the importance of the topic.	Background information is absent or is not in the student's own words.
Investigation Question	The investigation question is clearly stated and follows naturally from the background information given.	The investigation question is clearly stated.	The investigation question is stated but is unclear or inaccurate.	The investigation question is absent.
Hypothesis	Hypothesis stated clearly and includes	Hypothesis stated clearly and	Hypothesis is stated clearly	Hypothesis is absent or not stated clearly.

	justification based on sound logic and reasoning.	includes justification.	but lacks justification.	
<b>Results</b>	<b>4</b>	<b>3</b>	<b>2</b>	<b>1</b>
Gives Evidence	Gives three pieces of evidence that clearly support the conclusion. Includes graphs, charts, images, or other information.	Gives three pieces of evidence that support the conclusion, but evidence is only somewhat clear or is lacking graphs, charts, and images.	Only two pieces of evidence given or the evidence does not support the conclusion.	Fewer than two pieces of evidence given.
Uses Indigenous People's knowledge as part of evidence	Indigenous people's knowledge is used for at least one piece of evidence. The source of the evidence is clearly stated and its importance to the conclusion is clear.	Indigenous people's knowledge is used for at least one piece of evidence.	Indigenous people's knowledge is presented as evidence, but the evidence is not clear or is not connected to the conclusion.	None of the evidence includes indigenous people's knowledge
Describes Evidence	Clearly explains what the pieces of evidence (graphs, charts, etc.) demonstrate.	Explains what the pieces of evidence (graphs, charts, etc.) demonstrate.	Evidence is not clearly described.	Description of the evidence is absent.
<b>Methods</b>	<b>4</b>	<b>3</b>	<b>2</b>	<b>1</b>
Describe Methods	Clearly describes step-by-step methods used to gather each piece of evidence presented in the results section. It is clear which methods were used for each piece of evidence presented.	Describes step-by-step methods used to gather each piece of evidence presented in the results section.	Methods are described, but are incomplete. Some of the methods used to determine the evidence in the results section are not included.	Methods are absent or do not give enough specific information. (e.g. "We looked at graphs and tables and figured some things out.")
<b>Discussion</b>	<b>4</b>	<b>3</b>	<b>2</b>	<b>1</b>
States Conclusion	Conclusion of the investigation is clearly stated in the first sentence.	Conclusion of the investigation is stated in the first sentence.	Conclusion of the investigation is not clearly stated or is not in the first sentence.	No clear conclusion is given.
Restate Hypothesis	Restates hypothesis and clearly describes whether hypothesis was supported or	Tells whether the hypothesis was supported or unsupported by	Restates the hypothesis but does not tell whether it was	Does not return to the hypothesis.

	unsupported by the evidence.	the evidence, but does not restate hypothesis.	supported or unsupported by the evidence.	
Relates Evidence to hypothesis	Clearly explains how each piece of evidence is related to the hypothesis.	Sometimes explains how pieces of evidence are related to the hypothesis.	Connection between the evidence and hypothesis is weak or unclear.	There is no connection between the evidence and the hypothesis.
Connection to lives of indigenous people	Clearly explains how the topic and conclusions of the investigation impact the lives of indigenous people, giving at least two examples.	Clearly explains how the topic and conclusions of the investigation impact the lives of indigenous people, giving at least one example.	The impact of the topic and conclusions on indigenous people is unclear or inaccurate.	No mention of the impact of the topic or conclusions for indigenous people.
Follow-up	Clearly describes a follow-up study that would follow naturally from the results of this investigation.	Describes a follow-up study that would allow for more investigation on the topic.	Suggestion for follow-up study is inappropriate or not related to topic.	Suggestion for follow-up study is absent.

**Figure 1. SPRINTT Student Research Paper Rubric**

## Findings

Table 3 lists student mean scores by criterion. As would be expected, middle and high school overall mean scores were significantly higher (significance < 0.05) than the mean scores for elementary research papers. Elementary students were good at giving evidence (3.0) and stating conclusions (2.6). Middle and high school research papers showed strong evidence of good background information (3.6, 3.4) and clearly stated hypotheses (3.1, 3.0) as well as having detailed descriptions of the methods (3.1, 3.0) used for collecting their reported evidence. All levels stated conclusions well (2.6, 3.1, 3.2) while middle and high school student research papers were more consistent at restating their hypotheses (2.7, 2.6) and tying the evidence collected to their hypotheses (2.6, 2.4). None of the age levels consistently used indigenous peoples' knowledge as part of evidence (1.6, 2.3, 2.1) or connected the lives of indigenous peoples to their work in the discussion of their research papers (2.0, 2.0, 1.9) and only a very small number offered any follow-up investigations or direction for additional research (1.3, 1.8, 1.7).

**Table 3: Summary of Student Research Paper Mean Scores by Grade Level and Criteria**

Criteria (Scale of 1-4)	Grade Level Mean Score		
	Elementary (N=8)	Middle (N=40)	High (N=41)

<b>Introduction</b>			
Background	2.4	3.6	3.4
Investigation question	2.4	3.1	2.8
Hypothesis	2.3	3.1	3.0
<b>Results</b>			
Gives Evidence	3.0	3.6	3.5
Uses Indigenous Peoples' Knowledge as Part of Evidence	1.6	2.3	2.1
Describes Evidence	2.5	3.0	3.0
<b>Methods</b>			
Describes Methods	2.0	3.1	3.0
<b>Discussion</b>			
States Conclusions	2.6	3.1	3.2
Restates Hypothesis	2.3	2.7	2.6
Relates Evidence to Hypothesis	2.1	2.6	2.4
Connection to Lives of Indigenous Peoples	2.0	2.0	1.9
Follow-up	1.3	1.8	1.7
<b>Overall</b>	<b>2.2</b>	<b>2.8</b>	<b>2.7</b>

Referring back to the NSES standards correlations noted in the curricular materials, we noted that all five modules address the standards for scientific inquiry, use of evidence and change, constancy and measurement.

- Science as Inquiry standards on: 1) Abilities necessary to do scientific inquiry, and 2) Understandings about scientific inquiry
- Unifying Concepts and Processes of: 1) Evidence, models, and explanation, and 2) Change, constancy, and measurement

Students' research papers showed evidence of positive effects in these areas, particularly giving and describing evidence.

### Examples of Student Research Papers

Two screen captures from student group research papers from each of the three student grade bands: elementary, middle, and high are shown below to illustrate the thinking and understanding students demonstrated. A brief discussion precedes each pair of images about how the student research paper demonstrates knowledge of the content through applying it to draw evidence-based conclusions. Note that the samples are from the Paleo-ice and Walrus module research papers.

**Elementary Example.** This example from an elementary student group shows how the evidence that both supports the hypothesis and informs the reader about how the changes in sea ice will affect the indigenous people of the area. In the discussion, s/he clearly states whether the hypothesis was supported or refuted based on the evidence collected, "I conclude that the walrus population is being affected by melting sea ice." The student continues to discuss how the evidence collected supports the conclusions and how the changing environmental conditions may affect the indigenous people in the future. The student also asks, "What can I do to help?"

**Piece of Evidence #2:**

Another problem caused by walrus dying is that the natives are running out of one of their main food sources is disappearing because the walrus stay near the sea ice so when the ice line is retreating the walrus are going farther out to sea. So lately natives are only catching about 17 walrus when they normally catch over 100 walrus.



Since the walrus are disappearing people have to find a new source of food.



Figure 2. Elementary School Student Research Paper Image 1. Image credits U.S. Satellite Laboratory, Inc.

**Discussion:**

I concluded that the walrus population is being affected by the melting sea ice. I had guessed this in the beginning of my research. My evidence supports this conclusion because as walrus are being abandoned they are dying so that means there is less walrus to reproduce. Also, as the ice line is retreating it is becoming harder to hunt along with the walrus food. This means the indigenous people are running out of food and the other things they can make from their bones and skin. The walrus are also starving because their food sources are disappearing like I said above. What we have to think of now is going to happen? If you think about it about it is like a vicious circle that affects almost everything. If the polynas are melting than the clams and mussels are dying. If the mussels are dying then ther walrus are starving. If the walrus are dying then the indigouenas people aren't finding food. If the people aren't finding food then they are dying. It really is sad. It makes me think "how can I help?"



Figure 3. Elementary School Student Research Paper Image 2. Image credit: Credit: NOAA/Budd Christman.

**Middle School Example.** This example from a middle school student shows an understanding of the content through evidence collected and how the situation affects indigenous peoples. The first piece of evidence is focused on indigenous people and how they have passed down information from generation to generation and that, "The indigenous people rely on this knowledge that they share with each other to

survive.” The conclusions combine the evidence that was collected by scientists about ice core samples with what has long been handed down from generation to generation to support the original hypothesis and draw conclusions based on the evidence.

### Results:

#### Piece of Evidence #1:

The indigenous people use their previous knowledge of the ice core temperatures to know what the previous temperatures were so they can prepare for the current and future temperatures. The indigenous people have gotten their knowledge by passing the information about the temperature patterns from generation to generation through stories and songs and other ways they communicate. They tell the stories and share with their family about the weather and climate and how it has changed and what happened when it changed. They did not really go out and measure the gases. This information helps to support that the data gotten from the measurements of the ice core are reliable.

The indigenous people rely on this knowledge that they share with each other to survive. For example if they know that the pattern of temperatures shows a decrease, then they know how to prepare for the lower temperatures and can change what they do for the plants and animals they need to survive. They might have to change the food that they will grow for the next season and how they prepare it. Some of the animals that they kill for food may not be able to survive in the colder temperatures so they may have to find new animals that have adapted to the colder climate. If the temperatures are going up, the same could happen with it being too warm for some plants and animals to survive. Either way, it would be helpful to know the patterns from long ago to help predict and plan for the current and future temperatures and what types of plants and animals they could use as food to help them survive.

Figure 4. Middle School Student Research Paper Image 1

### Discussion:

We can learn about temperatures from long ago by using ice cores because they can tell us what the temperatures were by measuring the gases that are in them. This helps us to see what the patterns of the temperatures were and how they have changed. This information can help us to predict what may happen and where we might be in the changing temperatures. My hypothesis is correct because we can tell if humans are the reason for the changes. The gas concentrations are huge and they never were before and they probably came from humans and what they do now to survive and live.

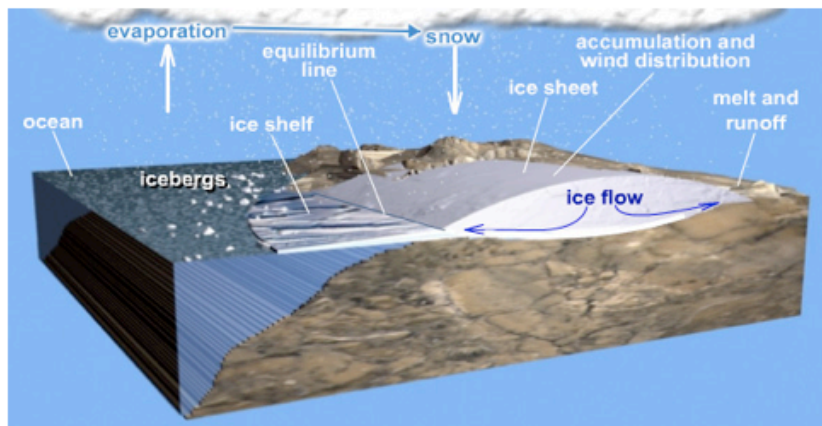
The evidence in the results section supports my conclusion because it talks about how you can find the temperatures using the O18 bubbles and how this shows the concentration of the gases like CO2 and methane that are present. When the concentrations are low, the temperature is low and the Earth was in a glacial period. When the concentrations were high, the temperature was higher and we weren't in a glacial period. Humans would have a hard time surviving in a glacial period because they need to have food, water and shelter and it would be hard for them to find this where there was mainly only ice and snow. The indigenous people used what they knew about the temperatures from the past to help them to survive. They could change what they grew or hunted because they had information from the people before them that helped them to predict what the weather would be like and the best things to grow and hunt during that weather. They could see patterns in what was happening and changed what they did to help them survive.

The indigenous people could use what they knew to help them to know what to grow and hunt during the different temperatures. They could tell from stories that the people who lived before them told, what the weather and temperatures might be like and how that would make them have to change what they were going to use for food, water and shelter. If it was suppose to be a cold period, they would only grow things that could survive in the cold. They might have to move to a different place if the temperatures were going to be too cold for them to live. They might have to move closer to the equator where it might be warmer when the temperatures were going to be colder so that it wouldn't be as cold and then move back when the temperatures were going to be warmer so it wasn't too warm.

I think that someone might want to study the amounts of CO2 and methane concentrations and what might have caused them to increase and decrease. They could see what things that humans do cause the most increase and what humans could do to make it decrease more. This would help us to learn about global warming and what we could do to stop it.

Figure 5. Middle School Student Research Paper Image 2

**High School Example.** This high school student research paper has a detailed introduction in which information is offered that reveals the problem from which a hypothesis is generated. The student was able to build an argument based upon the evidence and develop questions to be answered through his/her research. In the discussion, the student ties the conclusions directly to the evidence that was collected and summarized. Additionally, the student explicitly addresses how the indigenous people may be affected and asks additional questions that might help lead to further discovery. This student's research shows a balanced look at the issue in which the change to the climate may have both negative and positive effects on the indigenous people and their environment.



Specifically in Greenland, the change in ice is apparent. This ice is continental ice, and it has a much more severe effect on the ecosystem. Unlike sea ice, which does not change the sea level, the melting of continental ice does. Home to the third largest ice sheet in the world, scientists have become much more interested in changes happening in Greenland than ever before. They have done countless tests and research experiments, providing much information that has proven valuable in determining Greenland's role in the worldwide ecosystem. One item has become obvious its greatest role lies in the ice it maintains and how it is changing. This realization has led to the question as to what exactly its ice sheet is doing. Is the Greenland ice sheet growing or shrinking, thickening or thinning? After analyzing the data and observing the results of other scientists, we have concluded that the ice sheet is shrinking. This is due to extended melting period coupled with a shortened freezing period, leaving a greater amount of sea water and ice at the end than what was there at the beginning.

Figure 6. High School Student Research Paper Image 1. Image credit: U.S. Satellite Laboratory, Inc.

**Discussion:**

From completing this research, we have concluded that the Greenland ice sheet is indeed shrinking. This reaffirmed our hypothesis that the Greenland ice sheet is shrinking. We proved our hypothesis through our evidence and how we used it. We first presented the change in melt areas in recent years, which shows that the ice sheet is not freezing back completely, making it smaller. We then proved the irregularity of earthquakes to be related to the temperature, and showed how the ice sheet melting was causing this with less pressure on the crust. We finally solidified our claim by incorporating the indigenous people of Greenland, along with their response to the temperature increase and subsequent melting of the ice sheet.

The lives of the Indigenous people are most affected by this conclusion. With the ice melting and temperatures rising, they no longer can depend on the Arctic Char to provide food, money, and stability to their lives. Instead, they have to adapt to the climate changes and move to the more urbanized cities. There, they are beginning to search for minerals, an exploration than seems promising for the future. Also, the people have taken advantage of the warmer temperatures and now have a longer growing season for their plants.

Now knowing that the Greenland ice sheet is shrinking, many questions have arisen. The most prominent question is whether or not the Antarctic ice sheet is shrinking, for its impact would be tenfold of what the Greenland ice sheet has done.



Figure 7. High School Student Research Paper Image 2. Image credit: NASA.

Based on the analyses, we have evidence that SPRINTT enhances students' understanding of polar concepts and also science process schools. The strongest evidence comes from the analyses of the student research papers. In these research papers, students demonstrated they developed sufficient understanding of the content to draw evidence-based conclusions about a pivotal issue or an important question.

## Discussion

Using the EIC (Lieberman & Hoody, 1998) of Earth's Polar Regions and global climate change, students demonstrated the application of scientific thinking to scientific questions related to evidence and effects of climate change. They illustrated understanding of concepts related to Earth's poles and climate change, (e.g., day length, adaptations of tundra organisms, climatic variables, and the greenhouse effect), and also the effects of Arctic environments and observed changes on indigenous peoples of the circumpolar North. Students at the elementary, middle, and high school levels demonstrated abilities to write hypotheses, analyze data, cite evidence, and draw conclusions within the context of real-world problems. Additionally, they met standards of scientific communication as they presented their analyses and findings in the form of a research paper, much like scientists do. These and other skills of scientific thinking are an important component of scientific literacy (National Research Council, 1996, 2010). The data sets incorporated into SPRINTT Phase III to be analyzed by students came directly from scientists, and gave students the opportunity to scientifically analyze authentic data and draw conclusions based on evidence, rather than becoming embroiled in political battles surrounding the causes and effects of climate change.

This study shows promise in the area of climate change education and promoting scientific literacy. The findings support the idea of using global climate change as an EIC as a means for promoting student understanding of the Nature of Science (Khishfe & Lederman, 2006), and also scientific thinking and communication skills. When approaching socioscientific issues (SSI), such as climate change, students are asked to consider real-life problems about which they may be asked to make decisions (Sadler, 2004). However, research on using SSI in the classroom finds that it is very challenging to help students to draw upon their knowledge of science concepts and use scientific data to support their positions (Grace & Ratcliffe, 2002; Ratcliffe, 1997; Robinson & Kaleta, 1999). In the case of SPRINTT, students used a scaffolded online investigation tool which assisted them in using evidence to support their ideas and findings. The next step will be to work with students to apply such scientific ways of thinking to authentic decisions. SPRINTT students are working toward scientific literacy, as they apply content and process skills to the authentic problem of climate change.

Another area of needed research is to continue to promote the use of indigenous scientific knowledge as a means of promoting scientific literacy (Snively & Corsiglia, 2001). Although SPRINTT students were exposed to indigenous scientific knowledge and ways of knowing through stories, videos of elders, and other means, they did not consistently make the connections to these ideas in their research papers. While we cannot be sure why, we speculate that because students, and teachers, were less familiar with this type of scientific evidence, that they could not effectively articulate the evidence from indigenous sources. The SPRINTT program in the future will strive to assist students in understanding the areas of using indigenous

people's knowledge as evidence, making connections to indigenous people's lives, and discussing possible follow up studies. Examples of research papers at each level of the rubric could provide students with models for these areas. These areas might also be weighted more heavily in the rubric to encourage students to address them more explicitly.

Overall, the analysis of the sample of student research papers across grade levels and modules shows that students developed a good understanding of the content and the scientific inquiry process to draw evidence-based conclusions. Based on this work, we believe that students at the upper elementary, middle, and high school levels, if given the right tools for investigation, can effectively analyze important global problems and make decisions, or model decision-making based on scientific data. 'The SPRINT<sup>™</sup>' program is a step in the right direction, as students used the powers of the Nature of Science to consider climate change, but similar methods could be used to consider other socioscientific issues.

## Acknowledgements

This work was funded in part thanks to the National Science Foundation (NSF Award 0732793). *Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation*

Special thanks are in order to collaborators from the Alaska Native Science Commission and Alaska Native Knowledge Network, and, in particular, Dr. Patricia Cochran. Thank you for your work and support in assuring that indigenous science perspectives were evident in SPRINT<sup>™</sup>.

## References

- AAAS. (1989). Introduction to science for all Americans. Retrieved October 21, 2010, from <http://www.project2061.org/publications/sfaa/online/intro.htm>
- BSCS, & IBM. (1989). *New Designs for Elementary Science and Health: A cooperative project between Biological Sciences Curriculum Study (BSCS) and International Business Machines (IBM)*. Dubuque, IA: Kendall Hunt.
- Bybee, R. W. (1993). *Reforming science education: Social perspectives and personal reflections*. New York: Teachers College Press.
- Czerniak, C. (2007). Interdisciplinary Science Teaching. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of Research on Science Education*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Dewey, J. (1915). *The school and society & The child and the curriculum*. Mineola: Dover.
- Duit, R., & Treagust, D. (1998). Learning in Science-- From behaviorism towards social constructivism and beyond. In B. J. Fraser & K. G. Tobin (Eds.), *International Handbook of Science Education* (pp. 3-25). Great Britain: Kluwer Academic Publishers.
- Grace, M. M., & Ratcliffe, M. (2002). The science and values that young people draw upon to make decisions about biological conservation issues. *International Journal of Science Education*, 24(11), 1157-1169.
- Hull, D. (1993). *Opening Minds, Opening Doors: The Rebirth of American Education*. Waco, Texas: Center for Occupational Research and Development.

- IPY International Programme Office. (2010, February 4, 2010). International Polar Year. Retrieved January 14, 2011, from <http://ipy.arcticportal.org/>
- Khishfe, R., & Lederman, N. (2006). Teaching nature of science within a controversial topic: Integrated versus nonintegrated. *Journal of Research in Science Teaching*, 43(4), 395-418.
- Kimmerer, R. W. (2002). Weaving Traditional Ecological Knowledge into Biological Education: A Call to Action. *Bioscience*, 52(5), 433-439.
- Lambert, L. (2003). From 'Savages' to Scientists: Mainstream Science Moves toward Recognizing Traditional Knowledge. *Tribal College Journal*, 15(1), 10-13.
- Lieberman, G. A., & Hoody, L. L. (1998). *Closing the Achievement Gap: Using the Environment as an Integrating Context for Learning. Results of a Nationwide Study*. San Diego, CA: State Education and Environmental Roundtable.
- Marrero, M., & Schuster, G. (2010). Students making environmental connections to achieve scientific literacy: From local schoolyards to half a world away. In J. Hoot & J. Szente (Eds.), *The Earth is Our Home* (pp. 93-108). Olney, MD: Association for Childhood Education International.
- Moskal, B. M., & Leydens, J. A. (2000). Scoring rubric development: validity and reliability. *Practical Assessment, Research & Evaluation*, 7(10). Retrieved from <http://PAREonline.net/getvn.asp?v=7&n=10>.
- National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.
- National Research Council. (2010). *A Framework for Science Education: Preliminary Public Draft*. Washington, DC.
- Ratcliffe, M. (1997). Pupil decision-making about socio-scientific issues within the science curriculum. *International Journal of Science Education*, 19(2), 167-182.
- Robinson, M., & Kaleta, P. (1999). Global environmental priorities of secondary students in Zabrze, Poland. *International Journal of Science Education*, 21(5), 499-514.
- Sadler, T. D. (2004). Informal Reasoning Regarding Socioscientific Issues: A Critical Review of Research. *Journal of Research in Science Teaching*, 41(5), 513-536.
- Snively, G., & Corsiglia, J. (2001). Discovering Indigenous Science: Implications for Science Education. *Science Education*, 85(1), 6-34.
- Songer, N. B. (2007). Digital resources versus cognitive tools: A discussion of learning science with technology. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of Research on Science Education*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Songer, N. B., Lee, H.-S., & McDonald, S. (2003). Research Towards an Expanded Understanding of Inquiry Science Beyond One Idealized Standard. *Science Education*, 87(1), 490-516.
- U.S. Department of Education. (2004). *Toward a new golden age in American education: How the internet, the law, and today's students are revolutionizing expectations*. Retrieved from <http://www.ed.gov/about/offices/list/os/technology/plan/2004/plan.pdf>.