IPY STEM Polar Connections

Overview

The Science, Technology, Engineering, and Mathematics Education Institute (STEM Ed), the Climate System Research Center (CSRC), and additional scientists and engineers involved in polar research at the University of Massachusetts Amherst (UMass) propose to create *IPY STEM Polar Connections*: *A three region initiative to integrate the study of Polar Regions and activities associated with the International Polar Year into the middle and high school curriculum..*

STEM Ed, and its Director Morton M. Sternheim, has been a leader in teacher professional development in STEM fields since 1986. The CSRC, directed by Ray Bradley, brings together UMass graduate students, post-docs, research scientists, and faculty interested in many aspects of the climate system. Other faculty participating include Julie Brigham-Grette (Geosciences), whose work includes studies of the Bering Strait region and polar lakes in Siberia; and Wayne Burleson (Electrical and Computing Engineering, and the Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere (CASA)) who has been involved with placing specialized sensors at the south pole and with advanced weather radar networking..

IPY STEM Polar Connections will build on the experience of STEM Ed and faculty at UMass as it promotes the teaching of polar science in the New England, Mid-Atlantic, and Great Lakes Regions. It is a curriculum development and professional development program that includes residential summer institutes at UMass and academic year online communication for teachers involved in the professional development of colleagues. During the summer institutes, teachers will be introduced to Polar Connections Modules that will emphasize the processes of scientific inquiry. Participants will explore a variety of proven techniques for effective teaching, including inquiry-based teaching and formative assessments of student learning. Summer institutes will be designed to advance the knowledge that STEM teachers have of phenomena and processes that occur in Polar Regions so that they can effectively field test and disseminate curriculum modules at the local, regional, and national levels.

Polar Connections Modules will be aligned with National Science Education Standards and with standards for states in the participating regions and will emphasize the value of advancing society's understanding of the nature and possible causes of changes in the physical environment and ecosystems of the Polar Regions and the relationship of those changes with other physical environments and ecosystems. The activities of Polar Connections Modules will be designed to acquaint middle and high school students with many avenues of polar research, the extent of international collaborations in polar research, and opportunities they have to participate in that research. The modules will utilize several formats in order to maximize the range of STEM programs into which the modules can effectively be integrated. Earth and environmental science classes may use one or more modules in their entirety, while other classes may incorporate specific components that meet their curricular needs.

Teachers will be actively engaged in the process of producing final versions of the Polar Connections Modules initially drafted by the IPY STEM Polar Connections staff. A strong educational research component will assess the effectiveness of providing local and regional contexts for conducting research that results in an understanding of Earth's global systems that are influenced by and interact with the physical environments and ecosystems of Polar Regions.

The **Intellectual Merit** of IPY STEM Polar Connections includes opportunities it affords teachers and their students to conduct authentic research in association with staff and faculty at UMass who conduct polar research and the access that teachers and their students gain to international teams of researchers in Polar Regions. The **Broader Impact** is that the materials developed and disseminated have the potential to improve science education for large numbers of students in many areas. The **Relevance to the IPY** is that teachers and their students will gain an understanding of the importance of Polar Regions for everyone.

Rationale/Need

The performance of U.S. school children in the sciences has been a major concern for educators and policy makers. After more than a decade of reform efforts in science education, student achievement in science at the middle and high school levels remains in need of improvement. In this section we will examine (1) the student performance issues, (2) underrepresented minority concerns, (3) the teacher qualification problem in STEM disciplines, and (4) the rationale for IPY STEM Polar Connections.

(1) The National Center for Educational Statistics (NCES, 2006) in *The Nation's Report Card: Science 2005* has reported that U.S. fourth grade students have made progress in science proficiency in recent years as measured by the National Assessment of Educational Progress (NAEP). However, the performance of eighth grade students has not improved and the performance of twelfth grade students has declined over the past decade (Table I).

Fourth Grade	At or Above Basic Level	At or Above Proficient Level
2005	68%	29%
2000	63%	27%
1996	63%	28%

Eighth Grade	At or Above Basic Level	At or Above Proficient Level
2005	59%	29%
2000	59%	30%
1996	60%	29%

Twelfth Grade	At or Above Basic Level	At or Above Proficient Level
2005	54%	18%
2000	52%	18%
1996	57%	21%

Table I. National Assessment of Educational Progress science scores, (NCES, 2006)

Table II indicates that, with the exception of Vermont, all states in the region report that a greater percentage of their eighth grade students performed at a Below Basic level than their fourth grade students on the 2005 NAEP. It can also be concluded that there has been very little increase in students reaching the proficient or advanced levels of achievement.

State	Grades	Below Basic	Basic	Proficient	Advanced
Maine	4th / 8th	19% /28%	45% / 37%	33% / 32%	3% / 3%
New Hampshire	4th / 8th	17% / 24%	46% / 36%	35% / 36%	2% / 4%
Vermont	4th / 8th	22%/ 21%	41% / 35%	34% 36%	4% / 4%
Massachusetts	4th / 8th	21% / 28%	41% / 32%	34% / 35%	4% / 6%
Rhode Island	4th / 8th	37% / 42%	40% / 32%	22% / 24%	1% / 2%
Connecticut	4th / 8th	28% / 37%	40% / 30%	30% / 29%	3% / 4%
New York (2000)	4th / 8th	34% / 39%	41% 42%	23% / 27%	2% /2%
New Jersey	4th / 8th	28% / 35%	40% / 32%	29% / 29%	3% / 4%
Pennsylvania	4th / 8th	NA	NA	NA	NA
Ohio	4th / 8th	25% /33%	40% / 32%	31% / 31%	3% / 4%
Michigan	4th / 8th	31% / 34%	39% / 31%	27% /31%	3% / 4%
Indiana	4th / 8th	30% / 38%	43% / 33%	25% / 26%	2% / 3%
Illinois	4th / 8th	36% / 42%	38% / 30%	21% / 25%	4% / 6%
Wisconsin	4th / 8th	23% / 30%	42% / 32%	32% / 34%	3% / 5%
Minnesota	4th / 8th	24% / 29%	42% / 32%	31% / 36%	3% / 4%
United States	4th / 8th	34% / 43%	39% / 30%	25% / 29%	2% /3%

Table II. NEAP scores by state, (NCES, 2006)

Internationally, some improvement in U.S. student performance is reflected in the TIMSS reports (TIMSS, 2003). While there was no measurable difference in the average science performance of U.S. fourth grade students between 1995 and 2003, U.S. eighth grade students improved in science since 1995 and 1999. Fourth grade students in the U.S. outperformed students in 16 of the 24 participating countries. Eighth grade students in the U.S. outperformed their peers in 32 of the 44 participating countries. The improvement among eighth grade Black and Hispanic students also demonstrated improvement since 1995 and 1999. The 2003 TIMSS report did not include data for twelfth grade students. However, a downward trend that starts in middle school and continues through high school was revealed when U.S. twelfth grade scores were below average and among the lowest of the twenty-one nations compared (National Center for Educational Statistics, 2001).

(2) In many states, students from underrepresented minorities achieve lower than average math and science test scores. For example, Table III gives the results of the 2004 Massachusetts 8th grade tests. Far fewer minority students achieve advanced or proficient levels than white students, and far more need improvement or are in the new warning/failing category.

	Advanced	Proficient	Needs Improvement	Warning/Failing
	Mathematics			
African American	2	12	31	55
Hispanic	2	10	28	60
Native American	7	22	32	40
White	15	30	34	22
	Science and Technology			
African American	1	8	29	63
Hispanic	1	7	25	68
Native American	1	24	37	38
White	6	33	38	22

Table III. Massachusetts grade 8 scores by ethnic group. (Massachusetts Dept. of Ed., 2004)

This weakness in minority science and mathematics achievements is reflected in their under-representation among science and degree recipients and workforce. In 1999, Blacks, Hispanics, and American Indians as a group constituted 24 percent of the U.S. population but only 7 percent of the total S&E workforce; Blacks and Hispanics each represented about 3 percent of scientists and engineers, and American Indians represented less than 0.5 percent

	BS	MS	PhD	Population
Underrepresented minorities	**16.3%**	**13.2%**	**8.9%**	**28.2%**
Black, non-Hispanic	8.4	7.2	4.4	13.3
Hispanic	7.3	5.5	4.2	13.4
American Indian/Alaskan Native	0.7	0.7	0.5	1.5

Table IV. STEM degrees for minorities (NSF, 2002).

Clearly, while some assessments reveal progress for minority groups, there remains a great need to continue the effort to improve the performance and participation of these groups in STEM fields. The country needs their potential contributions to the STEM workforce, and the minority students should consider the excellent careers opportunities they afford. IPY STEM Polar Connections will target recruiting the relatively small number of minority science teachers who serve as critical role models and also science teachers serving heavily minority districts. It will also stress the student active learning approaches which have been found so effective in helping minority students. The number of women entering STEM fields is also a concern, although considerable progress has been made in this area. Again, active learning approaches have been found to increase interest and success rates among young women.

(3) One might expect that teachers' content and pedagogy qualifications would correlate with student achievements. Indeed, the research literature does support this expectation. Studies show that students in fact do learn more mathematics from teachers who were math majors (Goldhaber and Brewer, 1997) and learn more math and science from teachers who studied teaching methods in their subject (Monk, 1994; Goldhaber and Brewer, 1997).

Teachers of science and mathematics are often inadequately prepared, especially in the middle grades where school districts often have difficulty in recruiting qualified teachers. A large percentage of middle and high school teachers of earth and physical sciences have inadequate preparation in those areas (2000 National Survey of Science and Mathematics Education, 2002). Indeed, few middle school teachers hold undergraduate degrees in either science or science education. When asked to identify needs for professional development, 67% of middle school science teachers identified deepening their content knowledge as necessary; 54% also identified assessing learning in science, 61% using investigative science strategies, 58% understanding student thinking, and 78% using technology in instruction.

In too many classrooms, students are taught by teachers certified in subjects other than ones they teach. These teachers lack the content knowledge and content-specific pedagogic tools needed to address common misconceptions and topics that students find difficult or confusing. This problem is most acute in the middle schools and very serious in the high schools. In their report, Seastrom (Ingersoll, 1999; Seastrom, Gruber, Henke, Mcrath, and Cohen, 2002) and her colleagues showed that in 1999-2000 nearly 60% of middle school students were taught science by teachers not certified and without a major in the field. At the high school level, in biology 45% of students are taught by out-of-field teachers, and there are larger percentages in chemistry (61%), physics (67%) and earth science (79%).

The Glenn Commission report, *Before It's Too Late* (Glenn, 2000), again emphasizes the acute need for more and better-prepared science (and math) teachers. The nation will need 45,000 new secondary science and mathematics teachers annually over the next decade. At the national level, there is already is a severe shortage of qualified science teachers for middle and high schools (Ingersoll, 2003; Rhoton and Bowers, 2003). The shortage is attributed to several factors including the low retention rate of teachers, the large numbers of teachers at retirement age (NCTAF, 2003), and the low numbers of students majoring in science, technology, engineering and mathematics (STEM) disciplines (Hill, 2002).

The need for students in all academic and vocational programs to be well prepared in science increases with advances in technology and with the growing awareness of the impact of human activity on Earth's physical environment and ecosystems. The economy demands increasing numbers of people with science backgrounds since the technological and environmental problems facing our society require citizens who can understand these issues.

(4) The study of Polar Regions can play a key role in advancing the knowledge base of middle and high school teachers. IPY STEM Polar Connections will acquaint teachers and their students with systems and phenomena that are immediately accessible in their own environments, and can serve as an ideal vehicle for arousing interest in science and providing an understanding of how science is done, especially in Polar Regions. IPY STEM Polar Connections will improve teachers' content and pedagogic knowledge of polar science, promote a facility with scientific principles demonstrated in events and processes that occur in the Polar Regions, and enrich the teaching in middle and high school STEM courses more generally.

The core of IPY STEM Polar Connections will be curriculum materials tested and disseminated in part via a summer institute and with an academic year, online, follow-up component. Teachers from the three regions will be engaged in the development and field testing of Polar Connections Modules designed to investigate events and processes that occur both in the region where they teach and in Polar Regions. Through investigations of local, regional, and polar physical environments and ecosystems, teachers can better motivate their students to grasp scientific principles and processes that describe the physical environment and ecosystems of Polar Regions and the regions where they live. The program will focus on scientific content, but it will also address pedagogic issues, especially those relating to the use of information technologies.

Teachers will be motivated to participate in IPY STEM Polar Connections for a variety of reasons. They will value the opportunity to improve their knowledge and skills, working with a highly qualified team of university faculty and polar researchers as well as educators with extensive experience as middle and high school educators and curriculum developers. Curriculum reform initiatives often require teachers to revise their classroom practices and lesson content to meet the new national and state standards and to prepare their students for the various high-stakes tests they face. A stipend and materials will be additional incentives. Also, ongoing professional development is required throughout every educator's career, with recertification, in some states, mandated every five years; graduate credits and continuing education units or professional development points will be available.

Principal Goals:

The principal goals of the activities of IPY STEM Polar Connections project are to:

- Develop Polar Connections Modules that effectively integrate the study of the physical environment and ecosystems of Polar Regions into the curriculum of STEM programs in middle and high schools. Earth and environmental science classes may use one or more modules in their entirety, while other classes may incorporate specific components that meet their curricular needs
- Support the effort of STEM educators to enrich the process of meeting specific local, state, and national learning standards through the implementation of the Polar Connections Modules.
- Provide opportunities for middle and high school students to participate in a scientific inquiry process that results in an understanding of the interrelationships of the physical environments and ecosystems of different regions.
- Accommodate instructional strategies designed to meet the wide range of educational needs of middle and high school students and of underserved populations of students.
- Advance the knowledge of the physical environment and ecosystems of Polar Regions among middle and high school STEM educators.
- Utilize the evaluation of the field testing of Polar Connections Modules to develop a program of dissemination of the Polar Connections Modules.
- Disseminate the Polar Connections Modules at the local, state, regional, and national level in workshops and on the web.

The IPYSTEM Polar Connections Audience

The audience for IPY STEM Polar Connections will be students and their teachers from the New England, Mid-Atlantic, and Great Lakes Regions of the United States. The physical environments and ecosystems of these three regions are often influenced by the Arctic Region in similar ways and the three regions have many common physical environments and ecosystems. As an example, surges of arctic air across the three regions often set the stage for dramatic lake effect snow storms that periodically inundate portions of the coastal regions of Ohio, Pennsylvania, and New York and the western slopes of the Green Mountain range of Vermont. The common topographical features of the three regions, that were the result of the expansion and retreat of glacial ice during cycles of climate change, will also facilitate interactions among STEM teachers and students in the three regions during the school year activities of IPY STEM Polar Connections.

It has also been demonstrated that the physical environment of the three regions has the potential for influencing the Arctic Region's physical environment and ecosystems. As an example, the remnants of Hurricane Katrina, rather than moving in an easterly direction under the influence of the mid-latitude Westerlies, were guided northward along the western slope of the Appalachian Mountain range until a warm, humid air mass reached the very northern portions of the Province of Quebec. This resulted in an exceptional amount of precipitation in close proximity to the Arctic Region. Such heavy precipitation events can influence the rate of sedimentation in the lakes of the Arctic and southern Subarctic Region and, as research at the Climate System Research Center at UMass has revealed, lake sediments can provide a profile of weather events over many centuries. Events such as these serve as a basis for the development of Polar Connections Modules.

There are, however, many more and, in some cases, much more subtle interactions between the physical environments and ecosystems of Polar Regions and regions in the lower latitudes. These events provide additional local and regional contexts for students and teachers to investigate the interrelationships of the physical environments and ecosystems of Polar Regions and regions at lower latitudes and will also serve as the basis for the development of Polar Connections Modules.

Polar Connections Modules

Key distinctive environmental features that result from the location of Polar Regions include:

- Dramatic changes in the lengths of daytime and nighttime
- The accumulation of snow and ice
- The depth of permafrost
- Atmospheric phenomena such as the Auroras

To help provide a context for the study of these and other environmental features, physical characteristics, and ecosystems of Polar Regions, IPY STEM Polar connections will develop ten Polar Connections Modules so that students can experience the process of scientific inquiry as they compare and contrast the physical environment and ecosystems of the region where they live with the physical environment and ecosystems of Polar Regions. The rich descriptions of the scientific inquiry process in the National Science Education Standards (NSES) and in state science learning standards for each state in the three participating regions will guide the module development, field testing, and dissemination process.

Multi-lesson Polar Connections Modules can most effectively be presented as a complete unit of study when the content and educational objectives of the module is designed to be similar to existing units of study in a STEM curriculum. In STEM courses where the constraints of a carefully constructed curriculum limit the utilization of a multi-lesson module, individual activities from multi-lesson modules can enrich the curriculum.

As an example, many elementary and middle school STEM programs include a study of the migratory patterns of birds. The Arctic Tern (*Sterna paradisaea*) is a seabird that every year travels from its nesting grounds in the northern Arctic Region to summering grounds in the Antarctic Region. It is a long distance champion of the birds that migrate every year. These small, white, grey and black birds typically raise between 1-2 chicks (sometimes 3 in the far northern arctic) each year during a brief breeding season. The chicks learn to fly between 25-30 days of age and are known to travel the distance from the Gulf of Maine to the coast of West Africa in about 3 months. Typically, the migration route continues south to the ice shelves of Antarctica.

The Arctic Tern is being studied as an indicator species for changes in the global environment by researchers in Canada and the United States. In the New England Region studies have shown the importance of the Connecticut River watershed for providing stop-over sites for many spring migrants (e.g. see www.science.smith.edu/stopoverbirds/index.html). Students in each region participating in the IPY STEM Polar Connections project could become involved with collecting data about spring migrants and interviewing local birders about changes that they have seen in their time spent birding in this region. As part of this project, students will learn to identify migrant and local species of birds. Students will also learn to conduct interviews and compile valuable information about the history of the region. Some of the local history will be documented through tracing weather trends and correlating those trends with the species that have been documented visiting the region. The local trends observed can then be related to trends that have been and are being observed in Polar Regions and can be integrated into a Polar Connections Module entitled **Polar Habitats.**

Polar Habitats: Examples of activities in this module are:

- Relate an analysis of the distribution and changes in the populations of local and regional wildlife species to the distribution and changes in populations of wildlife species in Polar Regions.
- Relate an analysis of the distribution and changes in the populations of local and regional plant species to the distributions and changes in populations of plant species found in Polar Regions.
- Investigate the influence of changes in the physical characteristics and ecosystems of Polar Regions and of the participating regions on the migratory activity of animals.
- Evaluate the affect of changes in the permafrost and icepack of the Arctic Region on wildlife habitats.
- Evaluate the affect of changes in the climate on the activities of the indigenous cultures that populate the Arctic Region as well as activities of human activity in the lower latitudes.

The center for Collaborative Adaptive Sensing of the Atmosphere (CASA) at UMass in collaboration with its partner universities is designing and implementing a strategy to overcome the curvature of the Earth and obstructions such as buildings and mountain ranges by deploying low-cost networks of Doppler radars that operate at a short range. The research at CASA provides a model for the collection of data to study weather and climate in the three regions of IPY STEM Polar Connections and to apply the knowledge gained from that study to methods that researchers utilize to study the weather and climate of Polar Regions.

Activities that provide opportunities for students to conduct investigation to collect, analyze, and compare weather and climate data will be integrated into a Polar Connections Module entitled **Polar Weather and Climate.**

Polar Weather and Climate: Examples of activities in this module are:

- Design and deploy devices to collect local weather and climate data.
- Obtain real time data to construct weather maps that reveal the movement of air masses and storm systems into and out of Polar Regions.
- Use heating degree-days and cooling degree-days data to construct climate zone maps.
- Compare and contrast the influence of polar influences on the climates of the Northern and Southern Hemisphere.
- Relate the study of seasonal changes in temperature and Earth's climate cycles to changes in the permafrost, snow depths, and ice cover of the Arctic Region.
- Analyze data collected by international teams conducting research in Polar Regions, including studies carried out during earlier International Polar Years.
- Utilize resources of the International Polar Year web site to develop a compare the weather and climate of Polar Regions with regions in the lower latitudes.

The CSRC at UMass has conducted extensive investigations of the relationship between weather events and climate cycles and the deposits of sediments in lakes in the Arctic Region. An analysis of the extensive inventory of core samples of arctic lake sediments at the CSRC has resulted in the development of a model for establishing a paleoclimate archive and models of climate change.

An international team of scientists funded by NSF and by the governments of Germany, Russia and Canada ass well as the Intercontinental Drilling Program is being led by Julie Brigham-Grette of UMass. This team of researchers is engaged in a study of a polar lake in Siberia in an effort to provide a detailed record of the climate history of the Arctic Region.

Since every community is located in a watershed, all students have opportunities to observe significant weather events and to observe the effect those weather events have on the landscape of their region. They can, for example, observe the erosion and deposition of soil during single events, such as a heavy rainstorm, or gradual erosion and deposition processes that take place over a longer time period. These observations of a local physical environment can provide the familiar context that facilitates an understanding of processes that occur in the watersheds of Polar Regions and will be integrated into a Polar Connections Module entitled **Polar Watersheds.**

Polar Watersheds: Examples of activities in this module are:

- Utilize the United States Geological Survey resources made available on the International Polar Year web site and polar-themed content that can be viewed in Google Earth to describe the terrain of polar watersheds.
- Compare the characteristics of polar watersheds to those in the regions where students live.
- Design and construct instruments to collect and analyze precipitation and sediments and compare that data collection with the methods for collecting similar data in Polar Regions.
- Relate the study of water cycles and of local and regional watersheds to the study of the affect of changes in the amounts and types of precipitation on sedimentary deposits in rivers and lakes in Polar Regions.
- Relate the study of lake sediments in Polar Regions to the descriptions of changes in Earth's climate.

The New England, Mid-Atlantic, and Great Lakes Regions usually receive a significant amount of snowfall each winter, enough, during most winter, to alter the albedo of the three regions. As spring approaches, teachers and their students have opportunities to investigate the feedback mechanisms associated with changes in the albedo of a region. This can be accomplished through laboratory investigations where students simulate the affect of the color of a surface on the rate at which visible light in converted into thermal energy and the influence that the energy conversion has on the convection in the atmosphere. Observations of the effects of the extent of snow and ice cover on the weather and climate of their region provides a familiar context with which to evaluate similar effects in Polar Regions and will be integrated into a Polar Connections Module entitled **Polar Atmosphere and Hydrosphere.**

Polar Atmosphere and Hydrosphere: Examples of activities in this module are:

- Compare the annual precipitation of regions in the United States with that of Polar Regions.
- Use online resources to monitor snow cover in the participating regions and in the Arctic Region.
- Relate the study of global wind patterns and energy transfer (radiation, convection, convection) to the amplification of wind circulation as a result of changes in the albedo of the Arctic Region.
- Learn the difference between wind driven surface currents and deep sea currents resulting from seasonal changes in the density of water.
- Relate the study of the structure and movements within Earth's atmosphere to atmospheric phenomena (e.g., temperature inversions)

In his testimony before the Subcommittee on Technology, Innovation and Competitiveness of the United States Commerce, Science, and Transportation Committee on April 26, 2006, Dr. Ioannis Miaoulis, President of the Museum of Science, Boston and Director of the National Center for Technology Literacy (NCTL) made the following two statements. "I understand the concern for math and science education but I am worried that K-12 technology and engineering education is overlooked." and "The beauty of engineering is that it is a connector. It is the application of math and science that provides relevance to students."

It was an effort led by Dr. Miaoulis that resulted in the incorporation of technology and engineering into the Massachusetts Science and Technology/Engineering Framework that guides curriculum development and the assessment of K-12 academic performance in STEM programs in Massachusetts. The following Polar Connection Module will provide opportunities for students to experience the engineering design process as they learn how research of the physical environment and ecosystems of the Polar Regions is conducted.

Polar Design and Engineering Module: Examples of activities in this module are:

- Compare the technology available during some of the first polar explorations (e.g. expeditions led by Shackleton, Byrd, Amundsen, Scott, et al.) and during previous International Polar Years (1882-83, 1932 and in the 1957 IGY) with technologies used presently in Polar Regions.
- Design either a permanent or temporary structure to be used in Polar Regions to house scientists during their periods of study.
- Develop an understanding of the use of remote sensing devices to map the features of Polar Regions, monitor the movement of ice, and navigate across polar landscapes.
- Evaluate strategies for minimizing the environmental impact of research facilities in Polar Regions. Heating, water, food, sanitation, etc. will be discussed.
- Determine effective methods for transporting researchers and supplies to research facilities in Polar Regions.
- Compare the characteristics of locations of large telescopes in the United States with those constructed in Antarctica (Figure 1).

Figure 1.UMass engineering researchers in the Terahertz Lab have developed specialized sensors which have been installed in Antarctica at the Amundsen-Scott South Pole Station. Note the specialized aircraft, buildings, and radar.

Many future polar researchers are enrolled in rigorous courses taught at the high school level, especially those that prepare students for SAT II and AP exams. Given the constraints that teachers of these courses may have in terms of integrating multi-lesson modules into a carefully structured curriculum, modules that provide a variety of sophisticated activities with a narrower focus may be more effective. Therefore, in addition to the Polar Connection Modules previously described, additional Polar Connection Modules will be developed that focus on a variety of specific topics in Biology, Chemistry, Physics, Environmental Science, Earth and Space Science, and Information Technology. One example would be a Polar Connections Module developed for high school physics courses.

Polar Physics Module: Examples of activities in this module are:

- Determine the index of refraction of a transparent substance and relate that to a refraction phenomenon that takes place in Polar Regions. As the temperature of the atmosphere in Polar Regions increases, it has been observed that the length of daytime in Polar Regions has increased. Therefore, high school physics students can be expected to apply their knowledge of indices of refraction obtained from experimentation in order to develop an explanation for that observed phenomenon.
- Determine the orbit radii and velocities of satellites used to obtain remote sensing data in Polar Regions.
- Apply knowledge of the acceleration of charged particles to the production of auroras in Polar Regions.
- Analyze the circuits of devices that are used to collect data in Polar Regions.

IPY STEM Polar Connections Teachers and Summer Institute

IPY STEM Polar Connections has two interrelated components, the development of the curriculum modules and summer institutes. There will be two cohorts of 30 teachers each from the New England, Mid-Atlantic, and Great Lakes regions. Requirements for participating in the program will include commitments to testing some of the modules in their classes and also in providing professional development to other teachers in their districts or at regional and national teacher conferences. The first cohort will attend a 7 day institute in the summer of 2008, communicate with each other and with the staff online during the year, and attend a second 7 day institute in 2009. The second cohort will start a similar agenda in the summer of 2009.

In addition to the opportunity to learn exciting new material, teachers will have a variety of incentives to participate in the project. They will receive stipends, free continuing education or professional development points needed to meet state requirements for ongoing certification, and the opportunity to earn graduate credits at a third of the usual cost. We will cover their cost of travel to the institutes, meals, and housing in new air conditioned dormitories. They will also have an allowance for purchasing classroom materials and supplies and funds to attend conferences and do presentations. Below are some features of the summer institutes.

- Institute participants will conduct investigations associated with the Polar Connections Modules which focus on methods for collecting and analyzing data that can be utilized in investigations of local and regional physical environments and ecosystems and the information technologies that link those investigations to the characteristics of Polar Regions.
- Participants will enrich their understanding of the physical environment and ecosystems of Polar Regions during sessions with IPY STEM Polar Connections professional staff that includes UMass faculty who are conducting research in Polar Regions.
- Participants will identify opportunities for integrating Polar Connections Modules in their STEM programs.
- Participants of the first summer institute will assist in the design of additional Polar Connections Modules which then will be prepared for presentation at the second summer institute.
- Internet based resources will be presented that enrich the activities of Polar Connections Modules. Particular attention will be given to the resources of the International Polar Year web site.
- Discussions of strategies for field testing the Polar Connections Modules and communicating the results of the field tests so that the IPY STEM Polar Connections staff can produce the versions of the modules that will be disseminated locally, regionally, and nationally.

Activities of IPY STEM Polar Connections institutes will exemplify the pedagogy of the "Five E" Learning Cycle Model (*Engage, Explore, Explain, Elaborate, and Evaluate*), that the STEM Ed Institute at UMass has successfully integrated into summer institutes for STEM educators. The Five E Learning

Cycle Model was originally credited to Karplus and Thier (Karplus and Their, 1967; Karplus et al., 1975) and was later modified by Roger Bybee for the Biological Science Curriculum Study (BSCS).

Dissemination

An essential aspect of the dissemination phase of IPY STEM Polar Connections will be the communications that take place as the Polar Connections Modules are being field tested by the project participants. The input to the IPY STEM Polar Connections staff will facilitate the production of the final form of the modules that will be presented at teacher workshops, conferences of state science teacher organizations, and both regional and national conventions of professional associations in science education. At the national level dissemination will be done with the assistance of the Digital Library of Earth Systems Education (DLESE), and organizations such as the National Association of Science Teachers, the National Association of Geoscience Teachers, the National Association of Biology Teachers, and the American Association of Physics Teachers. Meetings of regional organizations, such as the Massachusetts Association of Science Teachers and the New England Association of Chemistry Teachers, will also offer opportunities for dissemination.

In addition to the Polar Connections staff, all the teachers participating in the program will be expected to be part of this dissemination effort in their districts and beyond. The budget includes significant funds to assist this effort.

The IPY STEM Polar Connections website will include the modules as well as annotated links to datasets and to other internet resources selected to be valuable for teachers using these modules.

The Evaluation Plan

The project evaluation will be undertaken by a team consisting of Drs. Alan Peterfreund and Ken Rath of Peterfreund Associates. Peterfreund Associates have been involved as evaluators for numerous educational projects funded by NSF, NIH, and DOE-FIPSE. Among these have been NSF GK-12 projects at four different institutions (Yale, Harvard, Northeastern, and San Francisco State), supporting projects that bring graduate students into middle and high schools for extensive science outreach and numerous pipeline programs focused on recruiting, developing and promoting under-represented minorities in STEM disciplines (UMass Amherst, UMass Boston, URI, San Francisco State, and Hampton University). In addition, they have supported programs associated with teacher education in Biodiversity and Climate Change (Yale), Computer Science and Information Technology (UMass Amherst, UMass Boston) and Teaching American History (Springfield Mass Public Schools.)

The evaluation of this project will consist of the following activities:

- *Periodic Meetings with Project Team:* A representative or representatives from Peterfreund Associates will attend quarterly meetings of the project team, providing formative feedback from their evaluation activities as the occasion demands.
- *Tracking of Project Milestones:* The UMass project team will track the activities performed and how the timing of these activities matches the project schedule.
- *Curriculum Assessment Activities:* These activities will be created by the project team, with input from the evaluators and the project team, with the intent of providing a standardized evaluation of the content- and skill-based goals of the STEM Polar Connections Modules. The activities will be developed concurrent with the modules and should be made available by early 2008.

The activities will be administered in the teachers' classrooms in the Spring of 2008 to provide a baseline for what students' skill and content knowledge levels would be at the end of the year in the absence of curriculum use. These activities will be administered for informational purposes only and will not have an effect on students' grades in these classes. It is likely that this will only be able to be done by a subset of the teachers involved in the program. Some modification of the activities may be necessary as issues with completion are unearthed.

In the 2008-2009 school year, the activities will be administered to the incoming classes in the Fall as pre-tests and then again in the Spring as post-tests. This will allow an examination both of the learning of the specific objectives over the course of the year and a comparison of the endpoint with an endpoint from the previous year in the absence of the modules. The assessments will be used again in subsequent years, allowing an examination of the improved outcomes due to module improvements.

Workshop Surveys

- Prior to coming to the summer institutes, the teachers will be asked to complete an online survey which will collect, among other things, demographic information, previous experience with science and science teaching, attitudes toward teaching science, and expectations regarding the project.
- A second survey will be offered after the end of the institutions that will gather information on attitudes toward the workshop and associated activities as well as measuring any changes in attitudes toward teaching science.
- Both surveys will be created, administered, and collected annually by Peterfreund Associates.

Final Participant Survey

At the end of the period in which the modules were used, the teachers will be asked to complete a third survey that will examine the quality of the overall experience, capture the demonstrated outcomes, and collect suggestions for changes moving forward. This survey will also be created, administered, and collected annually by Peterfreund Associates.

Reporting

Summary reports for each piece will be provided as evaluation activities are completed. Additionally, Peterfreund Associates will provide annual and final reports detailing the activities performed and the important findings of those activities.

Staffing and Management

IPY STEM Polar Connections will be developed by an exceptionally strong team of science educators and polar researchers. We will highlight their expertise here, leaving details to the vitae and the results from previous support below.

PI Morton M. Sternheim has been a leader in teacher professional development and STEM education for many years. He has also authored widely used college physics text books. Robert Snyder is a former earth science, chemistry, and physics teacher, with extensive experience in curriculum development and in state and national standards and testing. They will be responsible for the physical sciences modules. STEM Ed Project Manager Marie Silver has extensive experience in curriculum development and teacher training in biology and environmental science, and Catherine Devlin has done research on arctic terns and is currently teaching at a community college and in a local school district.; both of whom will be responsible for developing module activities relating to biological processes and the affect of changes occurring in Polar Regions on indigenous cultures. Polar researchers involved in the project will assist in the design of the modules, develop background materials and databanks, and verify the scientific accuracy of the materials. These researchers include co-PI Julie Brigham-Grette and Ray Bradley (Geosciences), who have made major contributions to polar research; and engineer Wayne Burleson, who has done extensive research in communications systems. Alan Peterfreund and Ken Rath will be the evaluators, as discussed above. Regular meetings of the staff and evaluators as a group and in subcommittees will facilitate the development process.

Table V below summarizes the project timeline.

Dates	Task or Event
Fall 2007	Start development of the initial set of Polar Connections Modules. Start bi-weekly staff meetings.
Spring 2008	Recruit STEM Educators from the New England, Mid-Atlantic, and Great Lakes Regions.
July 2008	Present the **initial set** of Polar Connections Modules at a 7 day summer institute for **first group** of STEM Educators and discuss additional modules to be developed.
Fall 2008	Start development of the second set of Polar Connections Modules.
Spring 2009	Revise the initial set of Polar Connections Modules based on feedback from the first group of STEM Educators. Recruit the second group of educators.
July 2009	Present the **final set** of Polar Connections Modules at the second 7 day summer institute for the **first group** of STEM Educators
August 2009	Present revised versions of the **initial set** of Polar Connections Modules at a 7 day summer institute for a **second group** of STEM Educators
Fall 2009	Finalize the initial set of Polar Connections Modules for dissemination based on feedback from the August 2009 institute and distribute to participants for dissemination activities.
Winter 2009	Complete the interim assessment of STEM Polar Connections.
Spring 2010	Revise the final set of Polar Connections Modules based on feedback from the first group of STEM Educators.
August 2010	Present revised versions of the **final set** of Polar Connections Modules at a 7 day summer institute for the **second group** of STEM Educators
Fall 2010	Finalize the final set of Polar Connections Modules for dissemination based on feedback from the August 2010 institute and distribute to participants for dissemination activities.
Spring 2010	Complete the final assessment of STEM Polar Connections

Table V, Project timeline

Results from previous support

In this section we highlight the most relevant STEM education and polar research efforts.

STEM Ed has its origins in teacher professional development programs begun over twenty years ago by PI Morton M. Sternheim. Together with the Geosciences Department, it is currently offering the NASA funded *STEM Earth Central: A statewide initiative to promote the teaching of Earth Science in the science curriculum.* Evaluations of this project have been very positive. STEM Ed has three current NSF grants, STEM Bridge for Noyce Scholars (#0434110, 2004-2007) for future secondary math and science teachers; STEM ACT (#0514620) (a conference on Alternative Certification for Science Teachers held May 5-7, 2006); and Franklin County STEM Research Academies for Young Scientists (STEMRAYS) (ESI-0639687, 2006-2009). STEM Ed is also a partner in the newly NSF funded UMass Center for Hierarchical Manufacturing, offering teacher workshops on nanotechnology.

STEM Ed's largest undertaking was the recently completed NSF/CETP STEMTEC program (#9653966, #0221265, 1997-2006) a 21 college; multiple-school district collaborative dedicated to producing more, better-prepared, and more diverse math and science teachers. It also managed the NSF/GK12 STEM Connections project, which connected urban middle school students and teachers with UMass graduate students and professors engaged in environmental research programs. Both projects have resulted in extensive publications. University funding and user fees support Science and Engineering Saturday Seminars for STEM teachers, STEM Adventures workshops for scouts, and the UMassK12 Internet service for teachers.

Co-PI Julie Brigham-Grette has an extensive record of polar science research. Recent highlights include ATM 99-05813. *Paleoclimate Record of El'gygytgyn Lake***,** $298,663 (2000-2002) and ARC 02-42324, *Proxy development for interpreting the paleoclimate record from El'gygytgyn Crater Lake,* $99,317 (4/03-3/04 with no-cost extension to 8/05). 14 papers are currently published from this work outlining the paleoclimate and multiproxy record extending to over 250,000 yrs in NE Russia. OPP-0242324, PI: J. Brigham-Grette**, "**Collaborative Research: Marine Climate and Relative Sea Level Across Central Beringia:" $201,516, Duration 09/01/2000 to 08/31/2004 with no-cost extension to 8/31/2005 (ship time delayed to 2002). Two cruises to the Bering and Chukchi seas on the *USCGC Healy* in summer 2002 resulted in the acquisition of nearly 100 sediment cores from between -48m and -3400 m. At UMass Amherst, the sedimentology and organic geochemistry of cores taken from a transect across the Chukchi Shelf have been analyzed including trends in elemental (C/N), and the isotopic ($\partial^{13}C$ and $\partial^{15}N$) composition of organic matter. These data suggest that sea level rise was accompanied by a major reorganization of the surface waters and changes in productivity especially after 11 ka cal years BP and at ~8.5 ka cal years BP possibly coincident with shifts in early Holocene sea ice extent. A major new project is underway, ATM-0602471. *Collaborative Research: Millennial Scale Arctic Climate Change for the last 3.6 My.: Scientific Drilling at Lake El'gygytgyn,* NE Russia, 48 months, $1,418,562.

Ray Bradley and the Climate Systems Research Center have undertaken a wide range of weather and climate research programs. Most relevant to this proposal is ATM- 9708071; $637,096; 1998-2002; *High Resolution Lake Sediment Studies for Paleoclimatic Reconstruction in the Canadian High Arctic.* Research focused on three main sites: Sawtooth Lake, Lake Tuborg and Lower Murray Lake. All sites have well-preserved laminated sediments. They undertook monitoring of hydrological and limnological conditions, and of sediment movement within the lake systems to better understand the links between climate, runoff and sediment deposition (Braun et al., 2000a, b; Lewis et al., 2003). These studies show a strong link between early summer temperatures and sediment flux, though each lake system has to be evaluated carefully, and sediment pulses can be associated with heavy rainfall events, slush flows or other singularities. They developed new techniques for analyzing varved sediments and pioneered in new approaches to high resolution studies of varve characteristics. The studies provide the most detailed varved records of High Arctic paleoclimate for the last millennium. Analysis of clastic sediments and diatoms from Sawtooth Lake indicate pronounced changes within the last century, indicative of less ice cover and increased sediment flux via warmer summer conditions. Diatom abundance and diversity is unique in at least the last 2600 years. Lake Tuborg varves show strong correlations with the record of melt on the Agassiz Ice Cap, and pronounced warming in the 20th century. At Murray Lake, the warmest period of the last millennium occurred from ~A.D.1100-1300. Paleomagnetic studies indicate varve chronologies can be matched at lakes hundreds of km apart, raising the prospect of developing a master secular paleomagnetic record for the region, and of using varved sediments from a network of lakes to reconstruct the geomagnetic pole position through the Holocene.

Bradley has been involved in extensive efforts to inform the general public on climate issues. He participated in a PBS NOVA/Frontline special, "*What's Up with the Weather*" that aired in 2000 and 2001. A publication for the scientifically literate reader on *Environmental Variability and Climatic Change* was published in 2001. Bradley testified in the Senate on climate change (2003), and gave a briefing to House & Senate staff members (2005). He has also given numerous TV, radio and newspaper and magazine interviews, and is a founding member and contributor to the public education web site, www.realclimate.org. This site has been visited more than 2.3 million times since it has been on-line, & it is now the primary source of clear, balanced information on climate change for journalists, policy makers and the general public.

Wayne Burleson's research in CASA is intended to develop next-generation technologies for tracking, predicting, and issuing warnings for severe weather events. These technologies are designed to complement current systems, such as the Next Generation Radar (NEXRAD), which do a poor job of resolving the lower atmosphere (<1 km) where the majority of severe weather events occur. Each year, these storms can cause billions of dollars in damage and take scores of lives. In addition, current information distribution systems do not fully meet the needs of a diverse group of end-users, ranging from researchers to emergency managers and to the general public. The CASA radars will communicate with one another and adjust their sensing strategies in direct response to the evolving weather and user needs in order to sample the atmosphere where and when end user needs are greatest. The basic philosophy of CASA can be generalized to distributed collaborative adaptive sensing (DCAS), a paradigm which can be extended to a broader class of problems including tsunamis, climate change, homeland security and other connections between engineering and science.

Burleson is co-director of CASA's education and outreach program. CASA has already demonstrated successful K-12 integration through development of an innovative Weather RATS (Research and Tracking System) program well suited to classrooms. Weather RATS is a collaborative, long-distance project that tracks and compares weather data from K-12 schools using a network of weather stations installed at member schools, along with weather data from the National Ocean and Atmosphere Administration and the National Weather Service. The project is multi-cultural in its focus on curriculum and its membership, and thus promotes cultural awareness and exchange, along with the development of a global perspective on the behavior of the Earth's atmosphere. Its goals are to foster an interest in STEM disciplines in K-12 students; to encourage participation of under-represented groups in STEM fields; and to create a new model of ongoing professional development for teachers. Weather RATS follows CASA's distributed, collaborative, adaptive systems engineering model in the way the K-12 curriculum is designed and implemented. The Weather RATS project is *distributed* (covers diverse climatic and cultural areas), *collaborative* (teachers from member schools design and implement an original curriculum in collaboration with CASA faculty and other personnel), and *adaptive* (emphasizes different cultural views of weather, climate and data analysis). Weather RATS has contributed to a shared understanding of how weather, climate and technology affect daily life on our planet.

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