PREPARING CULTURALLY RESPONSIVE TEACHERS OF SCIENCE, TECHNOLOGY, ENGINEERING, AND MATH USING THE GEOPHYSICAL INSTITUTE FRAMEWORK FOR PROFESSIONAL DEVELOPMENT IN ALASKA

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A

THESIS

Presented to the Faculty

of the University of Alaska Fairbanks

in Partial Fulfillment of the Requirements

for the Degree of

DOCTOR OF PHILOSOPHY

By

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Fairbanks, Alaska

May 2011

ABSTRACT

The Geophysical Institute (GI) Framework for Professional Development was designed to prepare culturally responsive teachers of science, technology, engineering, and math (STEM). Professional development programs based on the framework are created for rural Alaskan teachers who instruct diverse classrooms that include indigenous students. This dissertation was written in response to the question, "Under what circumstances is the GI Framework for Professional Development effective in preparing culturally responsive teachers of science, technology, engineering, and math?" Research was conducted on two professional development programs based on the GI Framework: the Arctic Climate Modeling Program (ACMP) and the Science Teacher Education Program (STEP). Both programs were created by backward design to student learning goals aligned with Alaska standards and rooted in principles of indigenous ideology. Both were created with input from Alaska Native cultural knowledge bearers, Arctic scientists, education researchers, school administrators, and master teachers with extensive instructional experience. Both provide integrated instruction reflective of authentic Arctic research practices, and training in diverse methods shown to increase indigenous student STEM engagement. While based on the same framework, these programs were chosen for research because they offer distinctly different training venues for K-12 teachers. STEP offered two-week summer institutes on the UAF campus for more than 175 teachers from 33 Alaska school districts. By contrast, ACMP served 165 teachers from one rural Alaska school district along the Bering Strait. Due to challenges in making professional development opportunities accessible to all teachers in this geographically isolated district, ACMP offered a year-round mix of in-person, long-distance, online, and local training. Discussion centers on a comparison of the strategies used by each program to address GI Framework cornerstones, on methodologies used to conduct program research, and on findings obtained. Research indicates that in both situations the GI Framework for Professional Development was effective in preparing culturally responsive STEM teachers. Implications of these findings and recommendations for future research are discussed in the conclusion.

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ACKNOWLEDGEMENTS

Twenty years ago, as part of the National Science Foundation's "Partner in Science" program, I traveled to rural areas of Alaska to share my excitement for geophysics with K-12 students and teachers. I was shocked to discover how little teachers and students in rural Alaska were learning in school about the unique geophysical processes occurring in the Arctic. In every one of the rural classrooms I visited, teachers were using outdated textbooks to teach science and math that did not refer to the fascinating geophysical processes occurring right outside the windows of the school.

During that trip 20 years ago, I was able to attend a school board meeting to which the public was invited. During the meeting, a researcher announced the findings of his latest research. He concluded that, according to his data, Alaska Native students simply could not learn science and math in public school. Understandably, his comment caused quite a stir among teachers and local residents. I explained to a group of Native Elders sitting near me that the researcher must have meant that public schools were not effective at engaging indigenous students in the study of science and math.

A day after this meeting, a group of Elders knocked on my hotel room door. They told me that I needed to figure out how to help their grandchildren learn to love studying science and math in public school. They remained as I explained that I was employed as a public relations director and did not have the status to make this change. They remained as I explained that I would need funding to make this change and that at that time I had never written a proposal. They remained until I ran out of excuses and I agreed to do what they asked.

I thank the Native Elders who illuminated this path, and who stayed with me until I found the courage to walk down it. For two decades, I have been working on their commission—I have been creating professional development programs designed to prepare culturally responsive teachers of science, engineering, technology, and math (STEM). I began my Ph.D. program several years ago to gain enough confidence to publish the results of research I have been conducting on this topic.

I thank my husband, Mark Bertram, for his unending patience and support as I have struggled to reach my goals. I thank my children, Rosalee and Noelle, who are only 10 and 6 years old as I write this, for coming on this journey with me. It is not easy to have a working mother, especially one who also sits at the home computer early in the morning before they rise for school and late at night after they are tucked in bed.

I thank my boss, Roger Smith, for believing in me, for encouraging me, and for trusting in my abilities. I thank Ray Barnhardt for his wisdom, guidance, and patience with me as I navigate through my doctoral program. I thank Claude (Chip) McMillan III, who understands the commission set before me by the Native Elders, and who has never wavered in his insistence I have something valuable to say. I thank Gerhard Kramm, who pulled me aside during one STEM professional development program and insisted that I earn my Ph.D. His steadfast belief in my work continues to support and encourage me. I thank Oscar Kawagley for his insight and for encouraging me to journal my thoughts while I sit listening to what nature has to teach.

I thank Adrienne Smyth for the months of time she dedicated to reviewing teacher open-ended comments to ensure all data entries were completely accurate, and I thank the numerous people who have helped me with text editing, including my mother, Barbara Dickey, my daughter, Rosalee, and my co-workers, Lori Schoening, Lynda McGilvary, Glenda Findlay, Doreen Hayward, Barbara Wadlinger, and Stevie Seibert.

Although I have not met him, I thank Indian Physicist Phillip Duran, whose articles helped me understand that the conceptual and practical world of the American Indian corresponds closely to quantum physics. He contends that quantum physicists and indigenous philosophers both believe that humans and everything else in the visible world are connected by an unseen force in an intricate, complex web of life. He calls this the Great Mystery.

I thank Jesus, the author of the Great Mystery, for the ability, energy, and perseverance to run this race until its end.

My Ph.D. is dedicated to my daughters—may it serve as an example to work diligently until you reach your goals at all stages of your lives.

The research conducted for my Ph.D. is dedicated to the two agencies responsible for funding it: the National Science Foundation and the Alaska Department of Education and Early Development. The National Science Foundation Innovative Technology Experiences for Students and Teachers (NSF ITEST ESI-0525277) funded the Arctic Climate Modeling Program. A Mathematics and Science Partnership Grant awarded through the Alaska Department of Education and Early Development, Division of Teaching and Learning Support (Award #PM 07.157.02), funded the Science Teacher Education Program.

INTRODUCTION

I.1 OVERVIEW

For two decades, the University of Alaska Fairbanks (UAF) Geophysical Institute (GI) has created and implemented professional development programs for K-12 teachers based on the GI Framework for Professional Development. The goal of GI framework-based programs is to prepare culturally responsive teachers of science, technology, engineering, and math (STEM).

GI framework-based professional development programs are designed primarily for rural Alaskan teachers in schools in which indigenous students comprise a substantial part of the student population. All GI framework-based professional development programs are designed by collaboration among researchers, teachers, and cultural knowledge bearers who are united in their efforts to help indigenous students successfully achieve educational goals while embracing their cultural heritage.

I.2 RESEARCH QUESTION

This dissertation was written in response to the question, "Under what circumstances is the GI Framework for Professional Development effective in preparing culturally responsive teachers of science, technology, engineering, and math?" To answer this question, research was conducted on two STEM professional development programs based on the GI framework: the Arctic Climate Modeling Program (ACMP) and the Science Teacher Education Program (STEP). These programs were chosen because they offered two distinctly different training venues for K-12 teachers. STEP offered two-week summer institutes on the UAF campus, which were attended in person by more than 175 teachers from 33 Alaska school districts.

By contrast, ACMP remotely served 165 teachers in one rural Alaska school district along the Bering Strait. This geographically isolated district contains 15 schools spread throughout an 80,000 square mile area larger than the state of Nebraska. Due to significant challenges in making professional development opportunities accessible to teachers throughout the district, ACMP offered unique "curriculum resource-based professional development" that provided a mix of year-round in-person, long-distance, online, and local training for rural teachers.

I.3 DISSERTATION ORGANIZATION

The first chapter of this dissertation describes the underlying philosophy of the GI framework. The second chapter focuses on ACMP, and the third chapter centers on STEP. These chapters describe research conducted on each program to assess their individual effectiveness in obtaining GI framework goals. The fourth chapter contrasts ACMP and STEP strategies used to meet GI framework cornerstones, compares methodologies used to conduct research, and outlines findings obtained as a result. The conclusion of this dissertation discusses findings as they apply to the research question and offers recommendations for future study.

I.4 THE NEED FOR CULTURALLY RESPONSIVE STEM TEACHERS

Providing STEM professional development for teachers of diverse classrooms that include students of Alaska Native, American Indian, African, and Hispanic heritage is essential because these populations are significantly underrepresented in STEM studies and careers (Huntoon & Lane, 2005). Of all STEM fields, geophysics—the study of the physical processes and phenomena of Earth and space—suffers from the lowest minority representation (Huntoon & Lane, 2005). Of these minorities, people of Alaska Native and American Indian heritage are the least represented (National Science Foundation [NSF], 2009). Research indicates that less than .001% of the nationwide Alaska Native and American Indian population is pursuing graduate geoscience degrees (NSF, 2004).

Although geoscience topics are an integral part of national science standards, recent research indicates that 90% of the nation's K-12 students are taught Earth system science by a teacher lacking appropriate certification (National Center for Education Statistics [NCES], 2007). Lack of STEM credentials often results in ineffective STEM instruction, which leads to low student achievement (Valenzuela, Velez & Schiefelbein, 1993). According to recent research, "students who have the misfortune of receiving a string of ineffective teachers . . . for three years in a row scored as much as 50 percentile points lower on statewide assessments" (Goodwin, 2010, p.8). Other research indicates that the overall performance of U.S. students in Earth and physical sciences is lower today than it was in 1996, and that the gap between Caucasian and minority student STEM achievement is as wide today as it was then (Grigg, Lauko & Brockway, 2006).

In Alaska, indigenous student achievement in science and math is substantially lower than that of their Caucasian peers. Alaska standard-based assessments (SBAs) are used to gauge student proficiency in science, math and language arts. Since 2008, SBAs measuring science proficiency have been administered to Alaskan students in grades 4, 8, and 10. Table I.1 contains data based on 2009 SBA science and math results. Data indicate that the percentage of Alaska Native students who are not proficient in science and math is substantially higher than the percentage of Caucasian students who are not proficient in science and math (Alaska Department of Education and Early Development [AKDEED], 2009a).

Table I.1
Percentage of Alaska Students Not Proficient in Science and Math in 2009

Grade level	Ethnicity	% Not Proficient in Science	% Not Proficient in Math
4th grade	Alaska Native	78%	45%
4th grade	Caucasian	38%	17%
8th grade	Alaska Native	70%	51%
8th grade	Caucasian	32%	24%
10th grade	Alaska Native	62%	53%
10th grade	Caucasian	25%	23%

Nationwide, the highest rates of out-of-field teaching occur in high poverty schools with high minority student populations (Ingersoll, 2008). In Alaska, 91% of the state's 54 school districts are in rural areas (Hill & Hirshberg, 2008) situated in geographically isolated, often economically depressed communities (Economic Research Service [ERS], 2010). In rural Alaska, indigenous students compose more than half (56.33%) of the student population (AKDEED, 2010); however, 95% of their teachers are non-Native (Suderman, 2008). Recent research indicates that effective teachers develop positive, sustained relationships with their students (Goodwin, 2010). Developing positive, sustained teacher-student relationships can be a challenge in rural Alaska, where teacher turnover averages 22%—higher than nearly anywhere else in the U.S. (except in America's largest inner-city neighborhoods). In rural Alaska, principals are even more likely to leave their jobs than teachers. Average annual turnover among principals in rural Alaska is 27% (Hill & Hirshberg, 2008).

High teacher and administrator turnover, lack of STEM credentials, geographic isolation, and limited school funding often result in STEM instruction based on outdated textbooks or inappropriate curricula. Popular STEM curricula or kits frequently used by incoming STEM teachers that are suitable elsewhere in the nation often are ill suited for use in rural Alaska.

For example, consider teaching STEM in the Lower Kuskokwim School District. Lower Kuskokwim serves a 98% Alaska Native student population, and the vast majority of students in the district are not proficient in math or science (AKDEED, 2009b). According to administrator estimates, 84% of the district's teachers offering STEM instruction do not have appropriate credentials for the task. The cost of shipping science kits to teachers in the district is high. Located in Southwest Alaska, the district covers 22,000 square miles (equal in geographic size to the state of West Virginia). Twenty-seven schools exist in 21 villages spread throughout this huge expanse; all are geographically isolated from urban centers and from each other. These villages are not connected by a road system and are accessible only by air or water way. Vendor sources for even the most basic school supplies are limited or non-existent.

"Honestly, the district ordered some kits a while back, but when we got them, we just burst them open to use the supplies," said one teacher. "We don't use the curriculum in the science kits because it is not based on the standards the district has set out for us and it discusses things and uses examples that kids out here really cannot relate to."

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CHAPTER 1

THE GEOPHYSICAL INSTITUTE FRAMEWORK FOR PROFESSIONAL DEVELOPMENT: PREPARING CULTURALLY RESPONSIVE TEACHERS OF SCIENCE, TECHNOLOGY, ENGINEERING, AND MATH[1]

1.1 ABSTRACT

The Geophysical Institute Framework for Professional Development was created to prepare culturally responsive teachers of science, technology, engineering, and math. This chapter reveals the cornerstones on which the framework is based and illustrates how these are interrelated in STEM professional development. Like leaves on a birch tree, each has its own intrinsic value, but is most valuable as part of a collective whole. The birch tree analogy also is used to show how GI framework-based professional development is rooted in student learning goals derived from Alaska standards and in principles of indigenous ideology. These principles have been used to craft professional development training in a variety of tools and research-based methods shown to increase the engagement of Alaska Native students in STEM study.

1.2 INTRODUCTION

Creating and implementing professional development programs that prepare culturally responsive teachers of science, technology, engineering, and math (STEM) has been a 20-year focus of the University of Alaska Fairbanks Geophysical Institute (GI) Education Outreach Office. This chapter describes the underlying philosophy of the GI framework for providing STEM professional development.

1.2.1 *GI Framework Cornerstones*

The GI framework was designed primarily for rural Alaskan teachers in schools in which indigenous students comprise a substantial part of the student population. The

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[1] Bertram, K.B. In Preparation. The Geophysical Institute Framework for Professional Development: Preparing Culturally Responsive Teachers of Science, Technology, Engineering, and Math. *Cultural Studies of Science Education.*

framework provides teachers with the tools and training they need to provide culturally responsive STEM instruction aligned with Alaska standards and Grade Level Expectations (GLEs). Alaska standards are "broad statements of what students should know and be able to do as a result of their public school experience" (Alaska Department of Education and Early Development [AKDEED], 2006, p.5) and performance standards or GLEs "define what all students should know and be able to do at the end of a given grade level" (AKDEED, 2006, p.37). In Alaska, GLEs form the basis of standard-based assessments (SBAs), which are tests used to gauge levels of student achievement in a variety of subject areas. Theoretically, using instruction aligned with GLEs will help increase student achievement on standardized tests. However, teaching to the test works only when instruction engages students. SBA scores indicate that most of Alaska's indigenous students lack science proficiency and about half lack math proficiency. This grim fact implies that either teachers do not have the training needed to provide standard-aligned science and math instruction, or that indigenous students are not engaged in the STEM instruction being provided, or both.

The GI framework is based on the following cornerstones, or overarching principles.

- To ensure professional development aligns with student learning goals, teacher-training programs are created by backward design. Backward design involves selecting student goals first, and then creating pathways to meet those goals (Wiggins & McTighe, 2005). In GI framework-based programs, student learning goals are derived from Alaska standards and rooted in principles of indigenous ideology.
- To increase teacher knowledge of STEM concepts relevant to students' lives, teacher training is offered through graduate-level courses that provide in-depth, place-based instruction focused on current Arctic research.
- To ensure professional development mirrors the real-world practices and processes involved in Arctic research, GI framework-based instruction interweaves the core areas of science, technology, engineering, math, language arts, social studies, and other subjects as applicable.

The manner in which these principles relate to each other and are interwoven in principle and practice is illustrated in Figure 1.1.

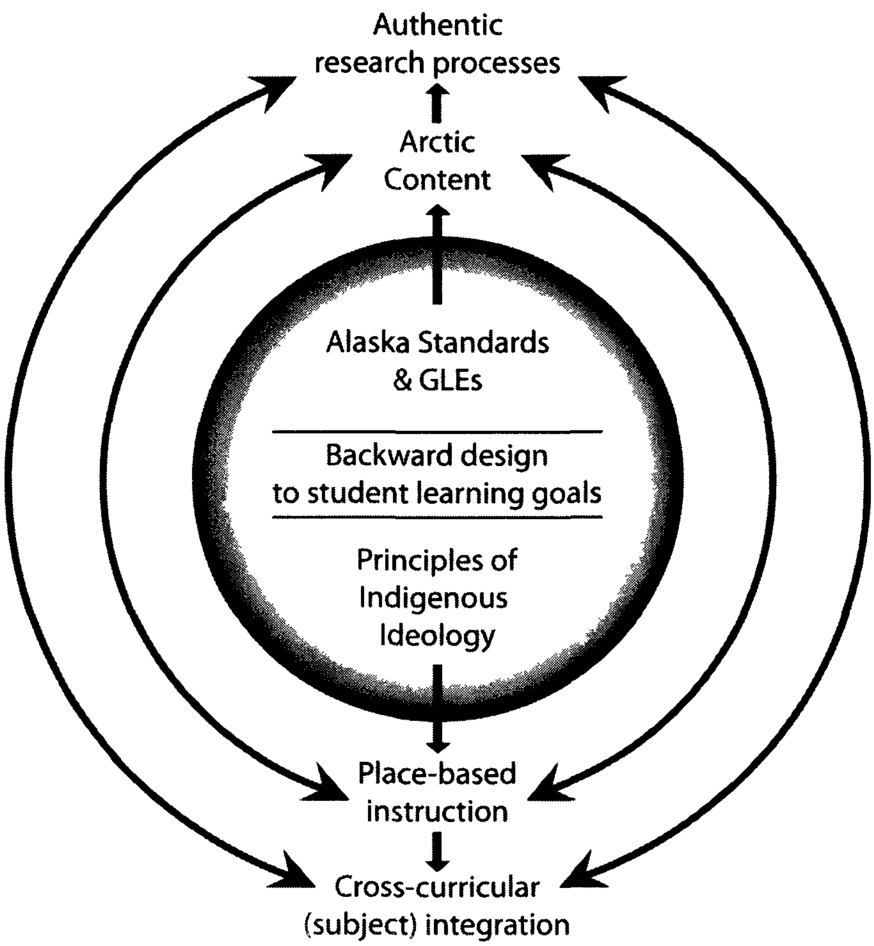

Figure 1.1
Backward Design to Arctic Research Practices and Principles of Indigenous Ideology

GI framework-based programs also provide tools to ensure teachers can transfer what they have learned in STEM professional development into classroom practice.

- To increase teacher ability to engage indigenous students in place-based STEM instruction, training is provided in a variety of research-based instructional methods shown to increase indigenous student interest in STEM.

- To help teachers learn to interweave core subjects in a manner reflective of that provided in GI framework-based STEM professional development, training is provided in cross-curricular integration.
- To help teachers transfer STEM training directly into K-12 classroom instruction, GI framework-based programs offer standard-aligned curricular resources designed for immediate classroom application. These multiple, flexible mechanisms for transferring STEM training into the classroom offer teachers a suite of options for meeting group and individual student needs.

1.2.2 *STEM Professional Development Derived from Stakeholder Collaboration*

All courses based on the GI framework are conceived through collaboration among five main stakeholders concerned with providing culturally responsive STEM education. These include: STEM education researchers, school district administrators, Arctic scientists, STEM master teachers (educators with 20+ years of STEM classroom experience), and Native Elders or other cultural knowledge bearers.

For each GI framework-based professional development program, school administrators guide selection of specific standards and GLEs that will clearly define student learning goals. Targeting specific standards and GLEs, rather than superficially covering numerous standards, helps create professional development training focused on key concepts aligned with state mandates (Stephens, 2001).

After specific standards and GLEs have been selected, Arctic scientists guide group selection of place-based STEM topics aligned with student learning goals. Once STEM topics have been chosen, scientists collaborate with master teachers in the design of integrated STEM instruction reflective of authentic Arctic research practices.

After professional development has been established, education researchers guide group collaboration in creating a storyboard that outlines multiple, flexible mechanisms teachers can used to transfer STEM training into classroom instruction. Scientists ensure all STEM content presented is accurate and current, and Elders ensure mechanisms for transferring STEM training to the classroom embody research-based methods shown to increase indigenous student engagement. Online and in-person mentorship from Arctic scientists, education researchers, and Native Elders offer ongoing networks of support.

To date, nine GI framework-based professional development programs have been designed. All offer yearlong STEM training and a mix of in-person, online, and technology-based remote-conferencing options for teachers in rural Alaska. Mechanisms for transferring STEM training into K-12 classroom instruction are embedded in professional development design.

In all GI framework-based professional development programs teachers are involved in creating and field-testing products that will sustain program training for future teachers.

Teachers are involved in the iterative design process because research indicates that teacher input into curriculum development builds teacher enthusiasm, pedagogical content knowledge, and ownership of the end product (Coenders, Terlouw, & Dijkstra, 2008; Hollon, Olson, Eierman, Havholm, & Hendrickson, 2002; White, 1992). A sense of ownership promotes use of the prescribed pedagogy (Coenders et al., 2008; Gess-Newsome, Southerland, Johnston, & Woodbury, 2003; Hollon et al., 2002), and teacher enthusiasm has been shown to increase student interest, engagement, and achievement (Anderman, Patrick, & Ryan, 2004; Patrick, Hisley, & Kempler, 2000; Brigham, 1991). Increased classroom use of resources that involve teachers as collaborators in development has been shown to result in student gains (Gunckel & Moore, 2005; Hollon et al., 2002; White, 1992).

1.3 A PICTORIAL VIEW OF THE GI FRAMEWORK

Figure 1.2 illustrates how GI framework-based learning goals are interrelated into a holistic design. Mechanisms for transferring STEM professional development into K-12 classroom instruction are a crucial element of all GI framework-based professional development instruction. However, because these mechanisms (or multiple, flexible curricular resources) are designed to embody all parts of GI framework-based professional development, they are not included in Figure 1.2.

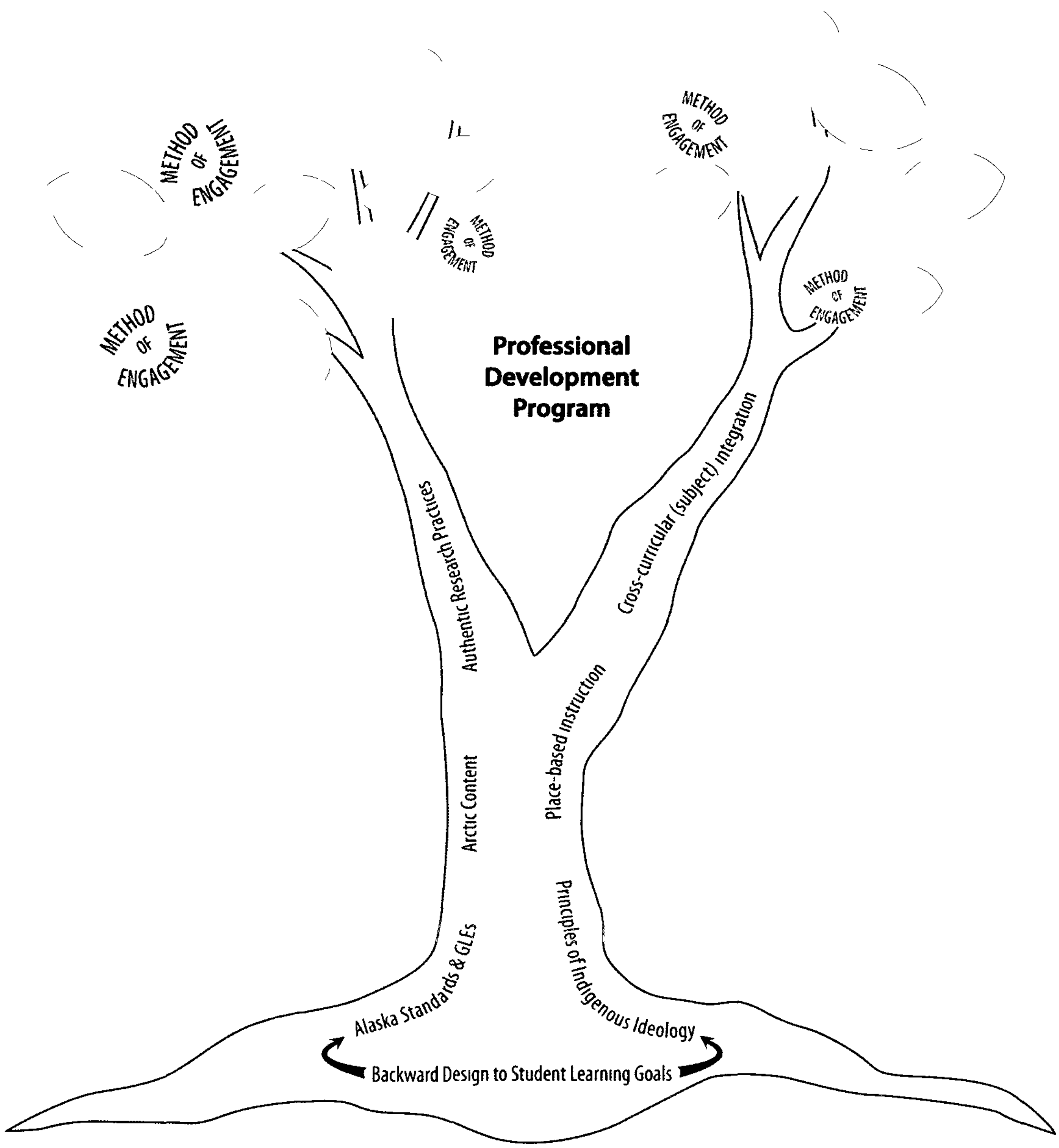

Figure 1.2
The GI Framework for Culturally Responsive STEM Professional Development

The left side of the diagram illustrates GI framework roots in student learning goals mandated by the state of Alaska (standards and GLEs). The right side of the diagram shows that the GI framework is equally anchored in principles of indigenous ideology, which promote place-based, integrated instruction. Research-based methods for engaging indigenous students in public school are shown as a suite of leaves. Like actual leaves, these individual methods are united in purpose—to facilitate STEM engagement and to meet the needs of individual students and classrooms as a whole. Underlying the entire framework are mechanisms for transferring STEM professional development training into classroom instruction. These multiple, flexible standard-aligned resources embody all framework foundational principles and serve as a direct interface between the individual professional development program and the world of classroom instruction.

In some ways, the GI framework is similar to those emerging from discussions among indigenous knowledge bearers. Like the Inupiaq Learning Framework and the Metis Holistic Lifelong Learning Model, the GI framework encourages cross-curricular integrated learning designed to help indigenous students embrace their cultural heritage while successfully achieving educational goals (Barber, 2010; Canadian Council on Learning [CCL], n.d.). In addition, each of these models is founded in collaboration among teachers, researchers, and cultural knowledge bearers, and all aim to encompass instruction rich in both mainstream and indigenous knowledge.

1.3.1 *Creating STEM Professional Development by Backward Design*

Backward design to state-mandated learning goals is the foundation of GI framework-based professional development. Public school administrators support STEM professional development that uses backward design to student learning goals rooted in state standards and GLEs. Training that is well supported by administrators is well attended by teachers. "Intentional instruction" occurs when teachers model the process of backward design to learning goals in their classrooms (Goodwin, 2010).

STEM professional development created by backward design to state standards and GLEs provides a ready platform for creating mechanisms for transferring teacher training into K-12 classroom instruction. Creating multiple, flexible mechanisms for the transfer of STEM teacher training into classroom application is a GI framework cornerstone.

Research indicates that STEM professional development that provides training that can be directly applied to classroom instruction is more effective (Gerhart, Saxe, Seltzer, Schlackman, Ching, Nasir, Fall, Bennett, Rhine & Slone, 1999) and is more likely to impact pedagogy and resulting student achievement than professional development that does not (Huffman, Thomas & Lawrenz, 2003). Failure to provide clear mechanisms for transferring STEM teacher training to classroom instruction has been cited as a major pitfall of most scientist-led professional development (Morrision & Estes, 2007; Radford & Ramsey, 1996; Sherman, Byers & Rapp, 2008).

The GI framework was used to develop the Arctic Climate Modeling Program, a professional development program that involves rural Alaskan teachers and students in authentic Arctic climate research funded by the National Science Foundation Innovative Technology Experiences for Students and Teachers program (Bertram, 2010). Like all professional development programs based on the GI framework, the Arctic Climate Modeling Program is founded in specific standards and GLEs and offers a suite of multiple, flexible mechanisms for transferring STEM professional development (aligned with student learning goals) into classroom application.

In addition to offering 200 classroom lessons within 10 instructional units, the program offers: (a) a 400-screen multimedia interactive learning system containing nine units of instruction that help students visualize complex STEM concepts; (b) two dozen online (Arctic scientist and Native Elder) lectures segmented for easy classroom application; (c) a mentor support system staffed by 21 Arctic researchers; and (d) the Student Network for Observing Weather (SNOW), which allows rural students to provide data useful to Arctic researchers.

1.3.2 *Designing STEM Professional Development that Reflects Indigenous Ideology*

Most schools in rural Alaska are situated in well-established, geographically isolated indigenous communities. Embracing learning in public school that is reflective of indigenous ideology helps motivate student interest in STEM involvement. Considering that in Alaska alone, there are 20 different indigenous groups (Barnhardt, 2001) and that there are many more distinctly different groups of indigenous people outside of the state, it can be difficult to discuss indigenous ideology in general terms.

However, most indigenous philosophers agree that most Alaska Native and American Indian groups are united by two deeply held convictions: (a) that the indigenous community feels closely connected to the place in which they live—to the natural environment in which they co-exist, and (b) that the indigenous community believes that humans and everything else in the visible natural world are connected in an intricate, complex web of life—a belief Indian Physicist Phillip Duran contends corresponds closely to the underlying principles of quantum physics (Duran, 2007).

In the book, "The Undivided Universe," renowned physicist David Bohm includes a mathematical basis for his conclusion that the universe is an unbroken, coherent whole in which both the visible world (of classical physics) and the invisible world (of quantum physics) co-exist in ceaseless movement (Bohm & Hiley, 1993). From this foundation, education researchers have deduced that indigenous students succeed academically at higher rates: (a) when STEM instruction is rooted in place-based themes that connect learning to the local environment (Barnhardt & Kawagley, 1999; Battiste, 2000; Kawagley, 1996; Lipka, 1998; Semken & Morgan, 1997; Snively & Corsiglia, 2001), and (b) when STEM instruction is presented as part of a united whole, rather than segmented into core subjects unrelated by theme (Barnhardt & Kawagely, 2005; Starnes, 2006). In public schools, instruction in core subject areas is rarely interrelated. Compartmentalizing student learning into the discrete and separate subject areas of science, math, reading, and writing begins in elementary school and continues on in institutes of higher education, in which these subjects are divided into increasingly smaller areas of specialization. Until he died in 1992, Bohm expressed concern about the current practice of fragmentation in learning in U.S. schools and society (Bohm & Hiley, 1993).

1.3.3 *Ensuring STEM Professional Development Mirrors Arctic Research Processes*

Uniting the discrete fields of science, technology, engineering and math by relating them back to a common theme (or whole picture) is one way to close the gap between the way academic subjects are taught in most public schools and the way many indigenous students have been brought up to understand the world (Kawagley, Norris-Tull, D., Norris-Tull, R., 1998). In addition to its synchronicity with indigenous ideology, cross-curricular integration—interweaving STEM subjects with reading, writing and history—more accurately mirrors the real-world practice of Arctic research. Arctic scientists integrate these skills in all phases of their research, from inception to conclusion—while developing research questions and formulating study designs, during data collection and analysis, and when sharing research findings through presentations and publications.

Earth systems science as a discipline provides a natural venue for integrating STEM topics under place-based themes directly related to students' life in the Arctic. Alaskans experience geophysical phenomena rare to those outside polar latitudes, such as the aurora borealis, and they live in the most seismically active state in the nation, in which volcanic eruptions and more than 25,000 earthquakes occur each year (Alaska Volcano Observatory [AVO], 2010). Earthquakes that change sea floor elevation can produce tsunamis, ocean waves of extremely long wavelength that build up such momentum they wreak destruction when they reach a shoreline. Alaskans have experienced 37 tsunamis since the 1800s, including the highest tsunami wave ever recorded (in 1958).

Currently, Alaskans are experiencing changes in climate that are "significant, accelerating, and unlike any in recorded history" (National Research Council [NRC], 2004). Climate literacy—the ability to understand Earth science and to make scientifically informed decisions about climate changes (NRC, 2007)—has become a high priority for all Alaskans. Climate research—the investigation of complex land, ocean, cryospheric, and atmospheric interactions—requires an understanding of how the major components of Earth's systems are interrelated. This integrative approach requires the use of instruments engineered to collect and synthesize data from space, sky (suborbital), and ground-based platforms; the use of empirical equations to interpret data; and the use of technologically advanced computer models to integrate past and present data to forecast future climate changes. Teachers need training in STEM research content and processes before they can make cross-curricular connections. This is the primary reason Arctic researchers are involved in the creation and implementation of all GI framework-based professional development courses. For more than a decade, policymakers have called for increased scientist participation in STEM education (NRC, 2001; National Science Teachers Association [NSTA], 2004). Benefits of scientist involvement in STEM education are well documented. Benefits include significantly increased teacher STEM content knowledge, process skills, self-efficacy, and use of technology in the classroom (Bazler, 1993; Miller, Thomson & Roush, 1989; Morrison & Estes, 2007; NRC, 1996; NRC, 2001; NSTA, 2003; NSTA, 2004).

Because recent research indicates that all (K-12) teachers benefit from in-depth STEM instruction (Duschl, Schweingruber & Shouse, 2007; Vasquez, 2008), professional development courses based on the GI framework are offered at the graduate level. In addition to offering place-based science content, GI framework-based professional development instruction includes math analysis and training in classroom applicable research technology (such as remote sensing imaging and computer modeling). The decision to provide all (elementary and secondary) teachers with training in STEM techniques used by Arctic researchers is based on recent research that shows that even young learners are capable of abstract thought (Metz, 1995), foundational modeling (DeLoache, 2004; Troseth, Pierroutsakos, & DeLoache, 2004), inquiry reasoning (Gopnik, Sobel, Schulz & Glymour, 2001; Gotwals & Songer, 2006), and inference from observations (Montgomery, 1992; Perner 1991; Sodian & Wimmer, 1987; Taylor, 1988; Wellman, 1990).

Providing teachers with the knowledge and skills they need to provide integrated STEM instruction that mirrors Arctic research opens a window for interactive, real-world learning in school. Education research indicates that school instruction linking STEM learning to real-world activities increases STEM engagement, deepens the learning experiences of indigenous students (Adams & Lipka, 2007; Klump & McNeir, 2005; Ruck, 1992; Stephens, 2001) and improves student achievement on math and science standardized tests (Lieberman & Hoody, 1998; Pertzborn & Limaye, 2000). In addition, school instruction that facilitates the practice of STEM workforce skills is expected to play a transformative role in STEM education (Borgman, Abelson, Dirks, Johnson, Koedinger, Linn, Lynda, Oblinger, Pea, Salen, Smith, & Szalay, 2008; Pea, 2002; Vahey, Yarnall, Patton, Zalles, & Swan, 2006). The Framework for 21st Century Learning advocates integrating the skills, knowledge, and expertise students need to succeed in today's work environment into public school curricula (Partnership for 21st Century Skills [P21], 2009). This framework underscores the importance of increasing school emphasis in areas that facilitate social and civic responsibility, that engage students in collaborative problem solving and decision making, that provide venues for students to practice critical, reflective, and inductive reasoning, and that help students practice making value judgments (P21, 2004).

All of these skills have been used for generations in indigenous communities (Barnhardt, 1997; Hill, Kawagley, & Barnhardt, 2004; Kawagley, 2006; Starnes, 2006). Historically, the ultimate goals of indigenous research were to determine how to survive within the carrying capacity of a system and to ensure resources remain available for future generations (Cruikshank, 2005). Cooperation and coordination of human activities toward a common goal has long been the basis for indigenous scientific experimentation, which has resulted in sophisticated technologic tools designed to imitate and work in conjunction with processes observed in natural cycles (Barnhardt & Kawagley, 2005; Klump & McNeir, 2005). All of these goals are part of "communal mindfulness," a cultural admonition to put the welfare of the community before the needs of the individual, the "we" before the "I" (Kawagley, 2006). These historic goals are remarkably synchronistic with the goals of today's 21st Century global community.

1.3.4 *Emphasizing Instructional Strategies Shown to Engage Indigenous Students*

Research-based methods of engaging indigenous students are portrayed as a suite of leaves in the GI framework diagram. Each leaf has a unique design, but is united in providing nourishment to the tree, just as each method of engagement in a GI framework-based program has it own intrinsic value, but is most effective when used as part of a whole network of instruction aligned with student learning goals. Because not all students of a similar cultural heritage have the same learning styles, GI framework-based programs offer teacher training in a suite of research-based methods shown to increase indigenous student engagement in STEM instruction. Including instruction in a breadth of methods for engaging indigenous students is critical because (a) research indicates that most STEM teachers "enter their preparation programs with little or no intercultural experience and with beliefs and assumptions that undermine the goal of providing an equitable education for all students" (Duschl et al., 2007, p. 303), and (b) effective teachers employ a variety of methods for guiding students toward their learning goals (Goodwin, 2010).

Because end goals are clearly defined in GI framework-based programs, teachers can choose the strategy or combination of strategies needed for students in their classrooms. However, just as a carpenter needs instruction in the diverse tools needed to get a job done, professional development needs to offer training for teachers in the most current research-based instructional strategies available.

Examples of research-based methods of engagement commonly taught in GI framework-based professional development include (but are not limited to) training teachers to provide STEM instruction aligned with students' prior knowledge; learning to incorporate tactile and visual activities into STEM instruction; relating STEM instruction to community concerns; involving students in STEM projects of local stewardship; providing opportunities for student teamwork and individual reflective thinking; setting up forums for sharing student findings with community members; training in cross-curricular integration; interweaving Native language into classroom STEM instruction; uniting university and indigenous research in STEM instruction; inviting community members to the classroom to share knowledge of local geophysical processes; incorporating related oral history, dance, art, song, and other cultural activities traditionally used to share geophysical information; and using modern technology to unite mainstream and indigenous research and perspectives.

Most good instructional strategies are not limited in their effectiveness to the minority group in which they are tested (Kleinfeld, 1994; Goodwin, 2010). Applying new information to core concepts and connecting what students are learning in school to their prior knowledge are research-based best practices for increasing Native student achievement (Aikenhead, 2001) that also are shown to improve the achievement of all students (Goodwin, 2010). Of course, the prior knowledge of students living in rural Alaska Native communities is markedly different than the prior knowledge of students living in inner-city neighborhoods in large urban centers.

An intimate connection with the land that has persisted for generations is a hallmark of indigenous ideology, and a platform for practicing cultural values such as sharing, unity, self-sufficiency, honesty, fairness, responsibility to the community, and respect for the environment (Alaska Native Knowledge Network [ANKN], 2006). Personalizing STEM classroom instruction by linking it to local concerns and cultural values helps teachers prepare indigenous students to become competent in mainstream and tribal societies (Brayboy and Castagno, 2007).

Designing STEM professional development courses for teachers in rural Alaska Native communities often means moving beyond an understanding of indigenous ideology toward an understanding of local history and activities that shape students' prior knowledge. This step often involves acknowledging Native Elders as esteemed knowledge bearers, as described below:

> Elders are critically important and provide a continuity of worldview; they lend wisdom to daily life and bring order to chaos. Elders are reminders of cultural heritage and survival and strength (Red Horse, 1980, p.466).

In many rural Alaska communities, subsistence activities are the primary venue for honoring the wisdom of Elders. For generations, Elders have relied on personal and ancestral knowledge of local indicators to forecast animal migration, plant survival, and other conditions essential for subsistence hunting and gathering success (Duran, 2007). Elders share this information with their children (and grandchildren) to increase their chances of success. When Elders are invited to the classroom, this model for sharing information is replicated in school, a strategy shown to engage indigenous students in STEM studies (Barnhardt, 1989; Kawagley et al., 1998; Stephens, 2001; Wilson, 1996). Research also indicates that inviting Elders into school reinforces indigenous students' sense of identity and belonging, and helps motivate students to acquire skills needed to take an active role in their community (ANKN, 1998).

1.3.5 *Offering Multiple Options for Transferring STEM Training to the Classroom*

The research-based instructional methods taught during GI framework-based professional development courses are embedded in the curricular resources designed to transfer STEM teacher training to K-12 classroom application. Research indicates that Alaska Native students demonstrate high visual and spatial acuity (Goodwin, 2010; Kawagley, 2006; Starnes, 2006), and that interactive visuals and online data-rich landscapes are effective tools for engaging students of all nationalities (Borgman, et al., 2008). For this reason, the GI framework-based Arctic Climate Modeling Program designed a 400-screen multimedia interactive learning system to help transfer STEM training into classroom instruction. The learning system enables students to visualize STEM concepts and processes—an approach that caters to multiple intelligences as well as to multiple student learning styles. Similar to the *Virtual Bead Loom*—used to illustrate the Cartesian coordinate system to Idaho's Shoshone-Bannock reservation students (Rensselaer, 2005)—the Arctic Climate Modeling Program's virtual learning system helps provide a cultural context for STEM instruction. Research indicates that using modern technology to display cultural concepts enhances student understanding, technical literacy, and ability to apply learning to the world (Meichtry & Smith, 2007).

Indigenous residents have interpreted and adapted to climate changes since the last ice age (Cruikshank, 2005; Pitulko, Nikolsky, Girya, Basilyan, Tumskoy, Koulakov, Astakhov, Pavlova, & Anisimov, 2004). To compliment current STEM research findings, the Arctic Climate Modeling Program's learning system animates song, dance, storytelling, and art that mimics methods used by indigenous residents to describe weather events before the written word. Many of these forms of communication have intrinsic educational value. For example, storytelling helps students exercise memory skills, imagination, and verbal and non-verbal communication, all of which have been shown to improve indigenous student engagement in learning (Cajete, 1999). When presented in a reverent manner in an appropriate setting, stories told by Native Elders can provide historical insight into complex local traditions (Barnhardt, 1997; Leonard, 2010) and include morals about the importance of local conservation (Kawagley, et al., 1998).

The Arctic Climate Modeling Program's learning system also enables students to see and hear the spelling and pronunciation of a variety of weather and climate terms in both English and in three Native languages used in the Bering Strait School District (for which the program was designed). Research indicates that incorporating Native language in public school instruction fosters family-school involvement, enhances indigenous student cultural self-efficacy (Boyer, 2006), and increases indigenous student engagement in classroom activities (ANKN, 1998). This is particularly true for students whose families speak a language different than the one used in the classroom (Borich, 2007).

A group of 20 Native Alaskan linguists from communities within the Bering Strait School District selected Native language terminology appropriate for use in the Arctic Climate Modeling Program. Seeking advice from Native language experts is a critical part of ensuring that indigenous terms interwoven into STEM curricula maintain their original meaning and sentiment (Aikenhead, 2001). Part of a system of knowledge developed out of long-term observation and a relationship with the land, Native languages focus on action words that reveal cause-and-effect relationships that can provide insight into Earth's geophysical processes (Denali Education Center [DEC] & Alaska Rural Systemic Initiative [AKRSI], 2007). For example, the Yupiaq language has more than 100 words for sea ice, each describing subtle differences in ice movement, consistency, appearance, and formation—conditions potentially affecting survival. Likewise, Chippewa observers include 19 different translations for the English word "thunder," each type forecasting a different environmental reaction (Price, 2007).

Commonly used in GI framework-based courses to transfer learning from STEM training to classroom application, a suite of lectures by Arctic researchers and Native Elders help contextualize use of English and Native language terms regarding Arctic weather and climate. On-demand lectures have been shown to be as effective in increasing STEM content knowledge as those delivered in person (Annetta & Minogue, 2004; Annetta & Shymansky, 2006). Lectures recorded for the Arctic Climate Modeling Program were digitized and segmented before final online publication. Segmented, interactive lectures that enable learners to view portions of the digitized presentation have been shown to yield higher content learning and user satisfaction than linear streaming in which the lecture flows from start to end (Zhang, Zhou, Briggs & Nunamaker, 2006).

Because research indicates that indigenous students succeed academically at higher rates when instruction is hands-on and inquiry-based (Barta, 1999; Hill et al., 2004; Laursen, Liston, Thiry, & Graf, 2007; Wilson, 1997), the GI framework promotes the use of standard-aligned tactile instruction, and encourages student investigation, cooperative learning, and community participation. According to Alaska Native Elder Kawagley, these skills appeal to indigenous students because they mimic essential strategies used for centuries by Native communities involved in subsistence hunting, fishing, food gathering, and preparation. "Native people have traditionally acquired their knowledge through direct experience . . . modeling and guided practice" (Kawagley & Barnhardt, 1998, p.1).

1.4 UNITING UNIVERSITY RESEARCH AND INDIGENOUS KNOWLEDGE

Acknowledging that expertise from all members of the diverse global community will be needed to adapt to a changing planet (National Aeronautics and Space Administration [NASA], 2006), university climatologists are among the first scientists to seek input for their research from Alaska Native Elders. Likewise, changes in Arctic climate have motivated many Native Elders to seek knowledge from university researchers. Indigenous climate observations are now shared at scientific conferences (American Geophysical Union [AGU] 2007; Arctic AAAS, 2007). Likewise, scientific observations are now being reported at cultural conferences (Alaska Native Language Center [ANLC], 2008; Nunavut, 2001). At one cultural conference, Kawagley spoke of an 80-year-old Elder falling to her death because seasonal indicators she had used all her life for assessing the timing of ice breakup were no longer valid. "It appears Earth's processes cannot be stopped," said Cup'ik Eskimo Ayuukung Andrews. "Our people desperately need education to improve our understanding of these processes" (ANLC, 2008).

1.4.1 *Providing Forums for Authentic Student Collaboration*

Providing venues for student collaboration with university scientists and Native Elders is an important step toward bridging the two worlds in which indigenous students find themselves—the mainstream society of university scientists and the traditional societies of their grandparents. The NSF-funded Alaska Rural Systemic Initiative has 10 years of student achievement data showing the importance of bridging these worlds in school so indigenous students don't have to deny who they are, but can build on the knowledge, traditions, and ways of knowing they bring with them (Hill et al., 2004).

In the Arctic Climate Modeling Program, student projects of local stewardship are used as a platform for addressing real-world issues relevant to rural Alaska Native communities. Mimicking processes used in Arctic research, stewardship projects involve identifying a climate issue of local importance, researching solutions to address the issue, and then sharing findings with the community. Stewardship projects involve collaborative group work among students, and contacting scientists and community members as expert resources.

This school activity with real-world application helps students understand how working on issues of local importance can have statewide relevance. For example, some stewardship projects center on developing practical, cost-effective ideas for helping rural communities adapt to changes in Arctic weather. Although rural Alaskans consume 15% less energy than urban residents, they pay three times more for it (Leask, 2008). For this reason, finding affordable solutions for heating homes is a major concern in rural Alaska (Alaska Federation of Natives [AFN], 2008). To mitigate this problem, stewardship projects task students with studying alternative energy sources (such as windmills, hydrokinetic turbines, and geothermal or biomass energy). After collaborating with scientists and indigenous knowledge bearers, students determine which solutions might be useful for their communities. Such projects increase indigenous student engagement in STEM areas by connecting the Native perspective to issues beyond their own communities (Starnes, 2006) and by helping students understand the adage, "think globally, act locally" (ANKN, 1998).

1.4.2 *Providing Venues for Sharing Student Work with Local Communities*

All GI framework-based programs provide teacher guidelines for hosting local community expos (or science camps) during which students share STEM research findings and lessons learned in school with community members. Sharing research findings at local school-hosted expos enables students to give back to others in the community who have shared knowledge with them. Giving back is a practice encouraged in indigenous cultures; "it completes a cycle that builds knowledge and encourages all to participate again" (Stephens, 2001, p. 31). Perhaps for this reason, creating service-oriented student projects and sharing findings with the local community is a strategy shown to increase student motivation to stay in school and achieve graduation (National Dropout Prevention Center/Network [NDPC/N], 2009; Rumberger & Lim, 2008).

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CHAPTER 2

THE ARCTIC CLIMATE MODELING PROGRAM: PROFESSIONAL DEVELOPMENT FOR RURAL TEACHERS[1]

2.1 ABSTRACT

The Arctic Climate Modeling Program (ACMP) offered yearlong science, technology, engineering, and math (STEM) professional development to teachers in rural Alaska. Teacher training focused on introducing youth to workforce technologies used in Arctic research. Due to challenges in making training accessible to teachers in geographically isolated areas, ACMP modified the more traditional format of offering professional development during two-week summer institutes with academic-year follow up. Instead, ACMP offered a mix of year-round training options for 165 teachers in the Bering Strait School District. Sustainable program resources were created to mimic the processes and instruments used to study Arctic climate, and were designed in collaboration with scientists from five research centers. Teachers were involved in the iterative design process because research indicates that teacher input into curriculum development builds teacher enthusiasm, pedagogical content knowledge, and a sense of ownership of the end product. This study explores the question: "Did ACMP provide teachers in rural Alaska schools with the tools and knowledge they needed to offer culturally responsive place-based STEM instruction?" Data sources reveal consistent high levels of participation, improved teacher STEM instructional ability, and increased student STEM content learning. A grounded theory approach was used to analyze qualitative feedback. Teacher comments were coded and patterns analyzed in three databases. A majority of open-ended comments indicate that ACMP involvement improved K-12 STEM classroom instruction and enhanced student-learning outcomes. Teachers most frequently cited the following reasons for improved STEM classroom

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[1] Bertram, K.B. (2010). The Arctic Climate Modeling Program: Professional Development for Rural Teachers. *Journal of Technology in Teacher Education.* 18(2), 231-262.

instruction: learning place-based STEM content, skills and processes that mirror authentic Arctic research; learning best-practice instructional strategies for engaging indigenous students in STEM study; and using multiple, flexible ACMP curricular resources to transfer STEM training to classroom instruction. Teacher feedback indicates that ACMP was particularly successful in increasing indigenous student engagement in scientific process and technology skills. This analysis, along with student field-test data, demonstrates that ACMP provided teachers in rural Alaska with the tools and knowledge needed to offer culturally relevant STEM instruction in K-12 classrooms. Unanticipated outcomes of this study include high community interest in ACMP and use of ACMP instrumentation for local purposes.

2.2 INTRODUCTION

Connecting teachers and students with Arctic scientists and Native Elders is the heart of the Arctic Climate Modeling Program (ACMP), funded from 2005-09 by the National Science Foundation Innovative Technology Experiences for Students and Teachers (NSF ITEST ESI-0525277). For rural Alaskan teachers in the Bering Strait region, ACMP offered yearlong science, technology, engineering, and math (STEM) professional development focused on increasing student climate literacy and engaging youth in Arctic research workforce technologies.

In the past decade, severe coastal storms have hammered the Bering Strait region, and the resulting loss of land has been so extreme that communities established for generations are being forced to move to higher ground. Scientists from around the globe have converged in this region and other areas of the Arctic to observe and measure recent changes in climate that are "significant, accelerating, and unlike any in recorded history" (National Research Council [NRC], 2004). Climate literacy, the ability to understand Earth science and to make scientifically informed decisions about climate changes (NRC, 2007), is a high priority for indigenous Alaskan residents, whose cultures, languages, and subsistence way of life are tied to activities connected with the land and guided by weather and seasons.

To adapt to a changing planet, expertise from all members of the global community will be needed (National Aeronautics and Space Administration [NASA], 2006). American Indians and Alaska Natives are the least represented of all minorities in STEM careers and disciplines (NSF, 2007). Geoscience, the key discipline for climate research, is the STEM discipline with the lowest minority representation (Huntoon & Lane, 2005). Only .001% of the American Indian and Alaska Native population is pursuing graduate geoscience degrees (NSF, 2004).

Climate studies provide a natural forum for helping students develop the problem-solving skills needed to explore the interconnected physical, geographic, social, and historic dimensions of STEM research. Research underscores the importance of increasing school emphasis in disciplines that facilitate global awareness and civic responsibility, and that foster critical thinking and other 21st century learning skills (Partnership for 21st Century Skills [P21], 2004). A common theme, such as climate, that integrates STEM subjects across disciplines has been shown to improve student technical literacy, ability to apply classroom learning to the world, and achievement on math and science standardized tests (Meichtry & Smith, 2007; Pertzborn & Limaye, 2000).

Climate research involves sophisticated technology, complex 21st century skills, and international collaboration, and climate studies offer insight into a variety of STEM careers, including geospatial technology, geophysical research, computer modeling, engineering, and policymaking. Professional development that trains teachers in these skills is essential considering that 90% of U.S. secondary students are taught Earth and physical science by a teacher lacking STEM certification (National Center for Education Statistics [NCES], 2007). Training that reaches teachers in rural and disadvantaged areas serving minority populations is critical since the overall performance of U.S. students in Earth and physical sciences is lower today than it was in 1996, and the gap between white and minority student STEM achievement is as wide today as it was then (Grigg, Lauko, & Brockway, 2006).

Despite its global and cultural importance, climate science is missing from most U.S. school curricula (National Oceanic and Atmospheric Administration [NOAA], 2007). In the Arctic, climate research is conducted in Native students' "backyards," making climate science a logical topic for place-based student study. A seven-partner consortium of research institutes and Native corporations created ACMP to motivate students to explore geoscience careers and to help teachers understand their role in using technology to nurture STEM talent. ACMP targeted the Bering Strait School District, a geographically isolated area on Alaska's Seward Peninsula.

This chapter examines the efficacy of ACMP's unique professional development framework and explores its ability to provide Bering Strait teachers with the tools and knowledge they need to provide culturally responsive STEM instruction. This chapter outlines research methods used to assess ACMP effectiveness, discusses research findings, and expounds on implications for future research.

2.3 CURRICULUM RESOURCE-BASED PROFESSIONAL DEVELOPMENT

ACMP was designed to help teachers understand STEM content and workforce skills associated with Arctic climate research. This focus dovetailed with the Bering Strait School District's goal to teach students to think like scientists. ACMP interweaves data and technology skills used by Arctic researchers with knowledge and observation skills used for generations by Native Elders. The ACMP was created as an outgrowth of the cooperative effort of five research centers—University of Alaska Fairbanks (UAF) Geophysical Institute, International Arctic Research Center, Center for Global Change and Arctic System Research, Alaska Satellite Facility, and National Weather Service (NWS)—and two Native organizations, Bering Strait Native Corporation, and Kawerak, Incorporated.

The Bering Strait School District spans 80,000 square miles (an area larger than the state of Nebraska), most of which is accessible only by small aircraft. The district serves about 1600 Alaska Native students in 15 schools. Schools range in size from 40 to 225 students, and exist in villages that are not connected by roads and are isolated from each other and urban centers. Due to significant challenges in making professional development opportunities accessible to the 165 teachers in the district, ACMP modified the traditional ITEST format of offering a two-week summer institute, followed by supplementary training during the academic year. Instead, ACMP offered a unique form of "curriculum resource-based professional development" that provided a year-round mix of in-person, long-distance, online, and local training for rural teachers.

Although the Bering Strait School District serves a 98% Alaska Native student population, 94.5% of the teachers are non-Native, which is representative of the state as a whole (Suderman, 2008). To address the cultural and experiential differences between teachers and students, ACMP professional development included training in a variety of research-based skills shown to increase minority student STEM success. Research indicates that Alaska Native students succeed academically at higher rates when instruction is hands-on and inquiry-based (Assembly of Alaska Native Elders, 1999; Wilson, 1997), links education to the students' physical and cultural environment (Barnhardt & Kawagley, 1999; Semken & Morgan, 1997), addresses topics of local interest (Kawagley, 1995; Lipka, 1998; Battiste, 2000), and incorporates local knowledge and culture (Boyer, 2006).

In some ways, the ACMP professional development model resembles the "curriculum implementation" model used when a school district switches to using a new curriculum (Loucks-Horsley, Love, Stiles, Mudry, & Hewson, 2003). Both models: (1) provide teachers with quality resources for use in class; (2) offer professional development opportunities for teachers to learn how to implement curricular materials locally; and (3) contain strategies geared toward the incorporation of curricula into long-term instruction.

The ACMP model is different in two essential ways. In the curriculum implementation model, teachers are provided with established curricular resources and are not involved in field-testing or curricular resource revision (Loucks-Horsley, et al., 2003). By contrast, ACMP involved teachers in both field-testing and curricular resource revision. ACMP involved teachers in the iterative design process because research indicates that teacher input into curriculum development builds teacher enthusiasm, pedagogical content knowledge, and ownership of the end product (Coenders, Terlouw, & Dijkstra, 2008; Hollon, Olson, Eierman, Havholm, & Hendrickson, 2002; White, 1992). A sense of ownership promotes implementation of the curriculum and enactment of the prescribed pedagogy (Coenders et al., 2008; Gess-Newsome, Southerland, Johnston, & Woodbury, 2003; Hollon et al., 2002). Teacher enthusiasm increases student interest, engagement and achievement (Anderman, Patrick, & Ryan, 2004; Patrick, Hisley, & Kempler, 2000; Brigham, 1991). Finally, increased classroom use of quality resources that involve teachers as collaborators in development has been shown to result in student gains (Gunckel & Moore, 2005; Hollon et al., 2002; White, 1992).

Representatives from partner agencies composed the ACMP Development Team. Arctic scientists, Native Elders, and education specialists collaborated with district curriculum coordinators to define a knowledge base. ACMP professional development relayed this knowledge to Bering Strait teachers, and sustainable curricular resources captured it for future teachers. ACMP curricular resources were designed to accommodate teachers instructing students of diverse abilities in multi-age classrooms. In the Bering Strait, students are grouped in a subject by "levels of attainment," rather than by grade or age. Students advance to higher levels after passing "End-of-Level" tests.

Bering Strait Native Elders helped tailor researched-based instructional methods for the districts' Yup'ik, Siberian Yupik, and Inupiat students. Sharing generational knowledge is a best-practice method for engaging minority students in STEM studies (Kawagley, D. Norris-Tull, & R. Norris-Tull, 1998; Stephens, 2001). Since the last ice age, indigenous residents have made observations of the Arctic and interpreted and adapted to climate changes (Cruikshank, 2005; Pitulko, et al., 2004). Arctic scientists draw upon indigenous wisdom to help build their knowledge of local climate impacts.

ACMP instruction was designed to help non-Native teachers value Native ways of learning and understand Native language related to geophysical processes. ACMP helped teachers see indigenous students—with one foot in the past and one in the present—as future leaders in climate research. Teacher field-testing input ensured that research-based instructional skills designed to engage indigenous students were clearly defined in ACMP curricular resources, and that STEM content pertained to issues of local and statewide importance.

2.4 ACMP CONTENT

Each year, ACMP professional development was aligned with a different Arctic research theme, and a new suite of curricular resources was created. During the first year, scientists established weather stations at Bering Strait schools so teachers and students could collaborate with scientists remotely. Because weather information from many Bering Strait villages previously had not been available, scientists designed a computer program to automatically capture data for the NWS and the UAF Geophysical Institute. Scientists also developed the Student Network for Observing Weather (SNOW) so teachers and students could post information not collected by weather stations, such as observations of sea ice conditions, snow depth, sky conditions, and visibility. SNOW provided online graphs and charts for classroom activities that showed temperature, wind, precipitation, and weather indicators across the Bering Strait.

In the second year, students compared local weather data with regional 10-day forecasts, 100-year predictions, and 200-year modeling projections. In the final year, scientists installed permafrost-monitoring stations near all schools that enabled students to collect data for scientific research and classroom use. Permafrost (frozen soil, sediment, or rock that remains at or below 0° C for at least two consecutive years) occupies a quarter of Earth's surface (Zhang et al., 2003) and plays a significant role in the global climate system with linkages and feedbacks generated by its influence on surface energy and moisture fluxes. In the Arctic, thawing permafrost is a serious issue. Ground frozen for generations is thawing, which prompts building collapse, septic and drinking-water system disruption, and landslides due to compromised soil integrity.

ACMP teacher training centered on helping students think like scientists; understand key scientific principles relevant to Arctic climate; analyze data associated with climate change research; and use information technology (IT) skills for recording, manipulating, and interpreting data. ACMP annually provided 160 professional development contact hours for teachers. Because professional development events were aligned with different research themes annually, teachers were able to acquire 480 contact hours by grant end.

Interest in ACMP professional development was so high that district administrators capped the number of teachers permitted to attend off-site workshops. Most Bering Strait schools have small staffs and substitute teachers are rarely available. For this reason, district administrators asked that ACMP professional development be divided into two categories: (1) training open to all 165 teachers in the district, and (2) training open only to a subset of 30 "Lead Teachers."

Two Lead Teachers from each school were selected based on exemplary service to attend offsite ACMP training. After returning to their schools, Lead Teachers duplicated ACMP training for other staff. ACMP provided Lead Teachers with instruction manuals, materials, and online support to facilitate knowledge transfer. In larger schools, Lead Teachers replicated entire ACMP workshops. In smaller schools, Lead Teachers transferred training more informally.

Lead Teachers also oversaw annual ACMP field-testing in their schools. In addition to distributing materials that facilitated local field-testing, Lead Teachers compiled field-test data and staff suggestions for curricular revision into monthly reports that were emailed to the program manager from November – April. A three-credit UAF course was designed for Lead Teachers. Because the course changed with ACMP themes each year, Lead Teachers could earn 9 credits by grant end.

2.5 ACMP PROFESSIONAL DEVELOPMENT EVENTS

Table 2.1 depicts ACMP training for Lead Teacher representatives from each Bering Strait school.

Table 2.1
Annual ACMP Training Solely for Lead Teachers

Event	Purpose	Timeline	Format
(a) STEM Workshops	Scientists share current Arctic research, science content and process	First Quarter	Four-day face-to-face at the UAF Geophysical Institute
(b) Monthly Reports	Lead Teachers share school-wide field-test feedback on ACMP resources	Monthly	Monthly emails compiled by Lead Teachers for ACMP staff
(c) Technology Workshops	Experts provide advanced technology instruction for Lead Teachers	Third Quarter	8-hr workshops in Unalakleet, AK, or onsite at rural schools
(d) Culminating Workshops	Lead Teachers share field-test feedback with the ACMP Development Team	Last Quarter	Onsite in all Bering Strait village schools

(a) STEM workshops featured new Arctic research findings. During these annual 4-day events, scientists and education specialists taught Lead Teachers classroom-applicable technology skills (i.e. how to collect data from weather and permafrost-monitoring stations, use SNOW to share data with scientists, and access images from polar-orbiting satellites). Elders shared traditional weather observation techniques and related Native language terms.

(b) Monthly reports were compiled by Lead Teachers, who oversaw ACMP field-testing in their schools. Reports highlighted field-test data and staff suggestions for curricular revision.

(c) Technology workshops were held annually for Lead Teachers desiring advanced technology instruction. Guided by technology experts, these eight-hour workshops focused on ACMP instruments (school weather stations and permafrost monitoring sites), online tools (SNOW, the ACMP website, the mentor network, digitized scientist and Elder lectures), and software required to facilitate data display.

(d) ACMP culminating workshops were held at the end of the second and third grant years. At these eight-hour workshops, Lead Teachers reviewed ACMP curricular resources developed that year with scientists, Elders, and education specialists.

Lead Teachers also attended annual professional development events open to all teachers in the Bering Strait School District, depicted in Table 2.2.

Table 2.2
Annual ACMP Training Open to All Bering Strait Teachers

Event	Purpose	Timeline	Format
(a) Introductory Workshops	Share Arctic research findings and introduce new curricular resources	First Quarter	8-hr workshops at district conferences in Unalakleet, AK
(b) Mentor Lectures	Update science and indigenous content and promote career awareness	Monthly	Live streaming to all schools, online, and on DVD
(c) Mentor Network	Answer inquiries about Arctic weather, climate, and research	All Year	Online community on the ACMP website
(d) Science Camps	Showcase student learning in ACMP for local residents	Last Quarter	School-based in all Bering Strait villages

(a) Introductory workshops were held during annual district in-service conferences. Each grant year, all 165 Bering Strait teachers attended these 8-hour workshops, during which scientists shared Arctic research findings, and education specialists presented new

ACMP curricular resources. In response to community interest, the introductory workshops were repeated in the evening for local residents.

(b) Mentor lectures were video-broadcast live to K-12 classrooms in all 15 Bering Strait schools simultaneously. During these annual monthly (November – April) video-broadcast lectures, Elders shared indigenous language and knowledge while scientists from diverse STEM disciplines shared multimedia animations and demonstrated climate research instrumentation. Scientists and Elders answered teacher and student questions either live on two-way camera or using Skype (a free online communication service). Lectures were recorded on DVD and posted online for future teacher access and classroom use.

(c) The Mentor network was staffed by 21 scientists. This online resource, accessible from the ACMP website (http://www.arcticclimatemodeling.org), enabled teachers to collaborate with scientists throughout the year. Commonly asked questions and responses were categorized by theme, and posted on the ACMP website for future teacher access.

(d) Science camps showcased ACMP student work for community members. Using ACMP manuals, teachers in all 15 Bering Strait schools organized daylong science camps each grant year. Aligned with ACMP Arctic research themes, manuals contained instructions for setting up nine "experimental stations" and included student investigation strategies for data collection, comparison, manipulation, interpretation, and display. K-12 students hosted all experimental stations.

2.6 ACMP CURRICULAR RESOURCES

The ACMP framework for creating curricular resources grew out of Development Team meetings held quarterly during the first grant year. Scientists, Native Elders, district curriculum coordinators, and ACMP education specialists collaborated to build a foundation for the creation of ACMP curricular resources. In consonance with the Development Team vision, ACMP resources focused on STEM topics relevant to Arctic residents that integrated indigenous knowledge. Tactile lessons and student investigations were included to encourage cooperative learning and community participation, both of which have been shown to increase retention for Native students (Hill, Kawagley, & Barnhardt, 2004). Multimedia tools were designed to help students visualize scientific concepts and learn climate-related Native language vocabulary. Classroom-applicable technology was incorporated to strengthen student 21st century workforce skills.

Curricular resources were created to coincide with district-defined "levels of attainment" in science. In the district, beginning level instruction correlates to concepts and standards aligned with grades K-4; intermediate levels with grades 5-8; and advanced levels with grades 9-12. At beginning levels, ACMP curricular resources introduce students to basic functions and applications related to scientific study, such as collecting and recording data, making graphs and charts, and deciphering basic information on maps, satellite images, and photographs. At intermediate levels, students manipulate, interpret, display, and present data for peer review. At advanced levels, students learn the basics of systems modeling. Critical thinking activities were included at all levels to help teachers practice methods for eliciting student sharing and for guiding independent and creative thinking. Below is an overview of ACMP curricular resources.

2.6.1 *Classroom Lessons*

The Development Team created nearly 200 classroom lessons aligned to multiple national, state, and regional science, math, and language arts standards. Lessons teach progressive levels of science inquiry, incorporate weather data from the Bering Strait region, and emphasize hands-on activities and practical use of equipment. At beginning levels, students construct basic weather instruments, gather data, and learn to observe local weather. At intermediate levels, students monitor regional weather and learn about Arctic cycles and systems. At advanced levels, students incorporate regional data into basic climate system models and learn about atmosphere-ocean-land interactions, feedbacks, and energy transfer. Curricular resources are organized online into three categories (and subdivided by themes): Observing & Forecasting (data analysis, remote sensing, weather observations, SNOW); Weather Basics (clouds, matter & energy, precipitation, seasons, temperature, water cycle, wind); and Climate Systems (climate change, greenhouse effect, permafrost, sea ice dynamics).

2.6.2 *Multimedia and Interactive Activities*

The ACMP website hosts the SNOW portal, digitized Scientist Lectures, the Mentor Network, and all classroom lessons. The website also hosts portions of the 400-screen *Climate Change in the Arctic* DVD created for ACMP to help students visualize scientific concepts. The DVD permits interaction with modeling and computer activities too large for website download. The DVD contains 9 units of progressive geophysical instruction (*Earth's Weather*, *Earth's Water*, *Permafrost*, *Earth's Systems*, *Changes Over Time*, *Measuring Change*, *Greenhouse Effect*, *Computers and Climate*, and *Climate Change Impacts*). Each unit contains exercises that help students understand Arctic weather concepts and climate interactions. Concluding units help students interact with computer modeling simulators. Based on teacher suggestions, Inupiaq, Yup'ik, and Siberian Yupik language terms were added as roll-over text throughout the DVD. All units contain narration-over text to assist students for whom reading is a challenge.

2.6.3 *Creating ACMP Curricular Resources*

ACMP curricular resources were developed by education specialists and technology experts from partner organizations, with detailed guidance from the project Principal Investigator. An average of 60 ACMP lessons (20 per level) and 130 interactive, multimedia activities were drafted each year to supplement ACMP website features (Scientist Lectures, Mentor Network, SNOW portal). Development Team scientists and Native Elders reviewed all drafted curricular resources. After quarterly review for scientific accuracy and appropriate presentation of cultural values, beliefs, and language terms, curricular resources were sent to Bering Strait schools for field-testing. Monthly field-test input from teachers in each school helped ensure guidelines and instructional methods were clear and effective in rural classrooms. Teacher input also helped ensure answer guides, assessment rubrics, and scientific and cultural background (contextual) information provided with each lesson were effective.

Continual teacher feedback was a critical part of the adaptive, iterative process by which drafted curricular resources were revised and new curricular resources were created. All curricular resources contain step-by-step teacher instructions and directions for accessing research tools, such as satellite images or climate models. Student worksheets include text and illustrations, ensuring success for students who do not have strong reading skills.

After field-testing and a final review by scientists and Elders, curricular resources were posted to the ACMP website, which continues to host classroom lessons and interactive activities, the SNOW portal, Scientist Lectures, the Mentor Network, and portions of the comprehensive multimedia *Climate Change in the Arctic* DVD.

2.7 PROGRAM OVERVIEW

ACMP's unique "curriculum resource-based professional development" provided a mix of year-round in-person, long-distance, online, and local training for teachers in rural Native villages isolated from each other and from urban centers. A hierarchy of mentoring support was established because geographic and logistical barriers prevented all Bering Strait teachers from attending all ACMP professional development events. Curricular resources were field-tested in all schools, allowing teachers to provide feedback on the resources themselves, as well as enabling teachers to practice research-based methods for instructing indigenous students in STEM concepts and processes that mirror authentic Arctic research.

Findings from a study of the impact of ACMP involvement on Bering Strait teachers and students are described below. Data helped determine if the ACMP curriculum resource-based professional development model provided a feasible alternative to the ITEST model for teachers in rural areas. Data also helped determine if the ACMP model provided teachers in rural Alaska schools with the tools and knowledge they needed to provide culturally relevant STEM instruction.

2.8 ACMP RESEARCH METHODOLOGY

2.8.1 *Sample*

ACMP professional development was provided for all 165 Bering Strait teachers, either directly or through a hierarchy of mentoring support. Curricular resources were developed for all levels so that teachers instructing multi-age classrooms could participate in field-testing. Because curricular resources addressed multiple (K-12) standards and were designed for cross-curricular integration, teachers in subject areas other than science also participated in field-testing.

2.8.2 *Data Collection and Analysis*

To address the research question, data were collected for three outcomes: teacher participation rates, participant-reported impact of the program, and student outcomes in science assessments. Each of these data sources is described below.

2.8.2.1 *Participation Rates*

Participation rates were calculated directly for in-person Lead Teacher professional development events and for introductory workshops open to all Bering Strait teachers. Participation at other events open to all Bering Strait teachers was calculated indirectly. For example, video streaming documented that Scientist Lectures were broadcast to all Bering Strait schools, but could not document if all students and teachers at the school attended live presentations. Follow-up with Lead Teachers helped determine how many teachers in each school watched the live feed, or viewed lectures online or on DVD. Similarly, supplies were sent to all Bering Strait schools so teachers could organize local ACMP Science Camps. ACMP staff relied on teacher and administrator documentation to verify that camps were held in each school. These documents included fliers prepared by teachers to entice community participation in the camps, and "passports" verifying local residents had completed camp experimental stations.

2.8.2.2 *Participant-reported Impact*

Participant-reported impact of ACMP on teacher practice was measured in three ways: through (a) field-test documentation, (b) in-depth case-study interviews, and (c) participant surveys.

(a) Field-test documentation was gathered throughout the year. Field-testing in all Bering Strait schools occurred annually after the conclusion of the ACMP introductory workshop. Lead Teachers distributed field-test forms monthly (November–April) in each school to prompt open-ended responses from school staff. Field-test forms contained the following questions: Consider the ACMP curricular resources field-tested this month in your school. What aspects do you find useful? Which aspects are ineffective and need revision? What are your suggestions for ACMP curricular resource revision? Consider this month's ACMP Scientist Lecture. Was the research discussed in the lecture relevant to local issues? If yes, how? Did you use the lecture to enhance ACMP classroom instruction? If yes, how? What questions do you have for a scientist?

In their monthly email reports, Lead Teachers summarized feedback from other staff. During the three-year field-test period, Lead Teachers in all 15 schools emailed monthly reports from November through April. The external evaluator for ACMP considered monthly reports from Lead Teachers critical, so entire monthly reports were input as single entries into the Lead Teacher field-test report database. A grounded theory approach was used to analyze qualitative feedback. Teacher comments were coded and patterns analyzed in three databases. Because each monthly report consists of two or more sentences, reviewers determined that some entries required two codes to correctly identify the main purposes of the report. No comment received more than two codes.

(b) Case-study interviews were conducted to supplement data in monthly reports. The program external evaluator conducted case study interviews with Bering Strait teachers (who were not Lead Teachers) at their schools. This was more difficult than planned. Because small planes are used to access most Bering Strait villages (spread throughout an 80,000-square mile area), it took two days to reach rural schools from the nearest city (Fairbanks, Alaska). No hotels exist in Bering Strait villages, so lodging was provided in the school gym or on teachers' floors. Inclement weather grounded planes and prolonged visits. In the end, the evaluator reached schools in the Bering Strait villages of Brevig Mission, Stebbins, and Teller. Ten teachers across these schools were randomly selected for in-depth interviews. During local visits, the evaluator also interviewed school principals. She interviewed three district administrators by phone. For all 16 case studies, the evaluator used a semi-structured interview protocol in which teachers, principals, and administrators were asked to broadly describe whether or not the ACMP program helped them instruct science, and why. To prompt open-ended responses, the evaluator asked the following questions: Did ACMP involvement affect classroom STEM instruction? Please explain. Did ACMP involvement affect student achievement or engagement in STEM studies? Did ACMP align with school or district goals?

Each interview was taped and transcribed verbatim. Transcribed paragraphs from each interview were entered into a "case study" database. Again, because each paragraph consists of two or more sentences, reviewers determined that some entries required two codes to correctly identify the main purposes of the report. No comment received more than two codes.

(c) Participant surveys were distributed each grant year by the external evaluator to all Lead Teachers attending four-day STEM workshops. External evaluator-prepared critique forms asked teachers to provide feedback about their satisfaction with the workshop and to report on the extent to which ACMP helped them learn science content and effective practices. Descriptive statistics were used to analyze workshop feedback to Likert-style questions. At the end of the form, teachers were asked, "Do you have any comments about ACMP professional development you would like to share?" Open-ended comments written in response to this question were entered into the participant survey database, and coded to ascertain patterns. Every comment received was one sentence long, and therefore received one code.

Three separate databases were created for open-ended comments, each associated with one of the sources described above. The field-test database contains Lead Teacher monthly reports. The case-study database contains open-ended comments transcribed from in-depth interviews conducted by the external evaluator. The participant surveys database contains short comments written on surveys administered at the conclusion of STEM workshops.

A grounded-theory approach was used to analyze teacher qualitative open-ended comments (written into online surveys and transcribed from case-study interviews) in all three databases. This approach involves analyzing qualitative data to look for emerging patterns. Rather than fit data into pre-determine themes, the goal of this approach is to derive themes from the data itself. To reduce bias in data analysis, four reviewers (the ACMP external evaluator, the ACMP principal investigator, the ACMP program manager, and an evaluation assistant) analyzed all entries in all databases several times. Each reviewer independently analyzed each entry to determine the primary reason it had been written. Reviewers assigned each entry a primary-purpose code. The primary-purpose code for each entry was discussed until consensus was reached. This process was repeated each time a further breakdown of a category was merited. Reviewers concurred that the primary purpose of each open-ended comment fell into one of the four main categories outlined in Table 2.3.

Table 2.3

Description of Primary-purpose Categories Assigned to Teacher Open-ended Comments

Primary-purpose Code	Brief Description of the Primary-purpose Code
Improved STEM Instruction	Comments that explain how or why ACMP methods or activities enhanced or improved teacher STEM instructional abilities
Enhanced Student Learning	Reports that describe enhanced student learning outcomes resulting from ACMP involvement
Mentoring Support	Reports about either (a) how teachers received mentoring support from scientists, peer teachers or program administrators (including the PI and ACMP staff or about (b) how teachers are mentoring or serving as sources of STEM information for school administrators
Revision Suggestions	Reports that give suggestions for revision

To identify the reasons teachers believed ACMP involvement improved their STEM instruction or enhanced student-learning outcomes, reviewers further analyzed data in these primary-purpose categories. Table 2.4 shows the four main reasons teachers said ACMP involvement improved their STEM instruction or enhanced student learning.

Table 2.4
Reasons ACMP Involvement Improved STEM Instruction or Enhanced Student Learning

Theme code	Brief description of theme code
Training in STEM content, skills & processes involved in conducting Arctic research	Teachers attribute improved STEM instruction and/or student learning to (a) training in scientific content and processes and in math and technology skills used in Arctic research; (b) training in how to replicate these skills in the classroom while guiding student inquiry, research, or experimentation; (c) training in use of ACMP information technology, including Scientist Lectures, the Climate Change in the Arctic DVD, online resources, the ACMP website, the SNOW portal, access to satellite imagery, and STELLA modeling.
Training in best-practice instructional strategies for engaging indigenous students	Teachers attribute improved STEM instruction and/or student learning to training in STEM instructional strategies. Four main strategies are named: (a) using locally or culturally relevant resources and topics that engage students and their communities; (b) using a hands-on (tactile) approach to engage students in STEM studies; (c) learning how to integrate STEM topics into other subject areas or how to integrate other subject areas into the teaching of STEM (such as art, reading, history, music, language arts); and (d) learning how to align instruction to the standards underpinning Alaska standard-based assessments.
Mentoring support	Teachers attribute improved STEM instruction and/or student learning to (a) mentoring support from scientists, Lead Teachers and ACMP staff (PI, curriculum developers, and program managers); or to (b) being able to mentor or share STEM information with school or district administrators, thereby garnering their increased support.
Ability to use multiple, flexible curricular resources	Teachers attribute improved STEM instruction and/or student learning to the ability to use progressive ACMP curricular resources, describing them as comprehensive and flexible enough to meet the needs of students at multiple levels (beginning, intermediate, advanced) of multiple learning styles (visual, kinesthetic, auditory) and with diverse abilities (special-need to advanced-placement students).

2.8.2.3 *Student Outcomes*

All Bering Strait students took pre-tests at the start of the ACMP program prior to field-testing STEM lessons. At the end of each program year, a random number of students were selected to complete post-test questions.

Originally, half of the students in each school were slated to participate in ACMP, so the other half could serve as a comparison group, but this did not work. Bering Strait schools are small and the teaching staff close-knit. Once teachers in the comparison group saw the benefits of involvement, they adopted ACMP resources. Although overwhelming interest forfeited the experimental design, pre- and post-tests continued to be administered.

The external evaluator worked with the PI and scientists to develop a Student Competency Exam that provided baseline data about student knowledge of Arctic research, STEM content, and scientific process. Pre-tests were developed for each level (K-4, 5-7, 9-12) and aligned with research content to be covered in ACMP that year. Pre-tests were designed to mimic End-of-Level tests created by the district and SBAs administered by the state. They included a variety of multiple choice, fill-in-the-blank and open-ended questions. The post-test was administered at the end of the year and at the end of each unit. Because students in the district frequently move from one village to another to live with different relatives and ACMP was not able to track students reliably, the modified post-test system allowed teachers to monitor student progress by unit, rather than solely by a full post-test at the end of the year. In addition to switching schools when they moved, students often shifted from one level to the next in the course of the year, so the post-test content did not always correspond to the pre-test level they took at the beginning of the year. In addition, it was possible for a transferring student to miss entire sections of ACMP field-test instruction. Students moving to a new school might join a teacher who was at a different point in ACMP field-testing. Although ACMP was being taught in all Bering Strait schools, each school structured its own field-test schedule. These limitations narrowed the annual pool of students from which random selection for post-testing was possible.

2.9 FINDINGS

2.9.1 *Participation*

Each grant year, not one school missed filing a monthly field-test report, which indicates consistent district-wide ACMP interest and involvement. Lead Teachers were responsible for overseeing and reporting on ACMP field-testing in their schools. At annual culminating workshops, Lead Teachers were able to ascertain how field-test input from teachers in their school and others across the district influenced ACMP curricular resource revision. Each grant year, the same 30 Lead Teachers (two from each school) participated in ACMP annual professional development events. This signifies substantial longevity for the Bering Strait, which has a 30% annual turnover rate (McDiarmid, Larson, & Hill, 2002). Each grant year, Lead Teachers reported mentoring up to five other staff in their schools who were field-testing ACMP material, or a total of up to 150 of the Bering Strait school district's 165 teachers. Identifying the exact teachers who participated in field-testing each year is difficult because teachers within the district swap schools, teaching one year in Brevig Mission and the next year in Savoonga, for example. It is clear, however, that there was extensive, consistent district-wide teacher involvement in ACMP all grant years.

Each grant year, all 165 teachers attended ACMP introductory workshops. These workshops were one of a dozen offerings at the district's mandatory October in-service conferences held annually at district headquarters in Unalakleet, Alaska. Because such a large number of teachers annually signed up to attend ACMP introductory workshops, district administrators capped attendance so that other in-service sessions would have participants. ACMP offered additional evening workshops to ensure all 165 teachers could benefit. Evening workshops also attracted community members. During the first grant year, 100 community members attended; in the second, 650 attended; in the third, 400 attended. Considering that the total population in Unalakleet is 752, this attendance is substantial.

All 15 Bering Strait schools held ACMP Science Camps in their rural villages each grant year. ACMP provided manuals and supplies, but local Science Camps were organized and managed entirely by teachers in the village. An annual average of 250 local residents attended each camp, where students ran experimental stations. A Lead Teacher wrote:

> At ACMP science camps, the kids do the interaction. The instruction was great for them because they were teaching the very lessons they learned in class. They were teaching it to their parents and to community members and to Elders. They came in and sat down with their grandchildren and great grandchildren and were working with them in understanding science concepts. It was very powerful for the teachers and the community to see the interaction of the students and the Elders working on ACMP projects together.

Consistently high numbers of teachers and students interacted with scientist lectures each grant year. Lectures were video-broadcast live from UAF to all 15 Bering Strait schools simultaneously, recorded, and digitized. Teacher comments indicate that virtual scientist interaction contributed to teacher STEM knowledge and student STEM career focus. Teachers also contacted scientists through the online mentor network. Although the number of interactions was not tracked, any question posed to a scientist more than twice was posted on the ACMP "Question-and-Answer" portal. At grant end, the Q&A portal contained 70 questions.

2.9.2 *Participant-reported Impact*

2.9.2.1 *Likert-style Responses*

Table 2.5 shows anonymous STEM workshop survey responses to the ten questions asked of participants each grant year. Responses indicate overwhelming satisfaction with the annual STEM workshop.

Table 2.5
STEM Workshop Survey Results by ACMP Program Year

External Evaluator Survey Question	% of teachers who agreed or strongly agreed		
Program Year (PY) & teacher number*	**PY1 (n=44)**	**PY2 (n=39)**	**PY3 (n=29)**
Workshop was of high quality	100%	100%	100%
Activities were carefully planned	100%	100%	100%
Presentation objectives were clear	100%	100%	97%
Time was used effectively	100%	100%	97%
Presenters were effective instructors	100%	100%	97%
Presenters were well prepared	100%	100%	100%
Presentations held my interest	96%	97%	93%
My questions or concerns were addressed	100%	100%	100%
Presentation was balanced with teachers interaction	96%	100%	90%
Facilities were conducive to learning	97%	97%	93%

* There are more than 30 teachers in years 1 and 2 because the district permitted a limited number of non-Lead teachers (from larger schools) to attend.

2.9.2.2 *Open-ended Responses*

Analyses of open-ended responses support and clarify Likert-style survey findings. Open-ended comments were derived from three sources: Lead Teacher field-test reports (FT), case study interviews (CS), and STEM workshop surveys (SW). All are displayed in Table 2.6. Responses for all years are combined in each database. The field-test report database contains 497 entries, well over the expected amount (6 mos x 3 yrs x 15 schools = 270 reports). In some months, enthusiastic Lead Teachers filed two reports. The database of case study interviews contains 342 paragraphs, and the database of open-ended responses collected from annual STEM workshop surveys totals 128.

As shown in Table 2.6, the primary purpose of 79.23% of the 967 comments in combined databases is to indicate that ACMP involvement improved teachers' K-12 STEM classroom instruction or enhanced the learning outcomes of their students. Of the remaining open-ended comments, 17.05% pertain to teachers receiving or giving mentoring support, and 3.72% contain participant recommendations for revising ACMP professional development training or curricular resources.

Table 2.6

Primary Purpose of ACMP Participant Open-ended Comments by Database

Category Comment Classification, by Database	FT	CS	SW	Total comments	% total
Sample Size (number of entries analyzed)	497	342	128	967	(100)
Improved K-12 STEM classroom instruction	178	190	105	473	48.86%
Enhanced student-learning outcomes	178	116	0	294	30.37%
Discussion about mentoring support	110	32	23	165	17.05%
Suggestions for revison	31	4	0	35	3.72%

2.9.2.2.1 ***Reasons ACMP Improved STEM Instruction***

Table 2.7 shows a breakdown of the 767 entries in the combined databases whose primary purpose is to describe that ACMP improved K-12 STEM classroom instruction or enhanced student learning. Many of these entries were two or more sentences long. For this reason, reviewers gave more than half (56.07%) of these entries two codes. Therefore, the sample size used in Table 2.7 reflects the total number of codes assigned to database entries, rather than the total number of entries.

Table 2.7

Reasons ACMP Improved STEM Instruction or Enhanced Student-learning Outcomes

Summary Codes	FT	CS	SW	Total codes	% total
Sample size (number of codes analyzed)	806	650	128	1368	(100)
Learning place-based STEM content, skills and processes related to Arctic research	357	218	70	645	47.15%
Learning best-practice instructional strategies	254	251	19	524	38.30%
Use of comprehensive ACMP curriculum	85	98	16	199	14.55%

Learning place-based STEM content, skills and processes related to Arctic research is the most frequently given reason for how ACMP involvement improved classroom instruction and student outcomes (see Table 7). Many teachers report that ACMP training in scientific content and processes helped them guide student inquiry and experimentation in their classrooms. Examples (1) and (2) are typical of such entries.

> (1): As for keeping students engaged, ACMP training in scientific content and processes has been wonderful and use of ACMP curricular resources shows results. Students get excited when you say: "Okay we will be doing an ACMP lesson tomorrow." The reply is usually: "Cool, those are fun." More important is that students are learning scientific content and processes and retaining the knowledge. The ACMP hands-on science experiments guide students from the ground up, and I believe this helps to instill in students a sense of ownership.

> (2): Oobleck is a fascinating, hands-on lesson in ACMP that really helps kids with the questioning and hypotheses aspects of scientific experimentation. It creates real fascination as they cannot easily classify the substance and they've never seen/experienced anything like it. They really seemed to feel like scientists and better understood the idea of classification, which is useful in so many areas.

The open-ended comments emphasizing increased use of technology and math skills in the classroom often underscore virtual interaction with scientists during monthly video-conference lectures. Scientist lectures were provided by live video-broadcast to all Bering Strait schools. During these lectures, students interacted with scientists using Skype, a free online communication service. Classes could later view a recorded lecture online from the ACMP website, or on DVD, as is expressed in Example (3). Example (4) describes how ACMP helped teachers incorporate technology skills in other subjects.

> (3): My students like to watch the lecture live, but I have had classes watch the lecture on DVD after the fact. I like to do the DVD version so we can pause the DVD to discuss how the lecture relates to what we have been doing in class. The lectures often are directly related to the standards that we have been studying. Thus, they make a good tie-in and a way for the students to hear it from another source, namely an expert.

> (4) ACMP has some great Internet and technology lessons. There was like a scavenger hunt in one of the lessons, and that gave me the idea to do scavenger hunts on the Internet in other subjects. I hadn't really thought about it before, and it went off really well.

Learning best-practice instructional strategies is the second most popular reason given for why ACMP involvement improved classroom instruction and student outcomes, followed by the ability to use the comprehensive ACMP curriculum to transfer STEM training into classroom instruction (refer to Table 2.7). The ability to use multiple, flexible resources to transfer STEM training to classroom instruction was cited in 14.55% of the entries in combined databases whose primary purpose describes how ACMP improved K-12 STEM classroom instruction or enhanced student learning. Example (5) is typical of entries that explain how ACMP training and curricular resources met the needs of a variety of students.

> (5): ACMP is helpful for instruction because it contains venues for reaching so many different learners. For the students who need kinesthetic hands-on, there are tactile activities. The Climate Change DVD with the Yup'ik words helps me reinforce the Native language students learn in their homes and in Bilingual/Bicultural classes. This is good for the auditory learners. Also, the pictures on the Climate Change DVD, which related directly to this community, are good for visual learners.

Table 2.8 shows a further breakdown of the 524 codes that attribute improved classroom instruction and student learning outcomes to ACMP training in STEM best-practice instructional strategies. The four instructional strategies most frequently mentioned by teachers include: (a) learning to relate STEM instruction to local concerns; (b) learning to incorporate tactile, hands-on activities into K-12 classroom STEM instruction; (c) learning how to achieve cross-curricular integration; and (d) learning how to align STEM instruction to the standards underpinning Alaska standard-based assessment tests.

Table 2.8

Teachers Identify STEM Best-practice Instructional Strategies

Summary Codes	FT	CS	SW	Total codes	% total
Sample Size (number of codes analyzed)	254	251	19	524	(99.99)
(a) Learning to relate STEM instruction to local concerns	131	63	0	194	37.02%
(b) Learning to incorporate tactile activities in K-12 STEM classroom instruction	75	90	4	169	32.25%
(c) Learning to achieve cross-curricular Integration	37	54	6	97	18.51%
(d) Learning to align STEM instruction to standards & GLEs	11	44	9	64	12.21%

(a) Learning to relate STEM instruction to local concerns is the specific instructional strategy cited most frequently in teacher comments. As illustrated in Example (6), teachers stated that learning how to relate STEM instruction in the classroom to local weather and other topics of community interest is an effective way to engage indigenous students in STEM studies. Because Bering Strait schools are located in Alaska Native communities, teacher comments on local relevance also refer to learning how to include Native culture or language in STEM classroom instruction.

> (6): Weather is an important science concept that affects students' lives here, so lots of real-world applications and high student interest in ACMP. We did the weather charting activity, but have not stopped. They enjoy it so much the kids won't let me stop working with ACMP.

(b) Learning to incorporate tactile activities into STEM instruction is the second most frequently cited instructional strategy in teacher comments. Example (7) illustrates how ACMP training helped one teacher integrate hands-on activities into classroom instruction.

> (7): Before I used ACMP, I taught from a book. I was actually dumbing down a college book. My mom sent up my college book and I started doing that sort of thing. And even the general science that I was teaching just went from a book, and I'd say, "read this and do these questions next," because I didn't know any better. That's what I came from. When ACMP came along I was like "Oh! I could, oh I never thought about doing that!" Now I do hands-on things with the kids. The ACMP lessons have science background. So now, it is usually, "we're going to read about this, and then we're going to do something. We'll build something."

(c) Learning to achieve cross-curricular integration is the third most frequently cited instructional strategy learned through ACMP. Example (8) is typical of entries that explain how ACMP training and use of curricular resources facilitated the integration of STEM with other subject areas (such as art, reading, history, language, and music).

> (8): I used the ACMP DVD in my social studies classes to demonstrate changes over time and to illustrate the land bridge. We used the ACMP Climate Change DVD to study Beringia and the geologic timeline. The students loved the interactive science games and it was extremely helpful for them to be able to look at some of the fossils on their desks and then look at the epoch periods on the

DVD to see when they came about. Before they could see it happening on the DVD, the kids didn't get it.

(d) Learning to align STEM instruction to standards is the fourth most frequently cited instructional strategy learned through ACMP. During the grant period, all Bering Strait teachers were required to meet the Alaska standards that underpin annual student standard-based testing. Examples (9) and (10) are typical of entries that explain how ACMP training and use of ACMP curricular resources helped teachers meet these standards.

(9) Teachers are constantly looking for material to cover the standards, so having this ACMP material and training has given teachers a progressive curriculum and standard-aligned resources they can use and that is really a plus for everyone.

(10) Using ACMP resources has really streamlined the learning process for the kids. I didn't have to reach for straws or go out of the lesson to make it a perfect fit to the standards required by the district. Using standard-aligned material also makes it easy to rationalize… to defend it to yourself and to anyone who would say, "Why are you doing this?" It is really easy to say about the ACMP resources, "here's what we would do, here are the objectives, here's what we were learning, here's how it is useful, and here's how it meets our district standards and GLEs."

2.9.3 *Student Outcomes*

Despite challenges in maintaining a consistent pool of students from which random selection was possible, 867 students completed pre- and post-tests over the three-year grant period, as is indicated in Table 2.9. Analysis revealed significant student improvement from pre-test to post-test for each program year and overall. Overall, students' average improvement was 74.9% (n = 867); a significant improvement (Z = 25.201, $P < 0.001$). In the first program year (PY1), students' average improvement was 83.1% (n = 299); a significant improvement (Z = 14.874, $P < 0.001$). In the second program year (PY2), students' average improvement was 68.7% (n = 382); a significant improvement (Z = 11.687, $P < 0.001$). In the third program year (PY3), students' average improvement was 74.3% (n = 186); a significant improvement (Z = 11.687, $P < 0.001$).

Table 2.9
ACMP Project Student Pre/Post Test Wilcoxon Signed-rank Analysis Results

Year	Number of Students	Average Pre-Test	Pre-Test Std. Deviation	Average Post-Test	Post-Test Std. Deviation	Average Improvement	*Z* Score	*P*
PY1	299	13.7%	26.6%	96.8%	14.1%	83.1%	14.874	<0.001
PY2	382	25.2%	32.1%	93.9%	10.7%	68.7%	16.678	<0.001
PY3	186	19.3%	27.7%	93.6%	12.1%	74.3%	11.687	<0.001
Overall	867	20.0%	29.8%	94.9%	12.3%	74.9%	25.201	<0.001

Qualitative data supports pre- and post-test student achievement results. In open-ended comments, teachers attribute improved student performance on End-of-Level (EOL) science tests to teacher involvement in ACMP. All Bering Strait students must pass EOLs in order to progress to a higher level of instruction. "Everyone (teachers and administrators) realizes that students are passing EOLs at an accelerated rate after their teacher has been involved with ACMP," a Lead Teacher stated in a monthly report. Example (11) is an open-ended comment typical of those in the field-test report database describing student achievement.

> (11): Student achievement has increased using ACMP. Although I do not have direct scores, I do have a class that did not get any ACMP lessons last year and one that did. The one that did, they seem to be more natural at problem solving and working towards an answer. The class that has worked with ACMP lessons this year – they have progressed rapidly in the scientific process area, which is where they previously were very weak. In this class, 12 of 14 were Proficient or Advanced on their Level 3 process test this year. Before ACMP, I had no proficient student; no one scored above 40%.

Examples (12) and (13) typify comments in the case-study database describing how ACMP involvement increased student achievement.

> (12) On the "Earth and Universe" End of Level science test, students are asked to pick 3 things that affect the Earth and explain how it applies to their communities. Before ACMP, students could not answer this question. We would feel extremely lucky if even one student picked one thing to write about. And, if they did write, it would be one or two sentences on the topic. This year, directly because of working with ACMP, all my high school students passed their "Earth and Universe" EOL science test. These kids all wrote on three topics related to climate and weather concepts they had learned in ACMP, pretty difficult concepts— such as the effect of the global ocean conveyer belt, ocean levels rising, and thawing permafrost—and they were able to apply these complex thoughts to effects in

> their local communities. And, the kids did not write just one or two sentences on each topic. Each kid wrote a book. It was amazing. ACMP really got them thinking.
>
> (13) Just look at this example of an EOL. Now, that is student engagement. Because of ACMP involvement, when students come to the EOL test they are more comfortable because in ACMP they have done scientific experiments, they have seen the local impact of climate change, and they say, "Oh, this is a piece of cake." All five students who took the EOL this week got the answer about global warming right. One is an 8th grader, another a 9th grader, another a 10th grader, and two seniors. After work on ACMP, they thought the question was "easy." Prior to ACMP, none of them felt that way.

Finally, Example (14) typifies teacher open-ended comments on student achievement found on STEM workshop surveys. This comment refers to students looking forward to studying the ACMP unit on permafrost in the program extension year.

> (14) Two of my classes actually asked if they could work longer on their End of Level tests so that they would be sure to pass. The reason? They told me, "If we pass, then we can go on to the next level and learn about permafrost next year, right?"

2.9.4 *Unanticipated Outcomes*

Both monthly reports and case study interviews described ways in which ACMP was useful to the community. Many teachers said local residents were interested in ACMP technology, as was evident in the Bering Strait village of Shishmaref. The owner of Shishmaref's only grocery store retrieved data from the ACMP school weather station daily and accessed online satellite imagery to examine weather patterns and near real-time sea ice movement influencing the region. A data display in the grocery store helped others in the community determine when local weather and sea ice conditions were favorable for engaging in subsistence hunting activities central to the Native village culture. In the Bering Strait community of Savoonga, local airlines used data from the school weather station to determine when flying out of the village was possible.

Example (15) is typical of comments that detail community use of ACMP resources.

> (15) Information from the school weather station put in by ACMP is actually being used by the airline agents here because the main weather station is not working. So that is making ACMP known throughout the village.

2.10 DISCUSSION

High levels of participation, teacher feedback, survey results, and student learning outcomes indicate that the ACMP "curriculum resource-based professional development" model provides a feasible alternative to the ITEST model for offering STEM professional development in rural areas. Participant-reported impact indicates that each facet of ACMP's year-round mix of in-person, long-distance, online, and local training was beneficial for rural teachers.

2.10.1 *Venues for Professional Development*

2.10.1.1 *In-person Training*

Survey results from each grant year indicate extremely high satisfaction with ACMP's main in-person event for Lead Teachers (the 4-day intensive STEM workshop). All grant years, Lead Teachers gave high ranking to all 10 facets of workshop instruction. Scientific findings and methods related to annual ACMP Arctic research themes were presented during these workshops, along with instruction on implementing newly created curriculum. Teachers' open-ended comments reveal that the workshop enhanced their knowledge of scientific processes and prepared them to incorporate research-affiliated technology into classroom instruction. Teachers also believed the workshop increased their ability to mentor others, and that standard-aligned, comprehensive resources were useful for instructing multiple levels and students with diverse learning styles and abilities. In three grant years, the external evaluator noted only one unfavorable qualitative open-ended comment.

2.10.1.2 *Long-distance Training*

Teacher feedback indicates high teacher satisfaction and support of ACMP field-testing, the main venue used for long-distance training. Throughout the three-year grant, Lead Teachers oversaw field-testing in their rural schools far from ACMP staff in the UAF Geophysical Institute. The persistent emailing of monthly reports from Lead

Teachers in all schools each grant year demonstrates consistent long-distance involvement. The majority (72%) of monthly reports, and the majority (90%) of case study interview entries describe specific reasons why teachers believed ACMP involvement was either improving their ability to provide STEM instruction in local classrooms, or enhancing student-learning outcomes.

2.10.1.3 *Online Training*

Use of technology skills topped the list of the reasons most frequently given for why ACMP involvement increased teacher STEM instructional ability or student learning outcomes. The technology skills theme code was applied to the variety of online ACMP training options available, including student and teacher interaction with Scientist Lectures, multimedia *Climate Change in the Arctic* interactive units and activities, the ACMP website, SNOW portal, access to Alaska satellite imagery, and computer modeling.

2.10.1.4 *Local Training*

Local training depended mainly on Lead Teacher mentorship of other staff in their schools. ACMP Science Camps were the outgrowth of local mentorship. The fact that every Bering Strait school held an ACMP Science Camp each grant year speaks volumes to the success of this mentoring hierarchy. Lead Teachers received supplies from the Geophysical Institute, but the Science Camps were staged entirely by teachers and students in local villages. High attendance at science camps in each village every grant year also indicates high levels of community interest in ACMP.

2.10.2 *Sustainability*

Community interest and high teacher enthusiasm provide a foundation for ACMP sustainability. The need to forfeit the experimental design so more teachers could field-test ACMP, the school district's need to cap teacher attendance at ACMP workshops, and qualitative comments from monthly reports and case study interviews indicate consistently high teacher enthusiasm for ACMP training, and for curricular resources designed to sustain ACMP for future teachers. For example, in the final grant year, the technology workshop focused on data collection from ACMP instruments that would remain in villages after grant end. More than 100 teachers (61% of all) signed up for the workshop, but the district capped attendance at 60.

The three-year grant ended in 2008; however, teachers throughout the Bering Strait continued to use online ACMP lessons and instruments installed near their school for at least one full school year after the grant ended. During this year, one teacher commented,

> As long as I am able, I am going to use ACMP. As long as I am in the Arctic, it absolutely has direct connections to student lives, great connections. If I go further south, yeah I would have to start juggling, but it still is going to have a direct impact on the students. I can make those real connections work. Absolutely, I am going to continue using this.

2.10.3 *Limitations*

To reduce bias, four people twice reviewed the codes for every entry in all three qualitative databases. Even so, assigning codes is a subjective process, and it is possible that other reviewers could have detected other patterns. Because the STEM content portrayed in ACMP mirrors Arctic research skills and techniques, it is probable that qualitative analysis underrated teacher appreciation for the place-based nature of ACMP. Only comments that specifically referred to how ACMP incorporated local knowledge and culture received the "locally relevant" theme code. Arguably, every comment referring to Arctic research-related science and technology could have fallen into this theme category.

Because ACMP was designed to advance 21st century technology and workforce skills and to promote understanding of scientific content and processes related to Arctic research, it is not surprising that most teacher comments address these themes. Because research-based instructional skills for engaging Native students were used as the basis for lesson creation, it follows that teachers referred to ACMP's emphasis on tactile, inquiry-based experimentation, and found diverse resources useful for cross-curricular integration and for meeting multiple student learning styles, abilities, and levels.

2.10.4 *Implications*

The volume of curricular resources created during the program, and the diverse, flexible opportunities for teacher engagement made it difficult to determine which aspect of ACMP was most critical in its success. Two findings stand out, however, and each has implications for policy, practice, and potential future research. First, ACMP kept teachers engaged. ACMP did not battle against attrition, as so many programs do. Teachers were motivated to use ACMP classroom activities, experiments, and inquiry related to authentic scientific research throughout the grant, and to organize annual ACMP Science Camps (largely on their own volition) for local residents. Even after the three-year grant period, teachers continued using ACMP curricular resources.

Second, teachers were enthusiastic about long-distance interaction with scientists. Rural Bering Strait teachers did not need to interact with scientists in person or to attend two-week institutes to benefit from STEM instruction. This may be the most critical finding considering in-person encounters are exclusive—they exist within a defined time frame, are limited to teachers who can be physically present (Falk & Drayton, 1997), are labor intensive for the scientist, and are expensive to conduct (Loucks-Horsley, et. al, 1998).

Based on these results and implications, the PI created Investigations in Cyber-enabled Education (ICE), an NSF Discovery Research K-12 grant (DRL-0918340). ICE will explore the research question: Under what circumstances can cyber-enabled collaboration between scientists and educators enhance teacher ability to provide STEM secondary education? The research goal is to clarify the constructs of a framework for promoting virtual scientist-teacher collaboration that is sustainable, affordable, replicable, and broadly accessible to teachers in all parts of the U.S., including those in rural and disadvantaged areas far from research centers.

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CHAPTER 3

THE SCIENCE TEACHER EDUCATION PROGRAM: UNITING ARCTIC SCIENTISTS AND RURAL ALASKAN TEACHERS[1]

3.1 ABSTRACT

The Science Teacher Education Program (STEP) offered intensive, graduate-level professional development courses focused on a breadth of research currently being conducted in the Arctic. Educators across Alaska participated in STEP. Arctic researchers offered science, technology, engineering, and math (STEM) training in partnership with master teachers who have 20+ years experience teaching STEM in K-12 classrooms. STEP offered in-person summer institutes and follow-on audio-conference field-test courses during the academic year, supplemented by online mentorship networks. STEP courses included in-depth STEM content instruction at the graduate level for teachers of all grade levels. STEP training culminated in the translation of information and data learned from Arctic scientists into standard-aligned lessons designed for immediate use in K-12 classrooms. This study explores the question: "Did STEP offer the content knowledge and skills teachers needed to provide culturally responsive place-based STEM instruction aligned with Alaska grade level expectations?" Data indicate sustained high levels of teacher participation, increased teacher STEM content learning, improved teacher STEM instructional ability, and increased student STEM content learning. Analyses of open-ended comments support and clarify these findings. A grounded theory approach was used to analyze teacher qualitative feedback. Teacher comments were coded and patterns analyzed in three databases. A majority of open-ended comments indicate that STEP involvement improved K-12 STEM classroom instruction. Teachers most frequently attributed improved STEM classroom instruction to learning research-

[1] Bertram, K.B. In Preparation. The Science Teacher Education Program: Uniting Arctic Scientists and Rural Alaskan Teachers. *Science Education.*

based instructional strategies. The five most frequently cited strategies were: (a) learning to align STEM instruction to Alaska science and math standards; (b) learning to guide student-driven inquiry, experimentation, and debate; (c) learning to incorporate hands-on activities into STEM instruction; (d) learning to relate STEM content to local community concerns; and (e) learning to integrate STEM concepts into other subject areas. Teachers also attributed improved K-12 STEM classroom instruction to developing sustainable scientist-teacher mentorship networks. Unanticipated outcomes of this study include scientist-reported benefits from networking with K-12 teachers.

3.2 INTRODUCTION

Preparing cutting edge Arctic climate and other geophysical research for use in K-12 classrooms is the foundation of the Science Teacher Education Program (STEP), funded from 2006-09 by the Mathematics and Science Partnership Grant awarded through the Alaska Department of Education and Early Development, Division of Teaching and Learning Support (Award #PM 07.157.02).

STEP provides a unique framework for creating professional development courses focused on current Arctic research. Under the STEP framework, practicing Arctic researchers partner with master teachers (with 20+ years of classroom experience) to provide science, technology, engineering, and math (STEM) training. To educators across Alaska, STEP offered in-person summer-intensive institutes and follow-on audio-conference field-test courses during the academic year, supplemented by online mentorship networks. STEP graduate-level training culminated in the creation of lessons designed for immediate transfer of place-based STEM content to K-12 classrooms.

The benefits of scientist involvement in STEM education are well documented. Benefits include significantly increased teacher STEM content knowledge, process skills, self-efficacy, and use of technology in the classroom (Bazler, 1993; Miller, Thomson & Roush, 1989; Morrison & Estes, 2007; NRC, 1996; NRC, 2001; NSTA, 2003; NSTA, 2004). The benefits of scientist-teacher interaction are clear. Less clearly defined are mechanisms for translating STEM training from scientists into standard-aligned K-12 classroom instruction. Research indicates that a major pitfall of scientist-led professional development is failure to provide mechanisms for transferring STEM teacher training to classroom instruction (Morrision & Estes, 2007; Radford & Ramsey, 1996; Sherman, Byers & Rapp, 2008). Research also indicates that STEM professional development that provides mechanisms for transferring training into classroom instruction is more effective (Gerhart, Saxe, Seltzer, Schlackman, Ching, Nasir, Fall, Bennett, Rhine & Slone, 1999) and is more likely to impact pedagogy and resulting student achievement than professional development that does not (Huffman, Thomas & Lawrenz, 2003).

STEP's unique framework helps teachers translate information and data learned from Arctic scientists into classroom lessons that meet state science and math standards and K-12 grade level expectations (GLEs). This chapter reports on a pilot study of the impact of STEP involvement on the Alaskan teachers participating in 2006-2009 STEP summer institutes and associated follow-on STEP field-test courses. The pilot study explores the question: Did the STEP professional development framework offer the content knowledge and skills teachers need to provide place-based STEM instruction aligned with Alaska grade level expectations?

3.3 RESEARCH-BASED PROFESSIONAL DEVELOPMENT

Research conducted by the National Research Council (NRC 1996, 2001) and National Science Teacher Association (NSTA, 2003) guided the initiation of STEP professional development in 2005. The University of Alaska Fairbanks (UAF) Geophysical Institute, the Alaska Science Consortium (ASC), education researchers, UAF scientists, and school district administrators collaborated on program design. Although STEP was offered to teachers across Alaska, eight school districts were involved in program design: Alaska Gateway, Delta Greely, Fairbanks North Star Borough, Lower Kuskokwim, Northwest Arctic Borough, Tanana City, Yukon Flats, and Yukon-Koyukuk. All of these districts have been identified by the Alaska Department of Education and Early Development as "high-need educational agencies," or public schools serving low-income students (U.S. Department of Education, 2003-2007).

Essential elements of STEP professional development are listed below.

- To increase teacher place-based STEM content knowledge, STEP courses will focus on current Arctic research;
- To increase teacher communication and collaboration with the Alaska science community, STEP place-based instruction will be delivered by practicing Arctic researchers;
- To increase the potential for student achievement on standardized science and math tests, STEP instruction will be aligned with the Alaska standards and GLEs on which these tests are based;
- To ensure STEP course instruction is aligned with GLEs, scientists will partner with ASC fellows (master teachers with 20 years experience teaching STEM in K-12 classrooms);
- To increase the potential for student engagement in STEM studies, STEP courses will include instruction on research-based best-practice strategies for teaching STEM;
- To ensure the STEP-endorsed best-practice methods are replicable, STEP instructor teams will model research-based best-practice strategies for teaching STEM throughout the course; and
- To ensure Alaska teachers become familiar with resources available in Alaska, STEP instruction will be provided in research labs, in science centers, and at research field sites, in addition to the college classroom.

Geophysics, the study of the physical processes and phenomena of Earth and space, was selected as the research focus for STEP. Living in the most seismically active state in the nation, Alaskans are affected by a range of geophysical events, including earthquakes, volcanic eruptions, and tsunamis. Alaskans also experience phenomena rare to those outside polar latitudes, such as the aurora borealis and extremes in daylight (from more than 20 hours of possible sunlight in summer to—in farther north locations—no direct sunlight in deepest winter). In addition to being locally relevant, these topics are the subject of many of Alaska's science content standards, formed to guide teacher instruction in K-12 classrooms. Earth systems science provides a natural venue for integrating the core STEM topics of science, technology, math, and engineering. For example, climate research—the investigation of complex land, ocean, cryospheric, and atmospheric interactions—requires an understanding of how the major components of Earth's climate system are interconnected. This integrative approach requires the use of instruments engineered to collect and synthesize data from space, suborbital, and ground-based platforms; empirical equations to measure and simulate climate; and technologically advanced computer models to forecast climate changes.

3.4 THE NEED FOR STEP

In 2006, the year STEP was funded, none of its eight partner school districts used science or math curricula aligned to Alaska GLEs, and none provided teacher training in aligning classroom curricula to GLEs. This was problematic because GLEs form the foundation of standardized tests used to gauge student achievement in science, math, and language arts. In addition, superintendents reported that 84% of the science and math teachers in these eight districts lacked the appropriate credentials or training required to teach these subjects. The combination of misaligned curricula and lack of teacher training contributed to a deficiency in teacher science and math content knowledge and to minimal use of best-practice skills for teaching STEM, both of which are shown to result in low student achievement (Valenzuela, Velez & Schiefelbein, 1993). Low student performance is one of the most serious reasons districts can fail to meet federally-mandated annual yearly progress. In 2006, five of these eight districts failed to meet annual yearly progress due to low student performance in math (AKDEED, 2006, 2007, 2008, 2009).

Despite being a critical part of both state and national science standards, recent research indicates that 90% of the nation's K-12 students are taught Earth system science by a teacher lacking appropriate certification (NCES, 2007). Research also reveals that the overall performance of U.S. students in Earth system and physical sciences is lower today than it was in 1996, and the gap between white and minority student achievement in STEM topics is as wide today as it was then (Grigg, Lauko & Brockway, 2006). This is particularly disturbing in Alaska, where indigenous students compose nearly half (46.71%) of the state's overall student population. In rural areas, indigenous students make up more than half (56.33%) of the student population (AKDEED, 2010). Research indicates that less than .001% of the nationwide Alaska Native/American Indian population is pursuing graduate degrees in Earth system sciences (NSF, 2004), and that geoscience—the key discipline for Earth system research—has the lowest minority representation of all STEM fields (Huntoon & Lane, 2005).

3.5 STEP PROFESSIONAL DEVELOPMENT OVERVIEW

STEP provided professional development training designed to increase teacher place-based STEM content knowledge, and to help teachers create K-12 lessons and assessments based on science and math GLEs. Although eight high-need school districts were involved in the creation of the STEP framework, STEP courses were open for enrollment to all in-service Alaska teachers. Preference was given to educators instructing science and math who were not highly qualified to teach these subjects. Professional development was offered through STEP summer institutes and STEP field-test courses held during the following academic year. Teachers completing the summer institute earned three graduate-level science credits, plus three graduate-level education credits (six credits total). Teachers completing the yearlong follow-on STEP field-test course earned three additional graduate-level education credits.

3.5.1 *STEP Summer Institutes*

From 2006-2009, STEP offered six, two-week summer institutes, which focused on current Arctic research aligned with STEM pedagogical instruction. STEP summer institute goals were: (a) to increase teacher knowledge of place-based STEM content; (b) to increase teacher use of STEM best-practice skills; and (c) to increase teacher ability to create lessons and assessments aligned with Alaska science and math GLEs.

Teams of Arctic researchers and ASC fellows collaborated to teach each STEP summer institute. Scientists provided information about research findings, data, and state-of-the-art laboratory and field-study techniques during four-hour blocks each morning of each summer institute. In the afternoon, ASC fellows helped teachers translate scientific information into standard-aligned lessons directly applicable for use in K-12 classrooms.

Several months before each summer institute, scientists were paired with an ASC fellow to ensure scientist presentations were rich in hands-on activities, classroom-friendly technical applications, field trips, and demonstrations that engaged STEP participants and facilitated their understanding of how to align current Arctic research topics to GLEs. During this preparation period, geophysicists helped ASC fellows understand current Arctic research content and process. ASC fellows helped geophysicists incorporate research-based instructional methods into their STEM presentations so they could model their use for STEP participants.

Scientist instructors were recruited from the UAF Geophysical Institute and the International Arctic Research Center. Scientists selected as STEP instructors received one-month's salary, while ASC fellows were paid by contract. Each scientist-ASC fellow team purchased materials to facilitate hands-on activities during STEM presentations. The majority of these materials were supplies teachers could readily obtain to replicate STEP presentation activities in their classrooms.

The Principal Investigator (PI) provided each team with a list of math and science GLEs that needed to serve as the foundation for STEM presentations. This list was compiled by administrators from STEP's eight partner school districts. The list contained GLEs teachers in each district found challenging or had difficulty implementing. Included on this list were all science as inquiry and process GLEs and content or foundation knowledge needed to conduct inquiries. Also included were earth science, physical science, and math GLEs that addressed models and experiments, energy transfer and form changes. A different Arctic research topic was chosen each year as the platform for instruction aligned with selected GLEs. Space physics, the focus of the first program year (2006), addressed GLEs related to atoms, chemical/nuclear reactions, electricity/magnetism and the planetary solar system.

Climate research was the focus of the second program year (2007), which coincided with the International Polar Year, when scientists from around the world converged in Alaska to study the Arctic climate. Instruction in the third program year (2008) focused on general Earth science (volcanoes, earthquakes, tsunamis, land, etc). The Alaska Department of Education and Early Development provided additional funding so STEP could extend this focus into a special (2009) summer institute on research being conducted on the concurrent eruption of Alaska's Mt. Redoubt Volcano.

Scientists provided instruction in research centers and at field-based instrument sites aligned with the annual STEP summer institute research focus, as shown in Table 3.1.

Table 3.1
Research Sites Visited by STEP Summer Institute Participants

Year and STEM Focus	Research Sites Visited
Year 1: Space Physics	Poker Flat Research Range and field-based instrument sites: Science Observation Center; Lidar Observatory; Alaska Polar Ground Station; Honeywell DataLynx satellite tracking facility; launch pads; payload assembly rooms; 80m meteorological tower; launch operations; blockhouse
Year 2: Climate Change	Alaska Satellite Facility; Alaska Climate Research Center; Arctic Facility for Atmospheric Remote Sensing; Geophysical Institute Ice Lab; National Weather Service; International Arctic Research Center; Arctic Region Supercomputing Center; Institute of Arctic Biology Greenhouse
Years 3-4: Earth Science	Natural Sciences Facility and Geophysical Institute: Geochronology Lab; Paleomagnetic Lab; Alaska Volcano Observatory; Alaska Earthquake Information Center; Tsunami Warning Environmental Observatory for Alaska; GeoData Center

Because research indicates that teachers of all grade levels benefit from in-depth discussion of research topics (Duschl, Schweingruber & Shouse, 2006; Vasquez, 2008), scientist instruction was offered at the graduate level, not at an introductory level. STEP instruction included computational math and training in research technology applicable in the classroom, such as remote sensing imaging and computer modeling. Training in information technology applications was aligned with student expectations by grade level, as indicated on the following page by Table 3.2.

Table 3.2
Progression of Information Technology Applications in STEP Summer Institutes

Grade	Information Technology and Supporting Software
K-4	Excel for entry-level spreadsheet use (data entry, data comparison); basic office hardware and software review; Word for writing reports on results; online calculators for simple data computation
5-8	Excel spreadsheets to organize, manipulate, display data (charts, bar/line graphs, maps); email; multimedia model interface; Internet searches to access data; PowerPoint for Science Fair presentations
9-12	Excel to analyze, manipulate data; GPS/GIS overview; computer modeling

ASC fellows used a backward-design approach that involved designing assessment rubrics and tools aligned to selected GLEs. Lessons were written only after multiple assessment and scoring tools were in place. To guide the creation of K-12 classroom lessons based on Arctic research, ASC fellows used the Learning Cycle Model (LCM) featured on the Alaska Department of Education and Early Development website (AKDEED, n.d.). This step-by-step lesson-creation process followed the stages outlined in the LCM (shown in Table 3.3).

Table 3.3
ASC Learning Cycle Model Instructional Stages

LCM stage	Description
Gear-up	Activities, demonstrations, or actions that engage students in a topic, and help teachers assess students' pre-lesson knowledge and preconceptions.
Explore	Hands-on, minds-on activities that help students discover new explanations for events or concepts.
Generalize	Questioning strategies that help students verbalize new discoveries & identify questions to be tested.
Experiment	Students design and conduct their own experiments (a fair test).
Interpret	Students display and interpret collected data.
Apply	Students apply newly learned concepts in different contexts.

A backward-design approach for creating assessment tools aligned with state GLEs, and LCM stages for lesson creation set the groundwork for ASC instruction in research-based instructional strategies for teaching STEM in K-12 classrooms. ASC fellows provided instruction on these strategies, and then asked teachers to incorporate one or more of the strategies into each lesson created during the STEP summer institute. Teachers practiced these strategies while presenting lessons created during summer institutes and while field-testing STEP-created lessons in their classrooms during the following academic year. The instructional strategies targeted in STEP summer institutes are described in Table 3.4.

Table 3.4
Best-practice Instructional Strategies Taught during STEP Summer Institutes

Best Practice Strategy	Description of instructional skill
Standard Alignment	Instruction is aligned with state standards and GLEs for science and math
Student-driven Inquiry	Instruction fosters student-driven inquiry, investigation, debate, and problem solving
STEM Integration	Instruction provides a broad view of how research requires STEM integration
21st Century Learning	Instruction on global awareness, civic responsibility, and use of 21st century learning skills
Place-based	Instruction focuses on STEM research, concepts and skills relevant to Alaskan residents
Tactile Experience	Instruction in which students actively participate and perform tactile (hands-on) exercises
Reflective Thinking	Instruction provides opportunities for student use of logical deduction, reflective thinking
Cooperative Learning	Instruction facilitates teamwork (interdependence with individual accountability)

The LCM outlines a teaching process that encourages student-driven inquiry, investigation, and application, all of which are shown to increase student engagement in STEM instruction (Borich, 2007). STEM integration and 21st century learning skills that deal with global awareness and civic responsibility are research-based best-practice strategies naturally synchronous with STEP summer institute Arctic research foci. Geophysical research on space physics, climate change, and earth processes require the integration of science content knowledge, technological skills, engineering application, and mathematical analysis. Research themes that integrate STEM subjects have been shown to improve student technical literacy, ability to apply classroom learning to the world, and achievement on math and science standardized tests (Meichtry & Smith, 2007; Pertzborn & Limaye, 2000). Educational studies also underscore the importance of increasing school emphasis in topics (such as global climate and seismology) that facilitate global awareness and civic responsibility and that foster critical thinking, international collaboration, and use of sophisticated technology (Partnership for 21st Century Skills [P21], 2004).

Focusing on place-based instruction opens a window for interactive real-world learning in school. Focusing on topics relevant to life in Alaska builds a bridge from the school to the broader local and statewide community. Both of these strategies have been shown to increase indigenous student engagement in STEM studies (Adams & Lipka, 2007; Klump & McNeir, 2005). School instruction that emphasizes physical engagement and use of tactile (hands-on) activities also is an effective strategy for increasing indigenous student engagement in STEM learning (Barta, 1999; Laursen, Liston, Thiry, & Graf, 2007), as is inclusion of strategies reflective of life in rural Native Alaskan communities (Barnhardt & Kawagley, 2005; Klump & McNeir, 2005; Starnes, 2006). Many of the instructional strategies indigenous Elders use to relay information to others in rural Native Alaska communities are synchronous with 21st century skills used to conduct Arctic research (P21, 2004). When replicated in the classroom, these strategies can be particularly engaging for students. One of the most effective strategies is involving students in projects that require cooperative learning and teamwork (interdependence with individual accountability) and that help students engage in problem solving, decision making, and critical thinking (Borich, 2007).

3.5.2 *STEP Field-test Courses*

STEP field-test courses were offered during the academic years following the 2006, 2007, and 2008 STEP summer institutes. Course goals were (a) to reinforce pedagogical training, science content knowledge, and best-practice strategies learned at the STEP summer institute; (b) to field-test lessons created during STEP summer institutes in K-12 classrooms; and (c) to engage in peer review of lessons and best-practice instruction strategies used during classroom field-testing.

ASC fellows instructed follow-on STEP field-test courses, which were conducted by audio-conference so they could be attended by teachers across Alaska. During weekly meetings, teachers shared field-test strategies and best-practice skills that were working (and those that were not) while implementing STEP lessons in their classrooms. Peer collaboration decreases isolation, and results in increased use of effective best-practice skills in the classroom (Lewis, Perry & Hurd, 2004). Systematic inquiry by practitioners also is linked to increased teacher STEM content knowledge (Feldman, 1996; Madsen & Gallagher, 1992; Mcintyre, 2003; Spiegel, 1995) and improved classroom instruction (Calhoun, 2002). Throughout the course, teachers were encouraged to engage in online peer mentoring, and to request scientist and ASC fellow mentoring. STEP also provided funding to send scientists and ASC fellows to classrooms for mentoring sessions.

3.5.3 *STEP Sustainability Workshop*

During the final grant year, STEP received additional funding to hold a 2009 sustainability workshop, which was attended by 12 teachers who had participated in at least two previous summer institutes and follow-on STEP field-test courses. These teachers originally had enrolled in the 2009 STEP summer institute, but because the course was full, they agreed instead to collaborate with UAF School of Education professors and the PI to create projects to ensure STEP's long-term sustainability. The two-week sustainability workshop was held at the same time as the 2009 STEP summer institute, but in a different location on the UAF campus.

Workshop collaboration resulted in the creation of the following products that remain broadly accessible to teachers throughout Alaska:

- an online STEP professional development course, which is permanently offered by the UAF School of Education;
- the STEP website, which is permanently maintained by the UAF Geophysical Institute; and
- the online STEP lesson bank, which hosts a database of 500 standard-aligned STEM lessons (accessible from the STEP website).

The online STEP professional development course "Dynamic Earth Processes," is the first online STEM course to be permanently offered by the UAF School of Education. Designed for in-service and pre-service teachers, course content covers 2006, 2007, and

2008 STEP summer institute research themes. The course includes instruction on STEM teaching methodology and on aligning Earth science content instruction with Alaska standards and GLEs.

The STEP website (http://www.stepalaska.com/) provides information about all STEP courses and course instructors. Scientist email addresses and biographical information are available to facilitate ongoing online communication and collaboration among teachers and scientists. Detailed course syllabi for each year and daily session outlines are available for educators wishing to replicate course activities. During the STEP grant, a draft form of the website was published. This draft site hosted a sample of standard-aligned K-12 lessons created by STEP participants. In preparation for the sustainability workshop, and as part of formative testing, a random sample of website visitors were prompted to complete a short online survey from March-May 2009. Data from this survey were used during the June 2009 sustainability workshop to measure the potential impact of the STEP website and to improve its function before online publication in the fall of 2009. In total, 48 website visitors completed the survey. All but 2 of the respondents identified themselves as K-12 teachers. Of the 46 educator respondents, 81% reported having five or more years of teaching experience. More than half (24 educators) stated they had visited the STEP website more than once. Many had visited the STEP website 10 or more times. Of the 24 educators who had visited the website previously, 17 indicated they were visiting the website to download lesson plans from the STEP lesson bank for use in K-12 classrooms. All of these teachers said they would use these STEP lessons in their classrooms again.

The STEP lesson database contains 500 lessons aligned to Alaska standards and GLEs. Accessible from the STEP website, the database is searchable by GLE, subject area, and keywords. Teachers attending the 2009 sustainability workshop reviewed all lessons and aligned them with four key Alaska science content standard themes: climate systems, earth systems, physical science, and space exploration. Sustainability workshop participants led a session on STEP for teachers from across Alaska attending the State of Alaska Math and Science Conference in October 2009. At the workshop, STEP participants disseminated information about the STEP online course, STEP website, and STEP lesson database.

3.6 PROGRAM OVERVIEW

STEP's unique framework was used to create graduate-level professional development courses that offered in-person summer-intensive training for teachers across Alaska, supplemented by audio-conference field-test courses and online mentorship networks. Described below are findings from a pilot study of the impact of STEP involvement on participating Alaskan teachers. Data helped determine if the STEP professional development framework provided the content knowledge and skills teachers needed to provide place-based STEM instruction aligned with Alaska grade level expectations.

3.7 STEP RESEARCH METHODOLOGY

3.7.1 *Sample*

Teacher attendance in all STEP courses was calculated directly. The total number of teachers participating in STEP courses falls into three categories: (a) teachers participating in 2006, 2007, 2008, and 2009 STEP summer institutes; (b) teachers participating in STEP field-test courses during the academic years following the 2006, 2007, and 2008 STEP summer institutes; and (c) teachers participating in the 2009 STEP sustainability workshop. Some teacher demographic information was collected by survey on teachers at the beginning of each summer institute.

3.7.2 *Data Collection and Analysis*

To determine if the STEP professional development framework provided the content knowledge and skills teachers needed to offer place-based STEM instruction aligned with Alaska grade level expectations, data were collected for four outcomes.

The four outcomes are: teacher participation rates; participant-reported impact of the program; participant outcomes measured by STEM assessments and by course grades;

and student outcomes measured in STEM assessments. Each of these sources is described below.

3.7.2.1 *Participation Rates*

Participation rates were calculated directly for each STEP summer institute and each follow-on STEP field-test course. One summer institute occurred in 2006. Two summer institutes were held in 2007 and in 2008. Follow-on field-test courses were held during the academic years following the 2006, 2007, and 2008 summer institutes. Extension funding made it possible to offer one additional "special theme" summer institute in 2009, and one sustainability workshop for teachers who had attended two or more previous STEP summer institutes.

3.7.2.2 *Participant-reported Impact*

Participant-reported impact of STEP involvement on teacher practice was measured in two ways: through online surveys and in-depth case study interviews. Online surveys were administered by the external evaluator at the conclusion of each STEP summer institute and at the end of each follow-on STEP field-test course. Teachers were told their answers would be anonymous. Summer institute online surveys were administered on separate laptop computers (one per participant) in a private room in the International Arctic Research Center.

Teachers did not meet in person during the audio-conference, follow-on STEP field-test course; consequently, the survey administered at course conclusion was conducted online at offsite locations. Online surveys prompted teachers to provide feedback about their satisfaction with each course and to report on the extent to which STEP helped them learn STEM content and effective STEM instruction strategies.

Online surveys contained questions that asked teachers to rank a variety of statements using a 1-5 Likert scale (ranging from strongly disagree to strongly agree, or from poor to excellent). Descriptive statistics were used to analyze feedback to Likert-scale questions on online surveys. Online surveys also provided the opportunity for participants to respond to open-ended questions. Written responses of any length were permitted. The following questions at the end of each STEP summer institute survey prompted open-ended responses from participants: What was the most beneficial part of the institute? How could the institute have been more useful to you? Will you comment on the STEM content presented at the institute? Will you comment on the teaching strategies presented at the institute? Did the institute further your professional goals? Will you comment on field trips to research facilities and labs? The following open-ended questions were asked at the end of each STEP field-test course survey: Have you benefited from the follow-on STEP field-test course? Do you have any suggestions for changes or improvements to the course? Will you comment on field-testing STEP lessons in your classroom during the course? Did the science and pedagogical training you received during the STEP summer institute help you implement science lessons you field-tested in your classroom? Did you learn any new skills from participating in the STEP field-test course?

Case study interviews were conducted with the 12 teachers involved in the STEP sustainability workshop during the final program year (2009). The external evaluator used a semi-structured interview protocol to prompt teachers to broadly describe how STEP had influenced their classroom instruction.

To prompt open-ended responses, the evaluator asked the following questions: Consider your instruction prior to and after STEP involvement. Has STEP involvement had an impact on students in your class? Has STEP involvement caused you to adopt new or bolster existing teaching methods or practices? Has interacting with practicing scientists during STEP courses impacted your classroom STEM instruction? Has participation in STEP summer institute labs and field experiences impacted your classroom STEM instruction? Has participation in STEP affected your ability to align science lessons and assessment with Alaska science and math content standards and GLEs? Will you comment on earning professional development credits through STEP? Is there anything else you would like to share about your overall STEP experience? Would you recommend STEP to a colleague? Each interview was taped and transcribed verbatim.

Three separate databases were created for open-ended comments, each associated with the workshop during which they were collected. The summer institute database contains open-ended comments compiled from annually administered surveys at the conclusion of STEP summer institutes. Likewise, the field-test course database contains open-ended comments compiled from annually administered surveys at the conclusion of STEP field-test courses. Finally, the sustainability workshop database contains open-ended comments transcribed from in-depth interviews conducted during the final program year by the external evaluator with STEP sustainability workshop participants.

A grounded theory approach was used to analyze all open-ended comments (written into online surveys and transcribed from case-study interviews). This approach involves analyzing qualitative data to search for emerging patterns. Rather than fit data into pre-determined themes, the goal of this approach is to derive themes from the data itself. Every sentence of each open-ended response written on surveys and each open-ended response transcribed from case study interviews was treated as a separate entry and placed into one of three databases defined by the target population. To reduce bias in data analysis, four people reviewed data entries: the STEP principal investigator (PI), a graduate student, and two teachers. One reviewing teacher had 20 years of experience instructing STEM in elementary grades K-6; the other had 23 years of experience instructing STEM in secondary grades 7-12. To determine the primary reason teachers wrote each open-ended comment, all four reviewers independently analyzed all data entries in each database. Reviewers assigned a code to each entry that summarized what they believed to be the primary purpose of the open-ended comment. All four reviewers compared the primary-purpose codes assigned to each data entry. Discussion ensued until consensus was reached for each open-ended comment. Reviewers determined that open-ended comments fell into three main categories. They were written: (a) to explain that STEP involvement had improved teachers' K-12 STEM classroom instruction; (b) to offer accolades for the STEP course; or (c) to offer suggestions for STEP course revision. These three main primary-purpose categories are summarized in Table 3.5. When consensus was not reached, the entry was not categorized.

Table 3.5
Description of Primary-purpose Categories Assigned to Teacher Open-ended Comments

Primary-purpose Code	Brief Description of the Primary-purpose Code
Improved STEM Instruction	The primary reason the comment was written is to explain how or why STEP involvement resulted in improved K-12 STEM classroom instruction
Accolades	The primary reason the comment was written is to describe what the teacher liked about the STEP course content, structure, administration, or facilities.
Revision Suggestions	The primary reason the comment was written is to offer suggestions for STEP course revision.

Because reviewers were searching for reasons teachers believed STEP involvement improved their STEM instruction, they further analyzed data in the "Improved STEM Instruction" primary-purpose category. Five main reasons emerged. Teachers attributed improved STEM instruction to:

(a) Learning best-practice strategies (affiliated with the LCM) that have increased student or teacher interest in STEM areas;

(b) Developing sustainable mentorship networks with scientists, peer teachers, and ASC Fellows;

(c) Learning current Arctic (place-based) STEM content and research processes;

(d) Increased self-efficacy (self-confidence) in providing STEM instruction in the classroom and/or in working toward STEM-related professional goals; and

(e) Discovering Alaska-specific (place-based) resources to augment STEM classroom instruction.

Again, the four reviewers discussed the categorization of all entries until consensus was reached. When consensus was not reached, the comment was not categorized.

(a) Learning STEM best-practice instructional strategies was so often identified in teacher comments as a reason for improved STEM instruction that the PI and graduate student re-examined all such comments. First, comments were divided into two categories: "specific" (those that identify specific best-practice strategies by name) and "general" (those that remark in general terms that learning best-practice methods had improved STEM instruction or increased student achievement). A re-examination of all comments in the "specific" category revealed that most teachers often identify five best-practice skills as the reasons for improved instructional ability as a result of STEP involvement. These skills included: learning to align STEM instruction and student assessment to Alaska standards and GLEs; learning to guide student-driven inquiry, experimentation, and debate; learning to incorporate hands-on STEM activities into classroom instruction; learning to tie STEM instruction to the concerns of the schools' neighboring community and to local events; and learning to integrate STEM into other subjects, such as social studies, reading, and language arts (cross-curricular integration). After the PI and graduate student had reached agreement on the coding of all entries in the "specific" category, the list was reviewed by the two master teachers. Finally, the four reviewers discussed the categorization of all entries until consensus was reached. When consensus was not reached, the comment was not categorized.

(b) Developing sustainable mentorship networks was so frequently mentioned in teacher comments about improved STEM instruction that the PI and graduate student re-examined all such comments to glean more information. The same re-examination process by all four reviewers confirmed that three STEM-supported mentorship outlets were named most frequently. These were: networking with scientists, networking with peers, and networking with ASC fellows.

(c) The value of learning current Arctic (place-based) STEM content and research processes was also frequently mentioned in teacher open-ended comments. These comments focused on the importance of showing Alaskan students real-world applications of Arctic STEM research, and discussed teacher enthusiasm for learning and incorporating Arctic STEM content and processes into classroom instruction. Comments in this category were not divided into subcategories.

(d) Many teachers attributed increased self-efficacy (self-confidence) in providing STEM instruction in the classroom and/or in working toward STEM-related professional goals to STEP involvement. The same four-reviewer process was used to re-examine teacher comments of this theme to glean additional information. As a result, these comments were divided into three categories. The first category includes comments that refer to increased teacher self-efficacy in STEM instruction and increased confidence in obtaining professional goals, such as becoming involved in national, state-, district-, and school-wide STEM-related committees. The second category includes comments explaining how UAF credits earned through STEP helped teachers reach personal goals, such as gaining pay increases, achieving recertification, working toward highly qualified status, and completing STEM degrees. The third category contains comments recommending STEP to peer teachers.

(e) Analysis of open-ended comments revealed that teachers value discovering place-based resources for use in STEM classroom instruction. These comments discuss how STEP helped teachers find virtual and physical resources to augment STEM classroom instruction. Comments in this category were not divided in subcategories.

3.7.2.3 *Participant Outcomes*

Pre- and post-test comparison of participant STEM content knowledge was made prior to, and after attending STEP summer institutes in 2007, 2008, and 2009. Because the STEM research focus was different for each institute, scientists designed new pre- and post-tests each year. Before every summer institute, each scientist instructor summarized three main concepts they wanted teachers to learn. With ASC fellow input, scientists helped design pre- and post-tests based on these three main concepts to gauge participant STEM content knowledge before and after STEP involvement. When concepts were taught by pairs of instructors, each scientist in the pair had the option of devising three conceptual questions, or of working together to devise three questions for the pair (a total of 6 pre-/post-test questions or 3 pre-/post-test questions, respectively).

The 2007 pre- and post-tests (which focused on Arctic climate research) contained 18 questions in the following content areas: atmospheric effects on climate change (3 questions); climate change and its impact on sea ice (3 questions); climate change and its impact on Arctic hydrology and Alaska's coastal areas (6 questions); and climate change and its impact on land-based cryospheric features (6 questions). The 2008 pre- and post-tests (which focused on current Arctic earth science research) contained questions in the following content areas: the paleoenvironment and paleoecology of Denali National Park

(3 questions); the dynamics of permafrost thaw (3 questions); landscape, plant composition, oil and gas (6 questions); soil physics and the rock cycle (6 questions); studying and monitoring volcanoes (3 questions); and remote sensing science and volcanic eruptions (6 questions).

The 2009 pre- and post-tests (which focused on research occurring as a result of the concurrent eruption of Alaska's Mt. Redoubt Volcano) contained 18 questions in the following content areas: deciphering the eruption history of Alaskan volcanoes (3 questions); Mt. Redoubt Volcano geophysics (3 questions); atmospheric aerosols (3 questions); tracking surface deformation (3 questions); remote-sensing archaeology (3 questions); and remote sensing and solar system volcanoes (3 questions).

After pre-/post-test questions were developed, scientists provided input to ASC fellows so they could create rubrics to accurately reflect teacher STEM content understanding. Each scientist used the rubric scales to assess answers on participant pre-tests and post-tests related to the content he or she had taught.

STEP's external evaluator used the Wilcoxon signed-rank test to determine if statistically significant differences occurred between STEP pre- and post-test scores. The Wilcoxon signed-rank test is a non-parametric test for the significance of the difference between distributions of two related samples involving repeated measures or matched pairs. Like the t-test for correlated samples, the Wilcoxon signed-rank test applies to two-sample designs involving repeated measures, matched pairs, or "before" and "after" measures. The evaluator used the Wilcoxon signed-rank test, rather than a t-test, because the STEP pre- and post-test student data did not fit a normal distribution. An α-level of 0.01 was used to assess significance, meaning that the chances of obtaining a significant result when the underlying distributions were not significantly different is less than 1%.

Beginning in 2007, each summer institute participant completing the course received two letter grades and six UAF graduate-level credits. Scientist instructors awarded the letter grade associated with three science credits, and ASC fellows awarded the letter grade associated with three education credits. Scientists used rubrics that assigned scores to five levels (A, B, C, D, F) for each STEM topic presented during each STEP summer institute. Levels ranged from "demonstration of no knowledge of the STEM topic" to "demonstration of advanced knowledge of the STEM topic." Scientists awarded letter grades for participants who demonstrated increases in individual STEM knowledge (evident from pre- and post-test comparison), and who showed an ability to accurately portray STEM concepts in K-12 lessons created as STEP final projects. Each scientist reviewed only classroom lessons based on topics within his or her area of expertise.

Letter grades given by ASC fellows reflected teacher ability to create K-12 lessons aligned with specific science and math GLEs, and to accurately incorporate best-practice instruction and assessment strategies taught during STEP. Letter grades awarded by ASC fellows were based on final projects only.

3.7.2.4 *Student Outcomes*

Because 2006 and 2007 summer institute participants indicated by survey that they believed the ideas and skills learned during the STEP course resulted in improved student achievement, final STEP field-test course participants tested this theory. Teachers taking the final field-test course were instructed to randomly select 10 percent of their students to take pre-and post-tests created by ASC fellows in collaboration with scientists and the PI. These tests gauged student knowledge of Earth science content and processes. Tests were administered prior to, and after teachers field-tested STEP-created lessons in their K-12 classrooms.

The pre-tests and post-tests followed strands of learning evident in GLEs for primary (students in grades K-3), elementary (students in grades 4-6) and secondary students (grades 7-12). This division was assigned because science GLEs exist for grades 3-11, and math GLEs exist for grades K-10. Students at all levels were required to demonstrate their understanding of Earth's geochemical cycles and of the forces that shape the Earth. Students also were asked to demonstrate their understanding of the characteristics, relationships, and effects of motions and forces. STEP's external evaluator used the Wilcoxon signed-rank test to analyze pre- and post-test results because data did not fit a normal distribution.

3.8 FINDINGS

3.8.1 *Participation*

A total of 175 teachers from 33 Alaska school districts attended STEP summer institutes; a total of 85 teachers attended STEP follow-on courses; and a total of 12 teachers participated in the 2009 sustainability workshop.

3.8.1.1 *STEP Summer Institutes*

Attendance at STEP summer institutes exceeded expectations. The first STEP summer institute was held in 2006, three weeks after funding was received. Because recruitment for this institute began a month after the school year ended, the hope was to recruit 15 teachers; but 23 teachers attended. To ensure appropriate instructor-teacher ratios, and to limit the size of groups visiting research centers, summer institute participation was capped at 30 for successive years.

The waiting lists for the 2007 and 2008 summer institutes were so long, the PI decided to hold two back-to-back institutes to accommodate 60 teachers each summer. In 2009, new funding was made available to hold one extra "special focus" STEP summer institute on research being conducted on the Mt. Redoubt volcanic eruption occurring that summer. Funding was available for one session only, but the waiting list was so long, scientists and ASC Fellows agreed to accommodate 41 teachers in the session.

Table 3.6 provides a breakdown of teacher attendance at STEP summer institutes by school district and year.

Table 3.6

Number of STEP Summer Institute Participants by District and Program Year

School District	2006 Total	2007 Total	2008 Total	2009 Total	Total
Alaska Gateway	2	2	1	1	6
Aleutians East Borough	2				2
Aleutian Region	1				1
Anchorage	2	4	4	8	18
Bering Strait	1	2	3	2	8
Chugach	1	1			2
Delta/Greely		2	4	1	7
Denali Borough		2			2
Dillingham City		1			1
Diocese of Juneau				1	1
Fairbanks North Star Borough	2	21	15	8	46
Family Centered Services of Alaska		1			1
Galena IDEA			1		1
Hydaburg City	1		2		3
Iditarod Area			2	1	3
Juneau			1	1	2
Kenai Peninsula Borough	1		1	1	3
Ketchikan Gateway Borough			3		3
Kodiak Island Borough	1	1	3		5
Kuspuk		1	2	1	4
Lake and Peninsula Borough			3		3
Lower Kuskokwim	1	4	2	1	8
Lower Yukon School	1			2	3
Matanuska-Susitna Borough	2	2	2	3	9
Monroe Catholic Schools (Fairbanks)				1	1
Nome City Schools				1	1
Northwest Arctic Borough	1	2	1		4
Skagway	1			4	5
Southwest Region		1	2	3	6
Tanana City	1				1
Yukon Flats	1	5	2		8
Yukon-Koyukuk	1	1	1	1	4
Yupiit		1			1
Unknown		2			2
Total	23	56*	55*	41	175

*In 2007 and 2008, the courses were filled to capacity, but a few teachers dropped out in the first three days (due to illness or inclement weather, which resulted in an inability to fly to Fairbanks from a rural area).

All STEP summer institute participants instructed STEM in elementary or secondary schools. Demographic information collected by the external evaluator at the start of each STEP institute (displayed in Table 3.7) indicates that, on average, 67% of the participants had more than five years of classroom experience (teaching any subject), but only 35% of the participants were highly qualified to teach in a STEM content area.

Table 3.7
STEP Summer Institute Participant Demographics

Participant responses	2006 (n=23)	2007 (n=56)	2008 (n=55)	2009 (n=41)	Ave.
Teaching for 0 – 5 years	48%	38%	24%	20%	33%
Teaching for 6 – 10 years	19%	31%	35%	40%	31%
Teaching for 11 – 20 years	29%	15%	38%	30%	28%
Teaching for 21+ years	5%	13%	2%	10%	8%
Highly Qualified in STEM	48%	36%	25%	33%	35%

3.8.1.2 *STEP Field-test Courses*

Due to the short time period between receipt of grant funding and the start of the 2006 institute, some districts could not send all of their science and math teachers to the first summer institute. For this reason, superintendents asked that additional teachers in their districts be able to enroll in the first follow-on STEP field-test course. This request was granted, and in the first year, 10 more teachers attended the follow-on course than the summer institute.

Attendance during the remaining follow-on STEP field-test courses matched expectations: the PI anticipated that half of the teachers attending summer sessions would attend field-test courses the following academic year. Because grant funding ended after the 2009 STEP summer institute, a follow-on STEP field-test course was not offered that year. Table 3.8 provides a breakdown of teacher attendance at follow-on STEP field-test courses by district and by year.

Table 3.8
Number of STEP Field-test Course Participants by District and Year

School District	2006 Total	2007 Total	2008 Total	Total
Alaska Gateway	2	1	1	4
Aleutians East Borough	2			2
Aleutian Region	1			1
Anchorage	2	1		3
Bering Strait	3		2	5
Chugach	1	1		2
Delta/Greely		1	2	3
Denali Borough		1		1
Dillingham City		1		1
Fairbanks North Star Borough	2	13	2	17
Hydaburg City	1			1
Iditarod Area			1	1
Juneau			1	1
Ketchikan Gateway Borough			2	2
Kodiak Island Borough	3	1	3	7
Kuspuk		1	2	3
Lower Kuskokwim	1	3	1	5
Lower Yukon	1			1
Matanuska-Susitna Borough	2	2	3	7
Northwest Arctic Borough	4			4
Skagway	4			4
Southwest Region		1	3	4
Tanana City	1			1
Yukon Flats	1		1	2
Yukon-Koyukuk	1			1
Yupiit		1		1
Unknown	1			1
Total Participants	**33**	**28**	**24**	**85**

3.8.1.3 *STEP Sustainability Workshop*

To further accommodate the overflow of teacher interest in 2009, the PI collaborated with the UAF Education Department to hold a STEP sustainability workshop, open to 12 teachers who had attended at least two summer institutes. Projects designed to sustain STEP instruction were completed on schedule. The first online course created to sustain instruction of STEP concepts and best-practice methods for teaching STEM was offered in the fall of 2010.

This was the first STEM-content course offered by UAF designed for (and by) teachers; the first UAF course to focus on STEM content aligned to Alaska state science and math content standards; and the first online STEM course offered by the UAF

Education Department. Although no advertisement or recruitment campaign was instituted, the number of teachers signed up for the course exceeded course capacity.

The STEP website continues to support opportunities for ongoing communication and collaboration with Arctic scientists among teachers around Alaska. The STEP database of 500 standard-aligned STEM lessons based on Arctic research themes and categorized by Alaska science content standards remains accessible to teachers throughout the state.

3.8.2 *Participant-reported Impact*

3.8.2.1 *Likert-scale Responses*

Findings from Likert scale responses on STEP summer institute and follow-on STEP field-test course surveys are addressed in this section. Findings from analysis of responses to open-ended questions at the end of each online survey are discussed in the following section. At the conclusion of all but the first (2006) STEP summer institute, teachers were asked to rate their overall experience in the course. As indicated in Table 3.9, the vast majority (96.36% to 100%) of participants ranked the course as good or excellent each year.

Table 3.9

Participant Overall Ranking of the STEP Summer Institute by Year

Year	Sample size	Percentage of participants giving the course a rank of good or excellent
2007	n=56	98.21%
2008	n=55	96.36%
2009	n=41	100%

At the conclusion of all STEP summer institutes, teachers were asked to rank instruction provided by scientist presenters, and instruction provided by ASC Fellows. As shown in Table 3.10, each year, the majority of teachers agreed or strongly agreed that both scientists and the ASC fellows were effective instructors, were well prepared, and conducted activities that were carefully planned. The majority also believed that scientists and ASC fellows used their presentation time effectively.

Table 3.10
2006-2009 Participant Responses to STEP Summer Institute Survey Questions

Survey statements ranked by participants	% agree or strongly agree			
Year and (Sample Size)	2006 (n=23)	2007 (n=56)	2008 (n=55)	2009 (n=41)
STEP scientists were effective instructors	95%	94%	100%	100%
ASC fellows were effective instructors	100%	87%	96%	100%
Scientists were well prepared	100%	96%	98%	100%
ASC fellows were well prepared	100%	78%	96%	96%
Scientist-guided activities were carefully planned	85%	100%	95%	100%
ASC fellow-guided activities were carefully planned	100%	80%	95%	90%
Scientists' presentation time was used effectively	85%	94%	95%	100%
ASC fellow presentation time was used effectively	70%	67%	91%	92%

In 2007-2009, STEP summer institute participants were asked to rank additional statements designed to evaluate their impressions of the organizational structure and the learning environment of sessions instructed by STEP scientists and ASC fellows. As shown in Table 3.11, from 2007-2009, the vast majority of teachers agreed or strongly agreed that the objectives of scientist and ASC fellow presentations were clear, and that activities were geared at a level appropriate for participants.

In addition, a vast majority of the teachers agreed or strongly agreed that scientists and ASC fellows had addressed their questions and concerns; that teacher interactions with scientists and ASC fellows were collegial; that peer interactions were collegial; and that an appropriate balance between content presentation and participant interaction was achieved. Again, scientists were ranked slightly higher than ASC fellows in all categories. However, in cases where less than 90% of participants agreed or strongly agreed that ASC presentations were clear and that ASC fellow instruction was collegial, data were used to guide formative revision that resulted in higher scores in later years.

Table 3.11
2007-2009 Participant Responses to Additional Summer Institute Survey Questions

Survey statements ranked by participants	% agree or strongly agree		
Year and (Sample Size)	2007 (n=56)	2008 (n=55)	2009 (n=41)
The objectives of scientist presentations were clear	98%	91%	98%
The objectives of ASC presentations were clear	78%	85%	92%
Scientist activities were geared at the correct level	98%	95%	98%
ASC activities were geared at the correct level	85%	93%	96%
Scientists answered my questions and concerns	98%	96%	98%
ASC fellows answered my questions and concerns	83%	96%	96%
Interactions among scientists & teachers were collegial	98%	100%	100%
Interactions among ASC fellows & teachers were collegial	83%	100%	96%
Peer teacher interactions in scientist-led sessions were collegial	98%	98%	98%
Peer teacher interactions in ASC-led sessions were collegial	89%	96%	100%
A nice balance between science content and interaction was achieved	91%	93%	98%
A nice balance between ASC presentation and interaction was achieved	91%	93%	96%

At the end of all but the first (2006) STEP summer institute, the external evaluator asked participants to rank the effectiveness of the course in the areas outlined in Table 3.12. The majority of respondents ranked the institute as good or excellent at improving their STEM content knowledge; enhancing their classroom application of STEM; increasing their interest in geophysical research; and improving their use of Alaska science and math content standards and GLEs.

Table 3.12
2007-2009 Participant Responses to Summer Institute Questions on Content Knowledge

Survey statements ranked by participants	% agree or strongly agree		
Year and (Sample Size)	2007 (n=56)	2008 (n=55)	2009 (n=41)
Improve STEM content knowledge	95%	96%	95%
Enhance STEM classroom instruction and application	91%	98%	95%
Increase interest in geophysical research	95%	98%	98%
Improve knowledge/use of Alaska science/math standards and GLEs	88%	96%	88%

At the end of all but the first (2006) STEP summer institute, participants were asked to rank confidence in their ability to perform specific tasks before and after STEP summer institute involvement. These tasks included: using Alaska content standards to teach science and math and using GLEs to guide assessment of student knowledge of science and math; developing lessons based on locally relevant STEM content; and finding and selecting place-based STEM resources for classroom use. Table 3.13 indicates that after STEP summer institute involvement, the majority of teachers felt well prepared or very well prepared to perform these tasks.

Table 3.13
2007-2009 Participant Self-report of Confidence Pre/Post Summer Institute Involvement

Survey statements ranked	% well prepared or very well prepared					
Year and Sample Size	2007 (n=56)		2008 (n=55)		2009 (n=41)	
Before or After attending the institute	Before	After	Before	After	Before	After
Use content standards to teach STEM; use GLEs to guide student STEM assessment	61%	96%	46%	100%	68%	100%
Develop classroom lessons based on locally relevant STEM content	65%	98%	70%	100%	75%	95%
Find and select place-based STEM resources for classroom use	57%	96%	56%	95%	68%	93%

Follow-on STEP field-test courses were instructed solely by ASC fellows. Table 3.14 indicates that the vast majority of teachers completing STEP field-test courses held during the academic years following the 2006, 2007, and 2008 summer institutes agreed or strongly agreed that: the content of the follow-on STEP field-test course was accurately and adequately delivered; course activities were carefully planned; course objectives were clear; an appropriate balance between presentation and interaction was achieved; and course time was used effectively. The vast majority also agreed or strongly agreed that ASC fellows were effective instructors, were well prepared, and addressed participant questions and concerns.

Additional survey questions were added in 2007 and 2008. A majority of the teachers responding to these additional questions agreed or strongly agreed that: ASC activities were geared at a level appropriate for the teachers present; interactions among ASC fellows and teachers were collegial; and peer interactions in ASC sessions were collegial.

Table 3.14
2006-2008 Participant Responses to Field-test Course Survey Questions on Training

Survey statements ranked by participants	% agree or strongly agree		
Year and (Sample Size)	2006 (n=33)	2007 (n=28)	2008 (n=24)
The course content was accurately and adequately delivered	100%	100%	96%
Course activities were carefully planned	100%	100%	100%
Course objectives were clear	100%	100%	96%
A balance between presentation and interaction was achieved	100%	100%	100%
Course time was used effectively	86%	100%	96%
ASC fellows were effective instructors	100%	100%	96%
ASC fellows were well prepared	100%	100%	96%
ASC fellows addressed participant questions and concerns	100%	100%	100%
ASC activities were geared at an appropriate level	n/a*	100%	96%
Interactions among presenters and participants were collegial	n/a	100%	95%
Peer teacher interactions in ASC sessions were collegial	n/a	100%	100%

In surveys administered at the conclusion of the 2007 and 2008 follow-on STEP field-test courses, participants ranked how well they learned course content. Table 3.15 shows that the majority of respondents ranked the follow-on STEP field-test courses as good or excellent at improving their: ability to apply STEM content learned at STEP summer institutes in the classroom; knowledge and use of the Learning Cycle Model to create standard-aligned STEM lessons; and knowledge and use of Alaska content standards and GLEs.

Table 3.15
2006-2008 Participant Responses to STEP Field-test Course Questions on Learning

Survey statements ranked by participants	% good or excellent		
Year and (Sample Size)	2006 (n=33)	2007 (n=28)	2008 (n=24)
Improve knowledge of how to apply STEM content learned at STEP in the classroom	n/a*	100%	100%
Improve knowledge and use of the LCM to create STEM lessons	n/a	100%	96%
Improve knowledge and use of Alaska standards and GLEs	n/a	95%	100%

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* *n/a – the question was not asked*

At the conclusion of each follow-on STEP field-test course, teachers were asked to rank confidence in their ability to perform four specific tasks prior to participating in the STEP summer institute and after completing the follow-on STEP field-test course. These tasks included: creating STEM lessons using the LCM; using Alaska content standards and GLEs to instruct STEM and guide student assessment; developing classroom lessons based on place-based STEM content; and finding STEM resources appropriate for classroom use. Table 3.16 indicates that after involvement in the STEP field-test course, a majority of the teachers felt well prepared or very well prepared to perform these tasks.

Table 3.16

Participant Self-report of Confidence Before the Summer Institute and After Field-testing

Survey statements ranked by participants	% well prepared or very well prepared					
Year and (Sample Size)	2006 (n=33)		2007 (n=28)		2008 (n=24)	
Before STEP institute; after field-test course	Before	After	Before	After	Before	After
Create STEM lessons using the LCM	32%	84%	48%	100%	30%	91%
Use Alaska content standards and GLEs	37%	95%	58%	100%	60%	96%
Develop lessons based on place-based STEM content	68%	94%	74%	100%	70%	100 %
Find and select STEM resources for classroom use	63%	89%	69%	100%	74%	96%

3.8.2.2 *Open-ended Responses*

All open-ended responses on surveys administered at the end of STEP summer institutes and follow-on STEP field-test courses, and all open-ended responses recorded and transcribed from interviews conducted at the end of the 2009 STEP sustainability workshop were entered into three separate databases. In the data tables below, SI=summer institute; FC=field-test course; SW=STEP sustainability workshop. Responses for all years are combined in each database.

In total, 2882 entries were analyzed: the STEP summer-institute database contains 1618 entries; the STEP field-test course database contains 394 entries, and the STEP sustainability workshop database contains 870 entries.

Table 3.17

Primary Purpose of STEP Participant Open-ended Comments by Database

Category Comment Classification, by Database	SI	FC	SW	Total	% total
Sample Size	1618	394	870	2882	(100 %)
STEP improved K-12 STEM classroom instruction	1131	299	809	2239	77.69%
Accolades (what teachers like about STEP courses)	239	26	43	308	10.69%
Suggestions for revision of STEP courses	239	68	9	316	10.96%
Unable to categorize	9	1	9	19	.66%

Table 3.17 indicates that the primary purpose of 88.38% of the total comments in all databases combined are positive in nature; 77.69% of the comments indicate that STEP involvement improved participants' K-12 STEM classroom instruction and 10.69% of the comments offer accolades for STEP course structure, administration, or facilities. Of the remaining open-ended comments, 10.96% contain participant recommendations for revising the STEP course. The reviewers could not categorize .66% of the comments.

A review of individual databases provides more detail. The field-test course database contains the highest percentage (17.26%) of comments suggesting course revision (68 of 394 entries), compared with 14.77% (239 of 1618 entries) in the summer institute database, and 1.03% (9 of 870 entries) in the sustainability workshop database. Examples (1) and (2) typify teacher suggestions for revision.

> (1) Start the field-test course sooner in the fall so there is more time to field-test lessons, and I would suggest dropping the December teleconference because teachers are too busy during this time to participate effectively.

> (2) Occasionally there was a teacher that was a little long winded, and so sometimes the discussions went long on one topic and it was a little boring; there were times when my attention span drifted because I was not all that interested in teachers of other grade levels lessons.

The summer institute database contains the highest percentage (14.77%) of comments providing accolades for STEP (239 of 1618 entries), compared with 6.60% (26 of 394 entries) in the field-test database, and 4.94% (43 of 870 entries) in the sustainability workshop database. Many of these comments were of a general nature, as illustrated by the following examples (3) and (4).

> (3) Everything about STEP is first rate, great, excellent, fantastic, fabulous, wonderful, incredible; it was remarkably well done—you couldn't have done a better job.

(4) I am beyond grateful I had this opportunity to participate in STEP this summer; I completely enjoyed every part of the 2 week class and being blown away by the research.

Other accolades were more specifically directed to staff and course structure, as shown in examples (5) – (7).

(5) I'm an organized person and can see that a lot of time, thought and a great deal of planning and preparation made this as successful as it was; the quality of what we did was outstanding, and the administrative organization (logistics of getting here, room & board arrangements, shuttle service) was excellent.

(6) How does one improve on perfect—I think we had a nice balance of lecture/activity/lesson planning and field trips to research facilities, our treatment, work time, runners, organizers, and anything else I am missing were outstanding.

(7) I felt treated like a professional; do not "water down" the science in this course, keep it as it is, my questions were answered—I felt it was ok to ask questions—the staff was so friendly, responsive, strong in their field, helpful, and showed genuine concern.

The sustainability workshop database contains the highest percentage (92.99%) of comments describing how STEP involvement improved participants' K-12 STEM classroom instruction (809 of 870 entries), compared with 75.89% (299 of 394 entries) in the field-test course database, and 69.90% (1131 of 1618 entries) in the summer institute database. Table 3.18 shows a breakdown of the 2239 comments in the combined databases whose primary purpose is to describe that STEP improved K-12 STEM classroom instruction.

Table 3.18

Reasons STEP Involvement Improved Teacher STEM Instruction

Category Comment Classification, by Database	*SI*	*FC*	*SW*	*Total*	*% total*
Sample Size	1131	299	809	2239	(100%)
Learning STEM best-practice instructional strategies	269	132	337	738	32.96%
Developing sustainable STEM mentorship networks	297	75	219	591	26.40%
Learning STEM content, skills and processes involved in conducting Arctic research	374	18	75	467	20.86%
Increased self-efficacy in providing STEM classroom instruction and in working toward STEM goals	145	13	130	288	12.86%
Discovering Alaska-specific resources for classroom use	46	61	48	155	6.92%

3.8.2.2.1 *Learning STEM Best-Practice Instructional Strategies*

Learning STEM best-practice instructional strategies is the most frequently identified reason given for how STEP involvement improved classroom instruction. Specific instructional strategies are named in some comments. More general comments, such as those illustrated by examples (8) and (9), describe in broad terms how learning best-practice methods had improved STEM instruction.

> (8) Just because you love science doesn't mean you know the best approach to teach it; STEP taught me many innovative ways of teaching science and math that I would not have thought of—it taught me how to grab kids interest and to focus their attention—now kids are so excited they are starting to see the scientific process in everything, even road kill and bugs outside the classroom windows.

> (9) STEP was life changing—I will never look at science (or math) the same way again; I have learned a new, a better way of teaching that has helped me to make STEM instruction relevant to Alaska students—before STEP, my instruction was relatively routine, just reading and posting science events that I heard of in the news or in magazines.

Table 3.19 shows a breakdown of the 738 comments in the combined databases that attribute improvement in classroom instruction to learning best-practice instructional strategies during the STEP program. In more than half (55.70%) of these comments, teachers identify specific instructional skills. The five strategies mentioned most frequently in teacher comments include: (a) learning to align STEM instruction to Alaska state standards and GLEs; (b) learning to guide student-driven inquiry, experimentation and debate; (c) learning to incorporate tactile activities into STEM classroom instruction; (d) learning to relate STEM content in school to local concerns; and (e) learning to achieve cross-curricular integration. These strategies are discussed in further detail in the paragraphs following Table 3.19.

Table 3.19
Teachers Identify STEM Best-practice Instructional Strategies

Category Comment Classification, by Database	*SI*	*FC*	*SW*	*Total*	*% total*
Sample Size	269	132	337	738	(100.01%)
General Comments	125	58	144	327	44.31%
Specific Comments	144	74	193	411	55.70%
(a) Align STEM instruction to state standards and GLEs	53	53	77	183	24.80%
(b) Guide student-driven inquiry, experimentation, & debate	41	9	41	91	12.33%
(c) Incorporate tactile (hands-on) STEM activities	32	6	34	72	9.76%
(d) Relate STEM content to local concerns (locally relevant)	11	0	30	41	5.56%
(e) Infuse STEM in other subjects (cross-curricular integration)	7	6	11	24	3.25%

(a) Learning to align STEM instruction to Alaska state standards and GLEs is the instructional strategy most frequently mentioned in teacher comments. Examples (10) and (11) are typical of comments about learning to align STEM instruction to the GLEs underpinning standardized science and math tests.

> (10) It's pretty evident everywhere in education that the test is the thing, and since the standard based assessments gauging student learning are based on GLEs, I think the time is ripe (well, overdue) to have a program like STEP to instruct teachers on how to use GLEs, and use them effectively; there's no other training on how to use them effectively, not in college, not anywhere.

> (11) My ability to write lessons based on GLEs was unheard of before STEP, because ten years ago, when I did my student teaching, we never focused on the GLEs—through my involvement with STEP, I was able to get a good grip on what the GLEs are, how they are used, and to see whether a lesson is meeting the GLEs or not.

(b) Learning how to guide student-driven inquiry, experimentation, and debate in STEM classrooms is the next most cited instructional strategy in teacher comments. Example (12) is typical of such comments.

> (12) Because of STEP, I'm letting the kids take over more, letting kids talk more, letting kids ask questions, and then letting them dig to find facts, and sometimes letting kids do their own thing means they'll make mistakes, but it's all part of the learning and scientific process, and, I'm reaching the students.

(c) Learning how to incorporate hands-on activities into STEM instruction also is identified by teachers as an instructional strategy that increases student engagement. Example (13) is typical of comments in this category.

(13) I joined STEP because I didn't want kids to hate science and math, it's amazing how much paperwork they're asking kids to do—writing and worksheets isn't science or math, which is what I was doing before I went to STEP; STEP showed me how easy hands-on activities are to do with simple everyday stuff, and I learned the more hands-on you can be, the more the kids are going to learn and the more excited they are going to be.

(d) Learning to align STEM classroom instruction to local community issues is a strategy teachers frequently attribute to improved classroom instruction and increased student engagement. Examples (14) – (16) typify comments in this category.

(14) STEP taught me to reach out to the community, which has really opened my classroom up to a lot of different people; kids are now more aware of the science and math in everything and they get their parents and siblings involved too.

(15) A new elementary school was recently built for us, but its construction was impacted by permafrost (sink holes, etc.) so I applied the knowledge presented at STEP by taking my kids out on an excursion to see if they could find other places affected by permafrost; then the students did a science fair project on permafrost because they learned there are more features of permafrost than a house falling into the ground.

(16) Teaching about real-time processes occurring outside the classroom is the key factor in rural Alaska for teacher success inside the classroom in STEM content areas.

(e) Learning to integrate STEM instruction across subject areas also is an instructional strategy teachers list as a benefit of STEP involvement. Examples (17) and (18) are typical of those that attribute improved instruction to learning cross-curricular integration.

(17) I've found Arctic research to be relevant to all the subjects I teach; before I went into STEP, my science instruction was more compartmentalized, but now I have opened it up to be one of the foundational curricula in the classroom. Now, when I teach science I am also teaching math and language, so STEP has affected how I teach everything.

(18) Science is now woven into the fabric of my classroom; my science instruction now stretches into all areas in the curriculum—math, writing, reading, social studies—and the classroom atmosphere as well.

3.8.2.2.2 *Developing Sustainable Mentorship Networks*

In open-ended comments, teachers most frequently attribute improved classroom instruction to learning best-practice instructional strategies. Developing sustainable mentorship networks is the second most popular reason given. In the combined databases, 591 comments refer to STEP-established sustainable mentorship networks. Table 3.20 shows a breakdown of the mentorship networks teachers identify as being most useful for improving classroom instruction.

Table 3.20
Teachers Identify Sustainable STEM Mentorship Networks

Category Comment Classification, by Database	*SI*	*FC*	*SW*	*Total*	*% total*
Sample Size (number of entries analyzed)	297	75	219	591	(99.99)
Scientist Mentorship Network	178	5	140	323	54.65%
Peer Mentorship Network	81	63	64	208	35.19%
ASC Fellow Mentorship Network	38	7	15	60	10.15%

More than half (54.65%) of these comments refer to mentorship networks established among teachers and Arctic scientists. Example (19) typifies teacher comments expressing appreciation for scientist-teacher interaction.

(19) The STEP program and interaction with practicing scientists has helped me see that science is happening all around us, and that people who take science seriously are having an impact on bettering the world.

Comments displayed in examples (20) – (23) are typical of those expressing how scientist mentorship has improved teachers' K-12 classroom instruction.

(20) Personal interaction with scientists has increased my knowledge in science and math areas as well as in the delivery of the content; I also have increased my application of technology, especially remote sensing, and working with scientists often gives me the right words (scientific terms) to use with my students.

(21) STEP has really opened that door of communication with scientists that wouldn't have been opened otherwise, and I have found that being in the world of scientists—so different than our teaching world—is refreshing and stimulating; by interacting with STEP scientists I have become aware of current research practices, which allows me to spark an interest in the kids and to let them know they can be a part of it.

(22) My increased understanding of the subject matter from working with scientists and their expertise has carried over to my students; by sharing with scientists and modeling their methods, I have developed better practices dealing with students in terms of waiting time, identifying the purpose of a question, recognizing the diversity of different thinking processes, and how to approach each student individually.

(23) Through STEP, I found that scientists are pretty personable after all; I count it a privilege to now have a sense of collegiality, to feel comfortable reaching out to scientists who are at the top of their fields, and to share with my kids in a small way what a real scientist does when conducting research.

Scientist mentorship is the most commonly mentioned network of support in both the summer institute and the sustainability workshop databases. In the field-test course database, peer mentorship is the most frequently mentioned STEP-established support network. Examples (24) – (26) typify comments about peer mentorship.

(24) Living in the bush isn't the easiest thing to do—we're so isolated here—but through STEP I have been able to make connections with other science teachers across the state; discussing experiences lets me know I am not alone if I have a problem.

(25) Peer networking was, and will continue to be, extremely beneficial to my ability to teach science in Alaska and to address Alaskan needs; sometimes I find it as valuable to interact with other teachers as it is to take a methods class.

(26) What I learn from the different teachers makes my life easier in the classroom (helps me avoid pitfalls), and my interaction with teachers at all levels has helped me understand the full progression of learning from K-12.

In the combined databases, ASC fellow mentorship is the least cited network of support. About 10.15% (60 of 591 comments on mentorship) refer to ASC fellow mentorship.

3.8.2.2.3 *Learning STEM Content, Skills, and Processes Involved in Arctic Research*

The third most frequently identified reason given for improved classroom instruction resulting from STEP participation is learning STEM content, skills, and processes involved in conducting Arctic research. In the combined databases, 467 comments refer to place-based STEM content, processes, and related technology skills teachers have learned and incorporated into classroom instruction as a result of STEP instruction. Many of these comments focus on the depth of STEM content offered by STEP scientists, as noted in examples (27) – (29).

(27) I really appreciated the fact that the science in STEP was presented by practicing Arctic scientists at a fairly high level, and that it was not dummied down for teachers as so often is the case in other professional development programs.

(28) STEP brought research that is going on in the world around our school—like on permafrost thaw and on volcanic activity—into the classroom and made it something my students and I could connect to on a real level; I now can show students skills that related to the real-world application of science, math, and technology.

(29) Climate change impacts students' daily life in rural coastal Alaska villages so I was especially interested to learn through STEP about research on our polar ice caps and how their melting affects our climate.

Examples (30) – (32) are typical of comments describing how learning in-depth STEM content has changed the way teachers provide STEM instruction.

(30) Because of STEP, I no longer just hit a few main science topics in class, now I systematically go through a science concept until I am done; having the more in-depth background knowledge of local research has helped me explain things better to students and to get across the big idea that science is not just a study of what has happened in the past, but that science is current and happening today.

(31) Until participating in STEP, I avoided volcanoes because I didn't know how to get the idea across; now I have learned so many skills, like Google Earth and the Hysplit and PUFF models, that I can apply in the classroom to help students learn how far reaching the effects of volcanoes all over Alaska can be and to help them determine where aerosols may have come from, or where they may go.

(32) Due to STEP, we now use science, math and technology to look at what happens to the orbits of planets in space as you change mass, and what happens to the orbits as you change the distance between the bodies.

3.8.2.2.4 *Increased Self-efficacy*

Teacher comments frequently emphasize the importance of increased self-efficacy. Table 3.21 shows a breakdown of the 288 comments in the combined databases that discuss how STEP involvement increased teacher self-efficacy in instruction and in achieving STEM-related goals.

Table 3.21
Teachers Comment on Increased Self-efficacy

Category Comment Classification, by Database	SI	FC	SW	Total	% total
Sample Size	145	13	130	288	(100%)
Increased confidence and ability to achieve STEM-related goals	81	6	44	131	45.49%
Ability to earn credits toward achieving STEM-related goals	39	1	46	86	29.86%
Recommending STEP to peers so they can advance their goals	25	6	40	71	24.65%

About half (45.49%) of these comments explain that STEP involvement resulted in increased confidence in teaching STEM or increased ability to work toward professional goals, such as becoming involved in national, state, district, and school STEM-related committees. Examples (33) and (34) are typical of such comments.

(33) Before STEP, I avoided teaching earth science; after STEP, I feel more confident as a teacher of science and more confident using technical tools and researching current topics, such as permafrost.

(34) STEP has taught me to be more proactive about science and to be an advocate for change; because of STEP, I became a member of NSTA [the National Science Teachers' Association] last year and will be joining the Alaska Science Teacher Association this year.

Just under a third (29.86%) of these comments indicate that credits for earned STEP courses helped teachers achieve personal goals. Teachers indicate that earning credits contributed to their ability to: move up on their district pay scale; renew state certification; earn highly qualified status in science; and to obtain college degrees in STEM fields. Example (35) is typical of a comment in this category.

(35) I've always been curious about science, and now it is a personal interest that I can confidently cultivate for the rest of my life; earning credits in STEP has benefited me academically, and the credits I have earned helped me get closer to being highly qualified in science.

3.8.2.2.5 *Discovering Alaska-specific Resources*

Teachers also express how discovering Alaska-specific resources has aided classroom instruction. In the combined databases, 155 comments discuss classroom materials and virtual resources teachers discovered through STEP involvement. Many of these comments refer to use of the STEP website, as indicated in examples (36) and (37).

(36) The STEP website is so far reaching and is constantly being added to, making a whole new bank of resources and valuable instructional tools readily available, and not only for me—each student in my class has a computer and Internet access, so the STEP website brings the world to them directly.

(37) In addition to the volumes of lesson plans offered on the STEP website and the links to a variety of research websites, I took with me from the STEP courses back to my classroom physical materials, like books, posters, CDs, and DVDs; books that I didn't know existed are now helping me.

3.8.3 *Participant Outcomes*

Tables 3.22 – 3.24 indicate that teachers made significant gains in their STEM content knowledge and understanding of current Arctic research. These gains were measured through pre- and post-test comparisons of teacher STEM content knowledge made prior to, and after attending each STEP summer institute in 2007, 2008, and 2009. Pre- and post-tests of STEM content knowledge were not administered in 2006.

Table 3.22
2007 STEP Summer Institute Wilcoxon Signed-rank Analysis Results by Science Topic

2007 STEM content topics	Sample Size	Average Pre-Test (%)	Average Post-Test (%)	Average Increase (%)	*Z Score*	*P*
Atmospheric effects on Arctic climate	n=56	44.47%	81.55%	37.07%	6.52	<0.001
Climate impacts on Arctic sea ice	n=56	60.20%	96.09%	35.89%	6.53	<0.001
Climate impacts on land-based cryosphere features	n=55	26.70%	87.59%	60.89%	4.47	<0.001
Coastal climate change & Arctic hydrology	n=56	49.49%	87.93%	38.44%	4.64	<0.001
Total	n=223	45.30%	88.29%	42.99%	12.93	<0.001

Data in Table 3.22 (on the previous page) indicate that 2007 participants' average improvement on combined pre- and post-test topics was 42.99% [N=446 (223 pre-tests and 223 post-tests)], a significant improvement (Z=12.93, $P < 0.001$). A review of the four individual STEM topics taught during the 2007 STEP summer institute indicates that teachers made their greatest gains in understanding climate impacts on Arctic land-based cryospheric features. Teachers had the lowest average pre-test score in this category (26.70%) and the greatest average increase (60.89%)—a significant improvement (Z=4.47, $P < 0.001$). Of the four individual STEM topics taught at the 2007 STEP summer institute, teachers had the greatest initial understanding of climate impacts on Arctic sea ice. Teachers had the highest average pre-test score in this category (60.20%) and the lowest average increase (35.89%)—still a significant improvement (Z=6.53, $P < 0.001$).

Table 3.23
2008 STEP Summer Institute Wilcoxon Signed-rank Analysis Results by Science Topic

2008 STEM content topics	Sample Size	Average Pre-Test (%)	Average Post-Test (%)	Average Increase (%)	*Z Score*	*P*
Oil & gas: landscape factors/plant composition	n=55	28.91%	92.91%	64.00%	4.58	<0.001
Arctic paleoenvironment & paleoecology	n=55	16.55%	68.91%	52.36%	6.45	<0.001
Arctic permafrost	n=55	9.82%	89.82%	80.00%	6.45	<0.001
Arctic soil physics & rock cycle	n=55	45.45%	88.18%	42.73%	4.58	<0.001
Studying and monitoring AK volcanoes	n=55	30.27%	88.82%	58.55%	6.46	<0.001
Volcanic eruptions & remote sensing science	n=55	24.03%	92.30%	68.26%	4.57	<0.001
Total	n=330	25.84%	86.82%	60.98%	15.72	<0.001

Table 3.23 data indicate that 2008 STEP summer institute participants' average improvement on combined pre- and post-test topics was 60.98% [N=660 (330 pre-tests and 330 post-tests)], a significant improvement (Z=15.72, $P < 0.001$). A review of the six individual STEM topics taught during the 2008 STEP summer institute indicates that teachers made their greatest gains in understanding Arctic permafrost. Teachers had the lowest average pre-test score in this category (9.82%) and the greatest average increase

(80.00%)—a significant improvement (*Z*=6.45, *P* < 0.001). Of the six individual STEM topics taught at the 2008 STEP summer institute, teachers had the greatest initial understanding about Arctic soil physics and the rock cycle. Teachers had the highest average pre-test score in this category (45.45%) and the lowest average increase (42.73%)—still a significant improvement (*Z*=4.58, *P* < 0.001).

Table 3.24
2009 STEP Summer Institute Wilcoxon Signed-rank Analysis Results by Science Topic

2009 STEM content topics	Sample Size	Average Pre-Test (%)	Average Post-Test (%)	Average Increase (%)	*Z Score*	*P*
Atmospheric aerosols and volcanoes	n=41	12.93%	93.41%	80.49%	5.60	<0.001
Eruption history of Alaska volcanoes	n=41	38.05%	88.54%	50.49%	5.58	<0.001
Remote-sensing archaeology in Alaska	n=41	19.27%	95.61%	76.34%	5.60	<0.001
Remote sensing & solar system volcanoes	n=41	36.46%	86.71%	50.24%	5.58	<0.001
Tracking volcanic surface deformation	n=41	22.68%	91.59%	68.90%	5.58	<0.001
Geophysics of Alaska's Mt. Redoubt Volcano	n=41	46.83%	89.02%	42.20%	5.60	<0.001
Total	n=246	29.37%	90.81%	61.44%	13.60	<0.001

Table 3.24 data indicate that 2009 participants' average improvement on combined pre- and post-test topics was 61.44% [N=492 (246 pre-tests and 246 post-tests)], a significant improvement (*Z*=13.60, *P* < 0.001). A review of the six individual STEM topics taught during the 2009 STEP summer institute indicates that teachers made their greatest gains in understanding how Alaska volcanic eruptions contribute to atmospheric aerosols. Teachers had the lowest average pre-test score in this category (12.93%) and the greatest average increase (80.49%)—a significant improvement (*Z*=5.60, *P* < 0.001). Of the six individual STEM topics taught at the 2009 STEP summer institute, teachers had the greatest initial understanding about Alaska's Mt. Redoubt Volcano geophysics. Teachers had the highest pre-test score in this category (46.83%) and the lowest average increase (42.20%)—still a significant improvement (*Z*=5.60, *P* < 0.001).

In 2006, teachers received pass/fail grades, not letter grades. As indicated in Table 3.25, scientists awarded grades of A or B to all of the STEP summer institute participants in 2008, and to 98% percent of the STEP summer institute participants in 2007 and 2009. Letter grades reflect participant ability to accurately portray complex STEM content in their newly created K-12 classroom lessons.

All 2007-2009 summer institute participants also received a letter grade from ASC instructors. A letter grade of A from ASC instructors indicated that teachers had: successfully aligned the STEM topic in their newly created lessons with Alaska science and math content standards; aligned their STEM lesson assessments with GLEs; and incorporated STEP-defined best-practice instructional strategies into their lessons. During the STEP summer institute, ASC instructors collaborated with participants until all of these goals were achieved. For this reason, 100% of the 2007-2009 participants received a grade of A from ASC instructors.

Table 3.25
2007-2009 Summer Institute Participant Grades by Program Year

Year and Sample Size of Summer Institute Participants Earning Grades	2007 n=56		2008 n=55		2009 n=41	
	Science	ASC	Science	ASC	Science	ASC
Percentage of participants receiving an A	55%	100%	65%	100%	93%	100%
Percentage of participants receiving a B	43%	0%	35%	0%	5%	0%
Percentage of participants receiving a C	2%	0%	0%	0%	2%	0%

3.8.4 *Student Outcomes*

In 2006 and 2007, STEP field-test course surveys reveal that 100% of participating teachers believed their STEP involvement resulted in increased student achievement. During the final STEP field-test course (following the 2008 STEP summer institute), teachers tested this impression by giving pre- and post-tests to a random sample of 2,341 students in 13 school districts across Alaska. The tests were aligned with Alaska STEM content standards and GLEs and with teacher-designed lessons covering STEM concepts taught during the institute. Because all lesson plans incorporated STEP-defined best-practice instructional strategies, test scores also may indicate how well teachers implemented these skills in their classrooms. Pre- and post-tests were designed by teams of scientists and ASC instructors to test student knowledge about Earth science content and processes before, and after teachers field-tested STEP-created lessons in their classrooms. Pre- and post-tests covered strands of learning evident in GLEs for primary and secondary students. Table 3.26 shows that of the 2,341 pre- and post-test pairs, 825 were completed by students in grades K-3; 600 by students in grades 4-6; and 916 by students in grades 7-12.

Students at all levels made significant gains from pre-test to post-test, with an average total increase of 28.4% (Z=35.11, P < 0.001). Secondary students in grades 7-12 had the lowest average pre-test scores (43.6%), suggesting that they knew the least about these subjects initially. Secondary students also had the highest average post-test scores (80.8%), and the highest average increase (37.2%: Z=24.64, P < 0.001), suggesting they learned the most from field-testing STEP created-lessons.

Table 3.26

2008-2009 Student Pre/Post-Test Wilcoxon Signed-rank Analysis Results by Grade Span

Grade level of randomly selected students taking STEP pre-/post-tests	Sample Size	Average Pre-Test (%)	Average Post-Test (%)	Average Increase (%)	*Z* Score	*P*
Students in Grades K-3	N=825	52.4%	78.1%	25.7%	20.53	<0.001
Students in Grades 4-6	N=600	60.7%	79.3%	18.6%	13.85	<0.001
Students in Grades 7-12	N=916	43.6%	80.8%	37.2%	24.64	<0.001
Total Average	N=2,341	51.1%	79.5%	28.4%	35.11	<0.001

Qualitative data support student pre- and post-test results. In open-ended comments, teachers often attributed increased student performance to STEP involvement. Examples (38) and (39) are typical of those that tie STEP involvement to student achievement.

> (38) After participating in STEP last year, my principal said our scores in science came way up over the year; we've seen an impact in student assessments/testing; you can see students growing in their learning.

> (39) Students are the ones who are truly benefiting from what I have learned in STEP; after adopting new teaching methods and practices, I have noticed an overall upswing in student achievement and in student enthusiasm and passion for science, even a difference in the overall thinking methodologies of the students, which has positively impacted the final outcome of their progress in school.

3.8.5 *Unanticipated Outcomes*

STEP's initial goal was to recruit two Arctic researchers to co-instruct each STEP summer institute. An unexpected high level of scientist interest in instructing STEP, however, caused the PI to revise this goal and to involve teams of scientist instructors in each summer institute. A team of 9 scientists instructed 2007 STEP summer institutes, and different teams of 10 scientists instructed 2008 and 2009 STEP summer institutes. Such a high level of scientist interest was unanticipated, especially considering the level of commitment required, and the fact that STEP institutes occurred during Alaska's relatively short summer field season. Each scientist instructor was asked to dedicate one month to the preparation and presentation of Arctic research in STEP; however, most scientists exceeded this time commitment. Scientists were asked to align their presentations to specific science and math GLEs and to collaborate with ASC fellows on STEP presentation creation and delivery.

In addition, scientists were asked to help create pre-and post-test questions for teachers based on presentation content, and to use rubrics to assess teacher understanding of content related to their presentations (prior to, and after teachers received STEP instruction). Scientist evaluation of teacher pre- and post-tests was labor intensive. All tests contained essay questions, and teachers' written answers ranged in length from a sentence to pages.

Several Arctic researchers discussed the benefits of STEP involvement with members of the University of Alaska Board of Regents, and arranged for a STEP presentation at the Board's Academic and Student Affairs Committee in June 2010. As a result of scientists' interest in STEP, Alaska Department of Education and Early Development representatives requested that a pilot study be conducted on the benefits of scientist involvement in STEP. Findings from this pilot study, conducted 1.5 years after the conclusion of STEP are discussed in a separate paper.

3.9 DISCUSSION

Data from all pilot-test sources indicate that the STEP professional development framework offered the STEM content knowledge and skills participants needed to provide place-based STEM instruction aligned with Alaska GLEs. Data indicate high levels of teacher participation; high teacher ratings of STEP courses (in online surveys and open-ended comments); and high place-based STEM content learning outcomes for both teachers and their students.

3.9.1 *Participation Rates and Participant-reported Impact*

Participation rates exceeded expectations. Capped at 30 participants, the waiting lists for the 2007 and 2008 STEP summer institutes were so long that two back-to-back sessions were held to accommodate 60 teachers each year. Because the waiting list for the final special session was so long, the 2009 STEP summer institute was expanded to permit the enrollment of 11 additional teachers. Twelve more teachers from the waiting list were invited instead to attend a concurrent sustainability workshop. Participation rates at follow-on STEP field-test workshops also met or exceeded expectations.

Online survey data reveal high teacher ratings of STEP summer institutes and follow-on STEP field-test courses. Each year from 2006 to 2009, the vast majority (96%-100%) of STEP summer institute participants ranked the two-week intensive course as good or excellent. Online survey data show that after 2007, 2008, and 2009 STEP summer institute involvement the majority of participants felt well prepared or very well prepared to: develop classroom lessons based on locally relevant STEM content; select resources appropriate for instructing place-based science and math in the classroom; and align STEM instruction to science and math GLEs. Online survey data also indicate that the majority of summer institute participants agreed or strongly agreed that STEP involvement improved their STEM content knowledge, enhanced their STEM classroom instruction, increased their interest in geophysical research, and improved their knowledge and use of Alaska science and math standards and GLEs.

The analyses of STEP participant open-ended comments support and clarify online survey findings: 88.38% of open-ended comments endorse STEP. Of these, 77.69% indicate that STEP involvement improved participants' K-12 STEM classroom instruction. Learning best-practice instructional strategies is the reason most frequently cited by teachers for improved STEM classroom instruction resulting from STEP involvement. Of these strategies, learning to align STEM instruction to Alaska science and math GLEs is most frequently cited as the reason for increased student achievement, followed by: guiding student-driven inquiry, experimentation, and debate; incorporating hands-on activities into STEM instruction; relating STEM content to local community concerns; and integrating STEM concepts in other subject areas. Teacher comments reflect understanding and application of most of the best-practice strategies taught in STEP courses.

Teachers also attribute improved STEM instruction to developing sustainable STEM mentorship networks during STEP. Comments about the value of scientist-teacher mentorship and peer mentorship far outnumber those depicting the value of mentorship by ASC fellows. This is surprising considering that ASC fellows are master teachers with 20 or more years of experience instructing STEM in K-12 classrooms and self-reported teacher demographic data show that only 35% of STEP summer institute participants were highly qualified to teach STEM, and that one third had less than five years of classroom experience.

Because teachers could earn a total of 9 credits for each year of STEP involvement (6 credits for each STEP summer institute plus 3 credits for each follow-on STEP field-test course), it is surprising that credits are not more frequently mentioned in open-ended comments. Far more comments discuss increased self-efficacy in teacher ability to provide STEM instruction and in joining STEM-related organizations.

Open-ended comments about the value of learning Arctic STEM content, research processes, and technology skills clarify and support online survey responses indicating that STEP improved teacher STEM content knowledge. Many open-ended comments express gratitude that STEP courses were offered at the graduate (rather than introductory) level and that the courses provided in-depth content transferable to STEM classroom instruction.

3.9.2 *Participant and Student Learning Outcomes*

STEM assessments administered before and after 2007, 2008, and 2009 summer institutes indicate that participants made significant gains in STEM content learning. Each year, participants' average improvement on all combined pre- and post-tests on Arctic research content revealed statistically significant ($P < 0.001$) improvement (Z=12.93 in 2007, Z=15.72 in 2008, and Z=13.60 in 2009). Letter grades awarded by scientists and ASC fellows indicate that STEP summer institute participants were able to transfer their newly acquired STEM content knowledge into lessons aligned to GLEs.

Pre- and post-assessment of randomly selected students of teachers who field-tested lessons created during the STEP summer institute indicate significant gains in STEM content learning. Pre- and post-tests covered strands of learning in GLEs for elementary through high school instruction, and students at all levels were asked to demonstrate their understanding of Earth science content and processes prior to and after interacting with STEP lessons. Students at all levels made significant gains from pre-test to post-test, with an average increase of 28.4% (Z=35.11, $P < 0.001$).

3.9.3 *Limitations*

To reduce bias, four people independently reviewed the codes assigned to every entry in all three qualitative databases. Even so, assigning codes is a subjective process, and it is possible that other reviewers could have detected other patterns. Also, it is tempting to draw conclusions from open-ended comments that may not be universally applicable. For example, learning to align STEM instruction to Alaska science and math GLEs is most frequently cited as the reason for increased student achievement in open-ended comments. GLEs form the basis of standardized tests that assess student learning in science and math. For this reason, it is tempting to assume that external pressure imposed on teachers to "teach to the test" is the reason this best-practice strategy is named more frequently than those that affect student engagement (such as incorporating hands-on STEM activities into classroom instruction or guiding student-driven inquiry, experimentation, and debate). This may be an unfair assumption. STEP was designed to enhance teacher place-based STEM content knowledge, and to help teachers create lessons on STEM topics aligned to GLEs. Therefore, the high number of comments focused on aligning STEM instruction to GLEs may be a reflection of the course purpose, rather than a reflection of external pressure on teachers to teach to the test.

Because scientists involved in STEP wanted to evaluate specific concepts taught during each summer institute, they created the pre- and post-test questions to assess teacher-learning outcomes. Although these questions were pilot-tested by teachers outside of the STEP program and reviewed by the PI and ASC instructors, it is preferable to use validated, published tests. Unfortunately, such a test was not available. The same is true of the pre- and post-tests used to assess student-learning outcomes during the 2009 follow-on STEP field-test course. To simulate the way STEP course enrollment will function in the future, the STEP pilot study was conducted with volunteer teachers. Not one of the teachers involved was required to take any STEP course. Results may vary if the STEP course was a mandatory requirement for teachers (imposed by a school district, for example).

3.9.4 *Implications*

One of the most significant findings from this pilot project is that STEP courses were popular. STEP did not battle against attrition, as so many STEM professional development programs do. Each year, summer institutes were filled to capacity with waiting lists. One year after grant end, the online course designed to sustain STEP instruction likewise was filled to capacity. A second important finding is a high level of teacher enthusiasm for collaboration with scientists. Many open-ended comments attribute improvement in STEM K-12 classroom instruction to the development of collaborative relationships with Arctic researchers. Unanticipated outcomes of the study include scientist-reported benefits from interaction with K-12 teachers. Based on these results and implications, the PI created Investigations in Cyber-enabled Education (ICE), an NSF Discovery Research K-12 grant (DRL-0918340). ICE will explore the research question: Under what circumstances can cyber-enabled collaboration between scientists and educators enhance teacher ability to provide STEM secondary education? The research goal is to clarify the constructs of a framework for promoting virtual scientist-teacher collaboration that is sustainable, affordable, replicable, and broadly accessible to teachers in all parts of the U.S., including those in rural and disadvantaged areas far from research centers.

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CHAPTER 4

ASSESSING THE GEOPHYSICAL INSTITUTE FRAMEWORK FOR PROFESSIONAL DEVELOPMENT[1]

4.1 ABSTRACT

The Geophysical Institute (GI) framework for Professional Development was designed to prepare culturally responsive teachers of science, technology, engineering, and math (STEM). Providing STEM professional development for teachers of diverse classrooms that include students of Alaska Native, American Indian, African, and Hispanic heritage is essential because these populations are significantly underrepresented in STEM studies and careers. Of these minorities, people of Alaska Native and American Indian heritage are the least represented. The framework provides a foundation for the creation of professional development programs that provide teachers with the tools and training they need to provide standard-aligned STEM instruction that interweaves data and information from Arctic scientists and Alaska Native cultural knowledge bearers. To test the effectiveness of the GI framework, research was conducted on two professional development programs based on the framework: the Science Teacher Education Program (STEP) and the Arctic Climate Modeling Program (ACMP). These programs were selected for research because they offered two distinctly different training venues. This chapter provides a detailed comparison of the strategies used by STEP and ACMP to meet the five main cornerstones of the GI framework for Professional Development, and a detailed comparison of the methods used to conduct research on these two different venues for offering STEM training for Alaskan teachers. The chapter concludes with a comparison of STEP and ACMP research findings and a discussion of how these findings work together to provide a comprehensive assessment of the effectiveness of the GI framework for Professional Development.

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[1] Bertram, K.B. In Preparation. Assessing the Geophysical Institute Framework for Professional Development. *American Educational Research Journal*

4.2 INTRODUCTION

To test the effectiveness of the Geophysical Institute (GI) framework for Professional Development, research was conducted on two professional development programs based on the framework: the Science Teacher Education Program (STEP) and the Arctic Climate Modeling Program (ACMP). These programs offered two distinctly different training venues.

STEP offered two-week summer institutes on the campus of the University of Alaska Fairbanks (UAF). More than 175 teachers from 33 Alaska school districts (91% in rural Alaska) attended STEP summer institutes from 2006-2009. Follow-on yearlong STEP training was provided in audio-conference field-test courses to accommodate teachers in their home communities during the academic year. Yearlong training was supplemented by online support from STEP scientists and Alaska Science Consortium (ASC) fellows (master teachers with extensive experience instructing STEM in K-12 classrooms). During STEP summer institutes, scientists and ASC fellows helped teachers translate STEM content learning into K-12 classroom lessons. In the final program year, a database of 500 standard-aligned STEM lessons based on Arctic research themes (http://www.stepalaska.com/) and a permanent online course were established to transfer training to future Alaska teachers.

By contrast, ACMP served 165 teachers from one rural Alaska school district along the Bering Strait. Geographically isolated on Alaska's Seward Peninsula, the Bering Strait School District contains 15 rural schools scattered throughout 80,000 square miles (an area larger than the state of Nebraska). Schools exist in villages that are not connected by roads and are accessible only by small aircraft. Due to significant challenges in making professional development opportunities accessible to district teachers, ACMP modified the traditional format of offering a two-week summer institute, followed by supplementary training during the academic year. Instead, ACMP offered unique "curriculum resource-based professional development" that provided a year-round mix of in-person, long-distance, online, and local training for rural teachers. Because the cost of two-week in-person training for all 165 teachers was prohibitive, representative Lead

Teachers were selected to transfer STEM training to others at each school. Scientists worked with ACMP curriculum developers to create a vast array of sustainable curriculum resources that Lead Teachers used as mechanisms for transferring STEM training to other staff. Teachers in all Bering Strait schools then field-tested ACMP curriculum resources to ensure they contained the training and contextual STEM information needed to make them applicable to future teachers. All ACMP curricular resources used to transfer STEM training to classroom instruction are permanently available on the ACMP website (http://www.arcticclimatemodeling.org).

4.3 AN OVERVIEW OF GI FRAMEWORK CORNERSTONES

Although STEP and ACMP offered different venues for providing STEM professional development, each embodied the following GI framework cornerstones or overarching principles.[2]

(A) To ensure professional development was aligned with student-learning goals, STEP and ACMP were created by backward design. Backward design involves selecting student goals first, and then creating pathways to meet those goals (Wiggins & McTighe, 2005). In GI framework-based programs, student-learning goals were derived from:

- Alaska standards K-12 teachers are required to address in their classrooms, and grade level expectations (GLEs) that form the basis of standardized tests gauging student achievement in science, math, and language arts; and
- Principles of indigenous ideology, which promote place-based instruction and cross-curricular integration.

(B) To increase teacher knowledge of STEM concepts relevant to students' lives, K-12 professional development instruction was offered in STEP and ACMP through

[2] For more information on GI framework cornerstones, see Chapter 1: The Geophysical Institute Framework for Professional Development: Preparing Culturally Responsive Teachers of Science, Technology, Engineering, and Math, pp. 9-11.

graduate-level courses that provided in-depth, place-based instruction focused on current Arctic research.

(C) To ensure STEP and ACMP professional development instruction mirrored real-world processes involved in Arctic research, GI framework-based instruction interwove the subjects of science, technology, engineering, math, language arts, social studies, and other subjects as applicable.

(D) To increase indigenous student engagement in place-based STEM instruction, STEP and ACMP provided K-12 teachers with training on a variety of research-based instructional methods shown to increase indigenous student interest in STEM.

(E) To help teachers transfer STEM training directly into K-12 classroom instruction, STEP and ACMP provided a variety of comprehensive, standard-aligned curricular resources designed for immediate classroom application. These multiple, flexible mechanisms for transferring STEM training into classroom instruction offer teachers a suite of options for meeting group and individual student needs.

The following sections compare and contrast the ways in which STEP and ACMP addressed each of these critical GI framework cornerstones.

4.4 A COMPARISON OF STEP AND ACMP STRATEGIES FOR MEETING GI FRAMEWORK CORNERSTONES

4.4.1 *Backward Design to Student Learning Goals*

Like all GI framework-based programs, STEP and ACMP were conceived through collaboration among education researchers, school district administrators, Arctic scientists, Native Elders (or cultural knowledge bearers) and master teachers with extensive STEM classroom experience. School district administrators were responsible for selecting student-learning goals aligned with state of Alaska standards and GLEs. Once selected, these GLEs became part of the foundation upon which STEP and ACMP were built.

STEP professional development training was open to teachers across Alaska, but preference for attendance was given to teachers instructing K-12 science and math classes without STEM credentials. For this reason, the STEP development team included not one, but eight districts with high numbers of teachers lacking appropriate STEM credentials. Defined as high-need educational agencies (public schools serving low-income students) by the Alaska Department of Education and Early Development (U.S. Department of Education, 2003-2007), the eight districts involved in STEP formation included: Alaska Gateway, Delta Greely, Fairbanks North Star Borough, Lower Kuskokwim, Northwest Arctic Borough, Tanana City, Yukon Flats, and Yukon-Koyukuk.

Administrators in each of these partner districts were tasked with providing other STEP development team members (education researchers, Arctic scientists, indigenous knowledge bearers, and master STEM teachers) with a list of the foundational GLEs on which STEP would be built. Administrators from these eight districts developed a list composed of the GLEs their teachers found challenging or had difficulty implementing. The GLEs they identified are listed in Table 4.1. In addition to this list, these administrators requested that all State of Alaska Science as Inquiry and Process GLEs (Alaska Department of Education and Early Development [AKDEED], 2006) be addressed each STEP program year.

Table 4.1

Grade Level Expectations Guiding STEP Instruction by Program Year

GLEs addressed by STEP instruction	Year
[9]SB1.1, [10]SB1.1, [11]SB1.1, [8]SB3.2, [9]SB3.2, [10]SB3.2, [11]SB3.2, [3]SB4.2, [7]SB4.2, [8]SB4.2, [10]SB4.2, [11]SB4.2, [5]SD3.1, [8]SD3.1, [5]SD4.1, [6]SD4.1, [7]SD4.1, [8]SD4.1	2006
[3]SB1.1-2, [4]SB1.1-2, [5]SB1.1-2, [6]SB1.1-2, [7]SB1.1-2, [8]SB1.1-2, [6]SB2.1, [7]SB2.1, [8]SB2.1, [10]SB2.1, [11]SB2.1, [8]SD1.2, [3]SD2.1, [4]SD2.1, [5]SD2.1, [8]SD2.1, [5]SD3.2	2007
[4]SB4.1, [5]SB4.1, [7]SB4.1, [8]SB4.1, [9]SB4.1, [10]SB4.1, [11]SB4.1, [6]SB4.3, [3]SD1.1, [4]SD1.1, [5]SD1.1, [6]SD1.1, [7]SD1.1, [8]SD1.1, [9]SD1.1, [10]SD1.1, [11]SD1.1, [4]SD1.2, [4]SD2.2, [6]SD2.2, [7]SD2.2, [8]SD2.2, [6]SD2.3	2008 2009

A different process was used to select GLEs in ACMP because ACMP was designed to serve teachers in one district only: the Bering Strait School District. Bering Strait administrators supplied other ACMP development members (education researchers, Arctic scientists, indigenous knowledge bearers, and master STEM teachers) with lists of standards and GLEs mandated by the district. Prior to ACMP formation, these mandatory standards and GLEs had been made mandatory in an effort combat extremely low student science and math achievement throughout the district. Science and math achievement in the district was so poor that administrators decided to abolish grades levels (associated with age) and adopt levels of attainment (associated with achievement) for use in multiage classrooms. Students advanced to the next level of attainment only after receiving passing scores on district-mandated "End of Level" tests aligned with state of Alaska standards and GLEs.

Bering Strait administrators involved in ACMP creation attributed poor student performance to lack of standard-driven curricula, lack of theme instruction that connected STEM instruction across levels, and lack of teacher training in STEM (evident by lack of teacher STEM credentials). In response to this situation, ACMP developed a pipeline of progressive STEM instruction tied to Bering Strait district-mandated standards and GLEs (Bertram, 2010).

STEP and ACMP development team members collectively reviewed administrator-selected standards and GLEs in an effort to identify overarching place-based research topics for STEM professional development. Research topics selected for standard-aligned STEM professional development met two criteria. The topic needed to be (a) of current interest to the Arctic research community, and (b) of relevance to rural Alaska Native residents.

The Arctic research topic had to meet these two criteria because student-learning goals based in administrator-selected standards and GLEs formed the basis for only half of the program foundation. Because GI framework-based programs are designed to prepare culturally responsive STEM teachers, the other half of the foundation is anchored by backward design to principles of indigenous ideology. The manner in which this is achieved is illustrated on the following page in Figure 4.1.

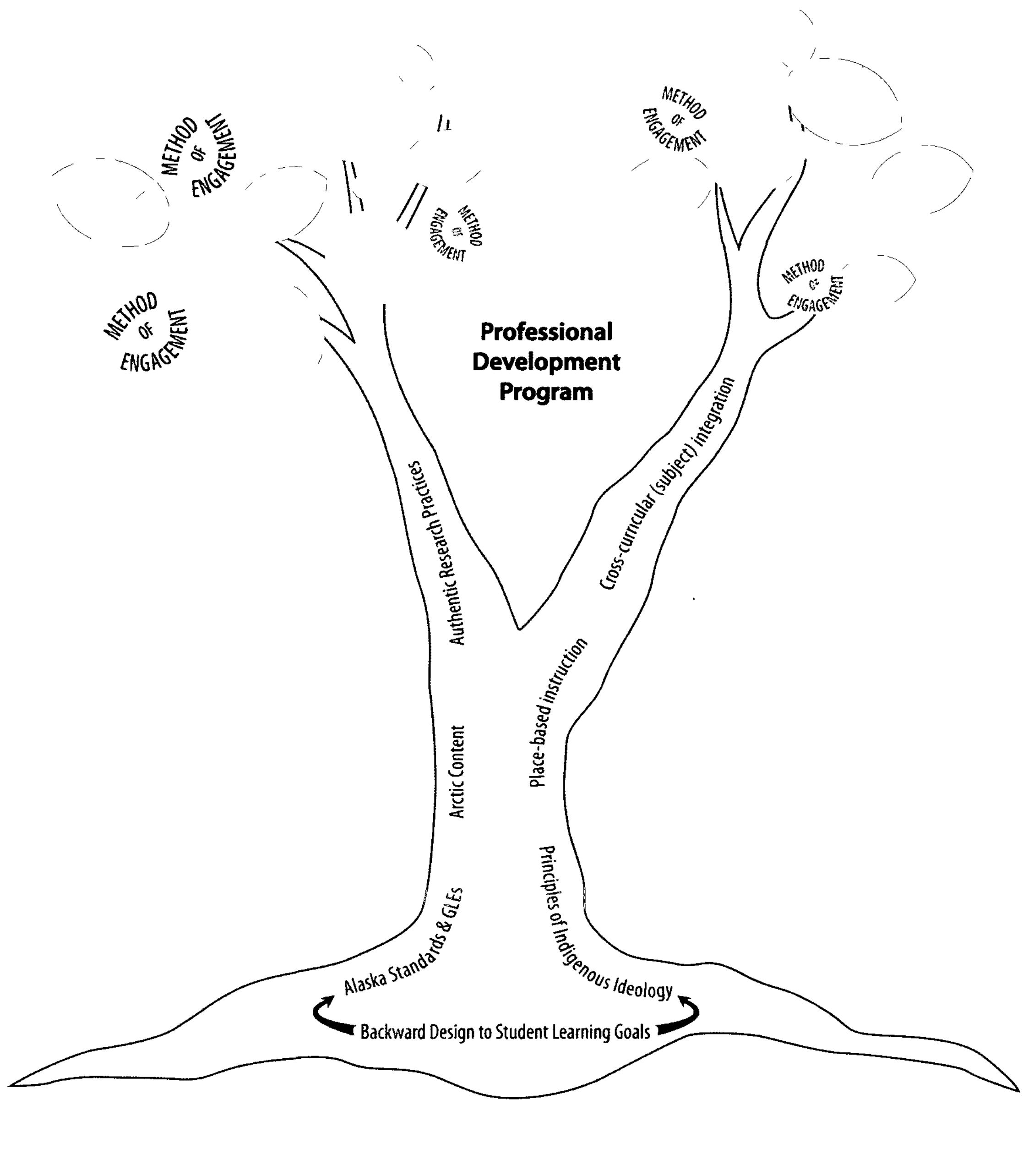

Figure 4.1
The GI Framework for Culturally Responsive STEM Professional Development

Place-based instruction and cross-curricular (subject) integration are core principles of indigenous ideology that are included in all GI framework-based instruction.

4.4.2 *Providing Place-based Instruction through a Focus on Arctic Research Content*

After ACMP and STEP development team members examined administrator-selected standards and GLEs, scientists provided a list of current Arctic synchronous with state-mandated student-learning goals. Indigenous knowledge bearers identified topics on the list of authentic research endeavors that were of importance to rural Alaska Native residents. Once STEM topics were selected, education researchers and master teachers framed the creation of STEM professional development for K-12 teachers focused on selected Arctic research themes.

The ACMP development team selected climate change research as the sole place-based focus for K-12 professional development. In the Arctic, climate change is "significant, accelerating, and unlike any in recorded history" (National Research Council [NRC], 2004).

Most Arctic residents, especially those in rural Alaska, are aware of the effects of recent changes in climate change. At a climate conference, Cup'ik Eskimo Ayuukung Andrews said, "It appears Earth's processes cannot be stopped. Our people desperately need education to improve our understanding of these processes" (Alaska Native Language Center [ANLC], 2008). At the conference, Andrews and other Alaska Native Elders stated that climate literacy is critical for indigenous residents because Alaska Native cultures, languages, and their subsistence way of life is inseparably tied to the land. Changes in climate foretell changes in knowledge that has used for generations as a basis for thriving and surviving in the Arctic (Hanna, 2007).

For example, in 2007, Arctic sea ice plummeted to the lowest levels since satellite measurements began in 1979 (National Snow, Ice and Data Center, 2007). This dramatic reduction endangers the survival of the polar bear and the ringed seal (the bears' main source of food), and has made subsistence hunting in coastal communities more dangerous and less productive (Eilperin, 2010).

As the landscape erodes and changes, so does the generational knowledge that provides insight to hunting grounds and practices, escalating the risks involved in hunting. Subsistence hunting is the primary venue for honoring the knowledge of Elders whose intimate connection with the landscape spans generations of hunting experience, and it provides a platform for practicing age-old cultural values, such as sharing, unity, self-sufficiency, honesty, fairness, responsibility toward the community, and respect for the environment (Kawagley & Barnhardt, 1998).

In the first program year, ACMP instruction provided an overview of the geophysical processes involved in Arctic weather and climate and outlined climate research projects being conducted in and near rural Alaska. In the second and third program years, ACMP professional development focused on helping teachers guide student inquiry aligned with Arctic climate-related research projects occurring near the Bering Strait. These projects are summarized in Table 4.2.

Table 4.2
ACMP Student Work Aligned with Arctic Research by Level

Level	Student work related to Arctic research
I-II	(Yr 2) Interview Elders; build weather stations; collect, record, compare data paralleling an Arctic research project on the nature & frequency of processes leading to extreme weather; (Yr 3) Collect, record, compare data paralleling research on aerosol effects on climate.
III-IV	(Yr 2) Compare current NWS weather data with similar data of past events and cycles; review 10-day forecasts and compare them with 100-yr predictions based on local climate models; (Yr 3) Analyze weather data from BSSD villages used in 200-yr models predicting how climate changes will impact hydrology and affect rural Alaskan life and culture.
V-VI	(Yr 2) Learn about conductive heat flow by studying lake ice growth and thickness; compare local data to circumpolar data; interpret, manipulate models simulating lake ice growth/decay; (Yr 3) Use data from Arctic coastal monitoring sites to analyze the impact of temperature increase on local Alaska ecosystems.

Additional funding that extended ACMP work for an extra year enabled students to practice many of the integrated activities displayed in Table 4.3 in an Arctic research project centered on permafrost. Permafrost is frozen soil, sediment, or rock (on land and under sea) that remains at or below 0°C for at least two years (Brown, Ferrians, Heginbottom, Melnikov, 2001). Permafrost plays a significant role in the global climate system with linkages and feedbacks generated by its influence on surface energy and moisture fluxes. In the Arctic, ground frozen for generations is thawing, prompting building collapse, septic and drinking-water system disruption, and landslides due to compromised soil integrity. Permafrost thaw and drier surface vegetation also contributes to winter overland travel hazards and an increase in summer forest fires (United States Geological Survey [USGS], 2006).

Unlike ACMP, which was designed to offer progressive theme instruction in climate change to a single group of teachers over a period of years, STEP summer institutes were designed to provide STEM instruction to teachers across Alaska. Rather than focus on a single theme, STEP covered Arctic research on geophysical processes ranging from the center of the sun to the center of Earth. During the first STEP program year, space physicists discussed STEM activities and skills needed to study the aurora, an important centerpiece in Alaska Native art, literature, and rural experience. In addition to learning about the solar origins of the Northern Lights, teachers learned why scientists launched rocket payloads into the aurora from UAF's Poker Flat Research Range. During the second STEP program year, a team-teaching approach was used to provide participants with a comprehensive overview of the breadth of research on climate changes in the Arctic, and their effect on subsistence activities in rural Alaska. Climate scientists divided STEP professional development instruction into four categories: atmospheric effects on Arctic climate; climate impacts on Arctic sea ice; climate impacts on land cryospheric features; and coastal climate change and Arctic hydrology. This team-teaching approach was so well liked by scientists and STEP participants; it was replicated in the third (2008) and fourth (2009) program years—when STEP instruction focused on Earth science research. In 2008, scientists divided their instruction into the following six themes: discovering oil and gas; landscape factors and plant composition; Arctic paleoenvironment and paleoecology; Arctic permafrost; Arctic soil physics and the rock cycle; studying and monitoring Alaska volcanoes; and using remote sensing science to study volcanic eruptions. In 2009, when the Earth science focus centered on research being conducted on the concurrent eruption of Mt. Redoubt, scientists discussed the volcanism of Alaska's Redoubt Volcano; the eruption history of Alaska volcanoes; atmospheric aerosols emitted from Alaska volcanoes; tracking volcanic surface deformation; remote sensing archaeology in Alaska; and how remote sensing is used to detect volcanoes on other planets in the solar system.

4.4.3 *Cross-curricular (Subject) Integration Mirroring Authentic Research Processes*

In both STEP and ACMP, professional development on cross-curricular integration focused on providing STEM instruction that mirrors authentic Arctic research practices. GI framework-based professional development uses Arctic content themes and authentic research processes to accomplish cross-curricular (subject) integration within the context of place-based instruction. Figure 4.2 illustrates this process.

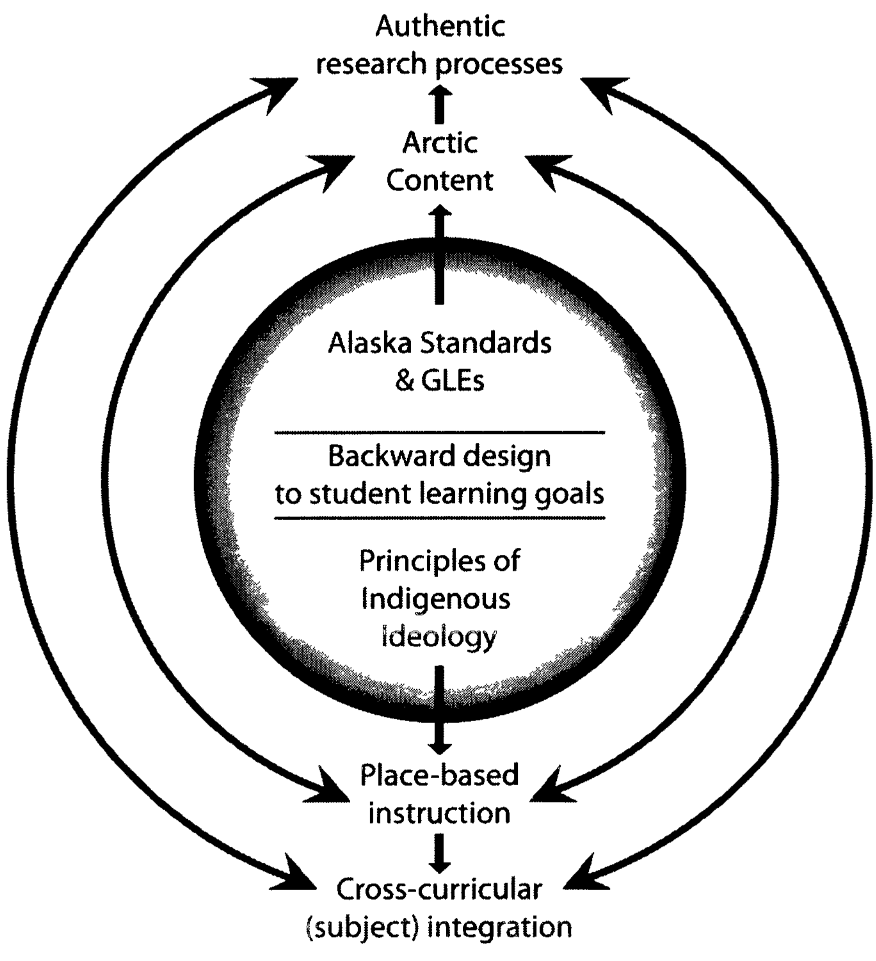

Figure 4.2
Backward Design to Arctic Research Practices and Principles of Indigenous Ideology

In STEP, cross-curricular integration was a natural outgrowth of scientists demonstrating how they interweave the subjects of science, technology, engineering, and math, with literacy skills and social sciences in the real-world endeavor of Arctic research. Arctic scientists integrate these skills in all phases of their research, from inception to conclusion—(a) while developing research questions and formulating study designs, (b) throughout data collection and analysis, and (c) when sharing research findings through presentations and publications. During STEP presentations, scientists talked about their research, which included consulting with rural Alaskan indigenous residents to learn about local environmental observations. They also discussed why their research was relevant to the lives of rural Alaska residents and invited teachers to engage in activities that mimicked authentic research practices.

In ACMP, cross-curricular integration likewise was a natural outgrowth of scientists demonstrating how they interweave the subjects of science, technology, engineering, and math, with literacy skills and social sciences in the real-world endeavor of Arctic research. ACMP partnered with the National Weather Service (NWS) and the National Oceanic and Atmospheric Administration (NOAA) to install automated weather stations on BSSD schools. Some of the weather stations in these remote areas continue to collect data that has never before been available to researchers.

To promote further student interface with scientists, ACMP established the Student Network for Observing Weather (SNOW). The interactive SNOW portal allows students to view and compare weather data collected by weather stations on all 15 BSSD schools. In addition to presenting automated information, SNOW allows students to add observational data not otherwise available to scientists, such as local observations of sea ice conditions, snow depth, sky conditions, permafrost melting, and visibility. As described in Chapter 2, Bering Strait residents used this information and ACMP-linked satellite images of regional sea ice to advance local subsistence hunting endeavors.

During the final ACMP program year, Arctic scientists drilled permafrost borehole sites near each Bering Strait school to provide data for continuing student and scientist research. Students enter permafrost data into the online SNOW network. A sensitive component of Earth's climate system, scientists believe the cryosphere is a key indicator of global climate change (Climate and Cryosphere Program, 2008).

4.4.4 *Research-based Methods for Engaging Indigenous Students in STEM*

In the GI framework diagram illustrated in Figure 4.1 (refer to p. 135), instructional methods for engaging indigenous students are portrayed as a suite of leaves. Each leaf has a unique design, but is united in providing nourishment to the tree, just as each method of engagement in a GI framework-based program has it own intrinsic value, but is most effective when used as part of a whole network of instruction aligned with student learning goals.

In both STEP and ACMP, Native Elders and education researchers worked together to define a suite of methods shown to be successful in engaging indigenous students in STEM studies. In both GI framework-based programs, place-based instruction zeroed in on geophysical processes occurring in the Arctic and provided training in real-world skills students could apply outside the classroom in potential Arctic research careers. Teachers in both programs learned that some of skills used for generations by Native Elders to teach their children and grandchildren overlap and align with those identified as 21st Century Learning Skills used by Arctic researchers (Partnership for 21st Century Skills [P21], 2004). These include providing venues for students to practice critical, reflective, and inductive reasoning, making value judgments, and cooperative learning (collaborative problem solving and decision making).

Teachers in both STEP and ACMP learned how to relate school education to community concerns and how to involve students in projects of local stewardship that facilitate social and civic responsibility. Kinesthetic (tactile and visual) activities and a variety of research-based methods shown to foster student-driven inquiry, investigation and debate were modeled in both STEP and ACMP presentations and included in curricular resources used to transfer STEM training to classroom instruction. A variety of instructional methods were identified and modeled so teachers could contemplate which strategies or combination of strategies would work best in their classrooms.

In STEP, where professional development was offered in person during intensive two-week sessions, scientists incorporated and modeled program endorsed research-based instructional methods in their morning presentations. Later, ASC fellows identified the instructional strategies modeled in scientist presentations so teachers could incorporate them into K-12 lessons they were writing to transfer STEM training to classroom instruction.

In ACMP, scientists and Native Elders modeled program endorsed research-based instructional methods shown to engage indigenous student in STEM studies. Because ACMP professional development was offered using a mix of year-round online, long-distance, in-person, and teleconferenced workshops, curricular resources were used as the main venue for outlining program-endorsed instructional methods.

4.4.5 *Mechanisms for Transferring STEM Training to Classroom Instruction*

In both ACMP and STEP, multiple curricular resources were designed to help K-12 teachers transfer STEM professional development into classroom instruction. These resources continue to offer teachers flexible options for meeting overall classroom needs as well as the needs of individual students.

ACMP's curriculum resource-based professional development was designed from the onset to help Lead Teachers transfer STEM training to other district educators, and then to help educators transfer what they had learned to K-12 classroom STEM instruction. Continual teacher feedback was a critical part of the adaptive, iterative process by which ACMP curricular resources were revised and new curricular resources were created.

The ACMP website hosts more than 200 K-12 classroom lessons aligned to multiple state STEM, language arts, and cultural standards; 21 lectures by Arctic researchers and Native Elders; the SNOW portal, which remains operational and displays ongoing weather and permafrost borehole data; and student inquiry handbooks containing detailed guidelines to help teachers set up local science camps. Tactile lessons and student investigations were designed to encourage cooperative learning and community participation.

The online SNOW portal and technology lessons were created to strengthen teacher knowledge and student learning of 21st century workforce skills. Digitized, online scientist and Elder lectures help teachers and students hear and see scientists and cultural knowledge bearers practice Arctic climate research and observation.

The ACMP website also host portions of a multimedia learning system that provides more than 400 interactive screens to help students visualize scientific concepts and to understand climate-related vocabulary in both English and indigenous (Inupiaq, Yup'ik, and Siberian Yupik) languages. All ACMP curricular resources interweave Arctic research findings with indigenous perspectives and contain contextual Whole Picture information that explains why the lesson is important to scientists and Alaska's indigenous residents. ACMP curricular resources also contain step-by-step guidelines for implementing research-based instructional strategies designed to engage indigenous students.

Part of STEP professional development training involved showing teachers how to design their own lessons for transferring Arctic research-based STEM training into K-12 classroom instruction. Teachers used a backward-design approach to creating lessons based on STEP instruction. Using this approach, teachers first identified student-learning goals, and then identified Arctic research themes aligned with student learning goals. Teachers designed assessment tools aligned with standards and GLEs before writing lesson plans.

To help teachers create lessons that portrayed STEM content and processes in an integrated manner that mirrored authentic research processes and reflected principles of indigenous ideology, all lessons were based on a breadth of GLEs. For each lesson created, STEP teachers were required to select two or more of each of the following standards and/or GLEs: (a) Alaska science GLEs; (b) math and language arts GLEs: (c) technology standards; and (d) Alaska Standards for Culturally Responsive Schools (Alaska Native Knowledge Network, 1988). Teacher lesson plans also were required to incorporate a mix of program-endorsed research-based instructional strategies for engaging indigenous students in STEM instruction.

Three parties reviewed all STEP-participant created lesson plans: ASF fellows ensured each lessons was standard-aligned and included a mix of STEP-identified instructional strategies; Arctic scientists ensured the accuracy of all STEM content and processes portrayed by each lesson; and teaching peers commented on lesson plan classroom usability.

All STEP teacher-created lessons were field-tested in K-12 classrooms and revised based on field-test input before they were posted to the STEP website for use by teachers across Alaska. The STEP website currently hosts 500 STEM lessons aligned to Alaska standards and GLEs, and the online "Dynamic Earth Processes" professional development course. This combination makes STEP professional development training and the resources used to transfer STEP training to the K-12 classroom permanently available for teachers across Alaska.

4.4.6 *Overview of STEP and ACMP Strategies for Meeting GI Framework Cornerstones*

This section describes how STEP and ACMP met GI framework cornerstones for creating culturally responsive STEM professional development. Both STEP and ACMP were created by backward design to student learning goals based in Alaska standards and GLEs and in principles of indigenous ideology. The state of Alaska mandates that K-12 teachers align their classroom instruction with Alaska standards and with the GLEs that form the basis of standardized tests gauging student achievement in science, math, and language arts.

Aligning student learning with principles of indigenous ideology means emphasizes place-based instruction and cross-curricular integration. Research indicates that indigenous student learning increases when STEM instruction is tied to place-based themes that connect learning to the local environment (Barnhardt & Kawagley, 1999; Battiste, 2000; Kawagley, 1996; Lipka, 1998; Semken & Morgan, 1997; Snively & Corsiglia, 2001), and when STEM instruction is presented as part of a united whole, rather than segmented into core subjects unrelated by theme (Barnhardt & Kawagely, 2005; Starnes, 2006). Both STEP and ACMP provided place-based instruction through a focus on current geophysical research occurring in the Arctic.

Cross-curricular (subject) integration was achieved by training teachers to mirror authentic research practices in their classrooms. To ensure STEP and ACMP professional development instruction mirrored real-world processes involved in Arctic research, GI framework-based instruction interwove the subjects of science, technology, engineering, math, language arts, social studies, and other subjects as applicable.

Both STEP and ACMP emphasized a suite of instructional strategies shown to engage indigenous students in STEM pursuits. Including instruction in a breadth of methods for engaging indigenous students is critical because (a) research indicates that most STEM teachers “enter their preparation programs with little or no intercultural experience and with beliefs and assumptions that undermine the goal of providing an equitable education for all students” (Duschl, Schweingruber, & Shouse, 2007, p. 303), and (b) effective teachers employ a variety of methods for guiding students toward their learning goals (Goodwin, 2010).

To help teachers transfer STEM training directly into K-12 classroom instruction, STEP and ACMP provided a variety of comprehensive, standard-aligned curricular resources designed for immediate classroom application. These multiple, flexible mechanisms for transferring STEM training into classroom instruction offer teachers a suite of options for meeting group and individual student needs.

4.5 EXAMPLES ILLUSTRATING STEP AND ACMP STRATEGIES FOR MEETING FRAMEWORK CORNERSTONES

The following examples are offered to further clarify the strategies and processes used in STEP and ACMP to create professional development designed to prepare culturally responsive STEM educators.

4.5.1 *An Example Illustrating the STEP Development Process*

In STEP, Arctic scientists guided the selection of place-based STEM research topics aligned with student learning goals. To facilitate this process, each Arctic scientist selected as a STEP summer institute instructor was asked to identify three (or more) aspects of their research that strongly aligned with program-identified GLEs (refer to Table 4.1, on page 133). Scientists worked with ASC fellows (master teachers with extensive experience instructing STEM in K-12 classrooms) to develop methods of presenting integrated STEM instruction that reflected authentic Arctic research practices. ASC fellows also helped scientists identify and model research-based instructional strategies for engaging indigenous students in their presentations. As a result, STEP scientist-provided STEM instruction included a mix of hands-on, visual, and interactive activities and employed a variety of other instructional strategies teachers could later replicate in their classrooms or on field trips.

During afternoon lesson-development sessions, ASC fellows helped course participants identify the specific best-practice strategies demonstrated by scientists and to translate the STEM content presented into information suitable for standard-aligned K-12 lessons development. In STEP, the Learning Cycle Model was used to help teachers create standard-aligned assessment and affiliated classroom activities.

Tracking the process one scientist-and-ASC fellow team used to develop a STEM presentation based on Arctic research illustrates this process. Aquatic Ecologist Katey Walter was one of nine 2007 STEP summer institute scientist instructors. An associate research professor with the UAF Institute of Northern Engineering and Water and Environmental Research Center, Walter's presentation fell under the overarching theme of "climate impacts on land cryospheric features." To align with Alaska science standards SB1.1 and SB1.2 and with math standards for all grade levels, Walter taught about her permafrost research and about her associated research on methane production in thermokarst lakes.

Walter was paired with ASC fellow Gary Cooper, who worked as a high school teacher in rural Alaska for 23 years. Cooper, who received the Presidential Award for

Excellence in Secondary Science Teaching ('92) and who served as the Alaska Science Teachers Association president ('03), is currently a state of Alaska Science Standards and Assessment committee member.

Together, Walter and Cooper designed her STEP presentation entitled, "Methane in the Arctic and the Role of Permafrost Thaw as a Positive Feedback to Climate Change." Below is a summary of Walter's main presentation points. A fact sheet written by Walter and Cooper providing more detail on each point for STEP teachers is presented in Appendix A.

1. Methane (CH_4) and carbon dioxide (CO_2) are important greenhouse gases in the Earth's atmosphere because they contribute to global warming.
2. Methane enters the Earth's atmosphere from different sources, with anthropogenic sources contributing ~60% and natural sources ~40%.
3. Permafrost is defined as permanently frozen ground (rock, sediment or any other earth material with a temperature that remains below 0°C for two or more years). Although permafrost does not always contain ice, ice is common in surface permafrost in the Arctic and is important because when permafrost thaws and ice melts, the ground surface subsides, a process known as "thermokarst".
4. Permafrost is a source of a large pool of carbon. There is as much carbon locked up in frozen Arctic permafrost in the form of organic matter (dead plant and animal remains) as there is in the atmosphere today.
5. Decomposition of organic matter in the presence of oxygen produces carbon dioxide, and in the absence of oxygen it produces methane. Methane emission occurs using three pathways: through molecular diffusion, through aquatic vascular plants, and by ebullition (bubbling). Ebullition is a very patchy process, but it dominates methane emissions from most lakes.
6. A new method has been developed by researchers to quantify methane ebullition from lakes, which takes into account its patchiness.

After outlining these six main concepts, Walter worked with Cooper to select and then incorporate into her presentation a variety of researched-based instructional methods shown to engage indigenous students in STEM studies. The various methods Walter chose to emulate through her STEP presentation included: aligning STEM instruction to a place-based theme; relating STEM instruction to community concerns; aligning STEM instruction to authentic research practices; using modern technology to unite university and indigenous research and perspectives; using visual aids and tactile activities to help portray complex STEM information; and incorporating a field activity STEP teachers could later replicate as a stewardship project with students in their local communities.

To illustrate her presentation on methane development and release, Walter used a PowerPoint presentation containing multimedia elements that permitted teacher interaction. Walter included pictures of her methane research on Alaskan thermokarst lakes adjacent to rural school districts. Figure 4.3 illustrates how information gathered by rural Alaska residents helped scientists pinpoint localized areas of methane gas release.

Figure 4.3
Interweaving University Research with Local Indigenous Observations

After emphasizing the importance of methane's role in climate change, Walter engaged teachers in a tactile activity. Using common classrooms materials, Walter helped teachers design methane gas traps. To help teachers recreate this activity with their students, Walter and Cooper created "How to Build a Methane Gas Trap" guidelines (see Appendix B). After this indoor activity, Walter took teachers outdoors to Smith Lake, a shallow body of water near the university. There, she taught teachers how to collect methane from the lake using their handmade gas traps. Back in the STEP classroom, teachers worked in teams to perform data analysis and to write reports on research findings.

In a follow-on session, Cooper expounded on the instructional methods Walter emulated in her presentation. He discussed how the methane gas trap activity could be replicated as a stewardship project in many areas of Alaska. During stewardship projects, students conduct classroom research on topics of local concern. The methane gas trap activity offers a platform for student teamwork and individual reflective thinking, and gives teachers a reason to invite rural community members into the classroom to share knowledge of local geophysical processes.

4.5.2 *An Example Illustrating the ACMP Development Process*

Once GLEs and a climate change theme were established, the ACMP development team collaborated to design STEM professional development that provided clear pathways to student-learning goals. Prior to ACMP, few Bering Strait teachers held STEM credentials. For this reason, ACMP professional development provided a foundation for understanding the basic STEM and literacy skills that underpin authentic Arctic climate research. Education researchers worked with scientists and Native Elders to design an overall plan for providing progressive levels of instruction on Arctic weather and climate based on district-mandated GLEs. Beginning level (I-II) instruction was created to align with district-mandated GLEs for K-4; intermediate level (III-IV) instruction to align with GLEs for 5-8; and advanced level (V-VI) instruction to align with GLEs for 9-12.

ACMP professional development began with training in basic STEM concepts, built to STEM instruction in climate cycles and systems, and concluded with STEM instruction in atmosphere-ocean-land interactions, feedbacks, and energy transfer. Progressive levels of math instruction were designed to start with basic data collection, recording, and comparison. Once this was mastered, training advanced to use of statistics and algebra for data manipulation and display, and culminated in using basic geometry and other advanced math to draw conclusions based on data interpretation and analysis. A progression of classroom technology likewise began with basic word processing and online calculators and culminated in working with STELLA modeling paradigms, as illustrated in Table 4.3.

Table 4.3
Information Technology Skill Progression and Supporting Software by Level

Level I-II: Basic hard- and software review; Excel for entry-level spreadsheet use (data entry and comparison); Word for writing reports on results; online calculators for simple data computation
Level III-IV: CDROM interface; email; Internet searches to access remote data; Excel spreadsheets to organize, manipulate, and display data; Adobe Photoshop to create Science Expo displays; PowerPoint to create presentations; Acrobat to format results for ACMP Website
Level V-VI: Computer model and STELLA modeling paradigm interface; Excel to analyze and manipulate entries in the indigenous knowledge database; Adobe Illustrator to create Science Fair displays; Macromedia Dreamweaver to create web pages on results; scripting languages (Perl, PHP, Java) for modeling

A similar progression of literacy training began with instruction that encouraged students to research climate information. Instruction then advanced to writing data summaries to communicate results, and culminated in guiding level V-VI students in defending scientific arguments, comparing perspectives provided by indigenous knowledge bearers and Arctic researchers, and applying bilingual (English and Native language) skills.

Indigenous knowledge bearers on the ACMP development team also designed a progression for sharing cultural instruction about weather and climate with teachers and students. In levels I-II, Elders shared traditional weather observation techniques and data collection skills; in levels III-IV, Elders shared long-term climate observations and Inupiaq language terminology for inclusion in curricular resources being developed, and in levels V-VI, Elders provided input into an indigenous knowledge database on weather variability correlated with data collected from weather instruments between 1980-2003.

These methods used by Elders to share cultural instruction about weather and climate encapsulated a variety of research-based instructional strategies taught for engaging indigenous students in STEM study.

Examples of research-based instructional methods of engagement taught in ACMP professional development include (but are not limited to): inviting community members to the classroom to share knowledge of local geophysical processes; interweaving Native language into classroom STEM instruction; incorporating related oral history, dance, art, song, and other cultural activities traditionally used to share geophysical information; relating STEM instruction to community concerns; involving students in STEM projects of local stewardship; training teachers to provide STEM instruction aligned with students' prior knowledge; uniting university and indigenous research in STEM instruction; learning to incorporate tactile and visual activities into STEM instruction; providing opportunities for student teamwork and individual reflective thinking; setting up forums for sharing student findings with community members; training in cross-curricular integration; and using modern technology to unite mainstream and indigenous research and perspectives.[3]

Teachers also learned how some of the instructional skills used for generations by Native Elders overlap and align with those identified as 21st Century Learning Skills used by Arctic researchers (P21, 2004). To emphasize the importance of this instructional method, ACMP provided 30 sample exercises to help teachers encourage students in critical thinking, review, reflection, and concept extension in their classrooms (see Appendix C). ACMP also provided teachers with sample guiding questions (Kagan, 1999) they could use to engage students in a variety of STEM activities, including analyzing, applying, categorizing, decision-making, defining, inferring, concluding, evaluating, investigating, generalizing (see Appendix D).

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[3] The research basis for these instructional methods can be reviewed Chapter 1: The Geophysical Institute Framework for Professional Development: Preparing Culturally Responsive Teachers of Science, Technology, Engineering, and Math, pp. 17-21.

Due to the unanticipated large number of Bering Strait teachers interested in participating in ACMP professional development, district administrators limited teacher attendance at off-site ACMP teacher training events to "Lead Teachers." After ACMP training events, administrator-appointed Lead Teachers returned to each Bering Strait community to transfer STEM training to other staff in their schools. Lectures by scientists and Native Elders monthly broadcast to all Bering Strait teachers supplemented this instruction for all school staff.

Scientists and Native Elders helped curriculum developers create a vast array of resources to help transfer STEM professional development training to Bering Strait teachers. To supplement teacher training and to refine resources, teachers in all district schools were asked to field-test ACMP resources with their students and to provide feedback to Lead Teacher representatives. Lead Teachers compiled input into the monthly reports education researchers used to modify ACMP curricular resources. After revision, curricular resources were posted to the ACMP website, which continues to host a breadth of sustainable resources for future teachers. ACMP sustainable resources include classroom lessons and interactive multimedia activities, scientist and Elder lectures, the online mentor network, and the online student network for observing weather (SNOW).

Tracking the process used to develop one ACMP resource used to transfer STEM training into classroom instruction illustrates this process. "How Fast is the Wind?" is one lesson in a suite of ACMP lessons rooted in the following district-selected GLEs for level III-IV students: math [7] S&P-3; science [7-8] SA1.1, [8] SD2.1, and [8] SG2.1. Scientists, education researchers, and Native Elders designed instruction aligned with these GLEs on different facets of weather and climate. Like all ACMP lessons, "How Fast is the Wind?" provides "Whole Picture" information for teachers that reviews science content training about the lesson topic and provides a context for why studying wind is important to Arctic researchers and Native Elders. This lesson reveals that rural indigenous subsistence hunters need information on wind speed and direction to aid in travel safety and animal tracking success. It also reveals that for National Weather Service (NWS) forecasters, information on wind aids in weather prediction.

Like all ACMP lessons, "How Fast is the Wind?" provides a list of materials and step-by-step instructions to help teachers facilitate hands-on classroom activities. In this lesson, students build anemometers and measure wind speed at different locations so they can learn how natural and manmade topography affects wind speed. The lesson begins with the digital lecture "Chief Robert Charley Talks about Wind," which helps students understand the importance of wind geophysics from a Native Elder's perspective.

Scientists and master STEM teachers on the development team used online checklists to review all ACMP curricular resources. These checklists were composed of a series of questions that required Likert-scale responses, and included a section for open-ended comments so reviewers could explain reasons for their ratings.

Instead of using online checklists, Native Elders on the development team opted to read hardcopies of lessons and then to engage in dialogue with curriculum developers. During these interviews, Elders offered verbal or written suggestions on how to make lessons more culturally meaningful.

4.5.2.1 *ACMP Master Teacher Reviewer Checklist*

Teachers used the following checklist to rank ACMP resources.

1. Rate the degree this set of lessons addresses the following research-based methods for increasing student achievement.
    A. Cross-curricular integration
    B. Hands-on lessons
    C. Interactive visual tools
    D. Multiple opportunities for review
    E. Relating concepts learned to local issues
    F. Including Native language and values
    G. Including cooperative work emulating Native life outside of schools
2. Please comment on your ratings.

3. Rate the degree this set of lessons addresses the following research-based strategies to motivate students towards graduation.
    A. Involving family in learning
    B. Creating service-oriented projects
    C. Sharing findings with Native Leaders, scientists and the public
    D. Building mentorship relationships with Elders and scientists
4. Please comment on your ratings.
5. Rate the degree this set of lessons addresses the identified tested GLEs.
    A. [[8] SB1.1 The student demonstrates an understanding of the structure and properties of matter by using physical and chemical properties (i.e., density, boiling point, freezing point, conductivity, flammability) to differentiate among materials (i.e., elements, compounds, and mixtures).]
    B. [[8] SB2.1 The student demonstrates and understanding of how energy can be transformed, transferred, and conserved by identifying the initial source and resulting change in forms of energy in common phenomena (e.g., sun to tree to wood to stove to cabin heat).]
    C. [[8] SD1.2 The student demonstrates an understanding of geochemical cycles by applying knowledge of the water cycle to explain changes in the Earth's surface.]
    D. [[8] SD2.1 The student demonstrates an understanding of the forces that shape Earth by interpreting topographical maps to identify features (i.e., rivers, lakes, mountains, valleys, island, and tundra).]
    E. [[8] SD3.1 The student demonstrates an understanding of cycles influenced by energy from the sun and by Earth's position and motion in our solar system by recognizing the relationship between the seasons and Earth's tilt relative to the sun and describing the day/night cycle as caused by the rotation of the Earth every 24 hours.]
    F. [[8] SD3.2 The student demonstrates an understanding of cycles influenced by energy from the sun and by Earth's position and motion in our solar

system by recognizing types of energy transfer (convection, conduction, and radiation) and how they affect weather.]

G. [[7-8] SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring, and communicating.]
H. [[8] SA2.1 The student demonstrates an understanding of the attitudes and approaches to scientific inquiry by recognizing and analyzing differing scientific explanations and models.]
I. [[8] SG2.1 The student demonstrates an understanding of the bases of the advancement of scientific knowledge by describing how repeating experiments improves the likelihood of accurate results.]

6. Please comment on the use and development of math in the curriculum.
7. What are your suggestions for increasing the degree to which GLEs are addressed in this set of lessons?
8. To what degree do the lessons prepare students for their stewardship projects? Please comment on your rating.
9. Please list any other suggestions, concerns, or questions.

4.5.2.2 *ACMP Scientist Reviewer Checklist*

Scientists used the following checklist to rank ACMP resources.

1. Rate the degree science content in this set of lessons addresses Arctic weather. Please comment on your rating.
2. Rate the degree science content in this set of lessons prepares students for completing projects of local stewardship. Please comment on your rating.
3. Rate the degree science content in this set of lessons addresses local energy concerns. Please comment on your rating.
4. Rate the degree science content in this set of lessons reflects current research on Arctic weather. Please comment on your rating.
5. Please list any other suggestions, concerns, or questions.

4.5.2.3 *ACMP Native Elder Reviewer Checklist*

Native Elders (or other indigenous knowledge bearers) used the checklist in Table 4.4 to help facilitate conversation with curriculum developers on research-based instructional methods for engaging indigenous students. During such interviews, Elders discussed instructional methods for engaging indigenous students identified in ACMP curricular resources and offered suggestions on how to incorporate cultural activities that would be meaningful to Bering Strait students. This checklist also was used as a reference source for providing related teacher training. The list is not meant to be exhaustive or exclusive; it simply provides a platform for use in creating resources that transfer STEM training to classroom instruction.

Table 4.4
ACMP Methods of Engagement Checklist Used in STEM Instruction

	Use of lessons aligned to Alaska standards		Helped students with stewardship projects
	Use of place-based lessons (based on information relevant to the natural environment in which students live)		Use of cross-curricular integration or whole-to-part instruction (relating parts of instruction to an overall purpose)
	Use of lessons on topics of interest to the community or that relate school instruction to community concerns		Use of lessons that include both indigenous and mainstream (science and/or math) perspectives
	Use of lessons that incorporated tactile (hands-on) activities		Asked students to share schoolwork with their families or with the community
	Use of multimedia tools or other visual tools that helped students visualize concepts		Asked local Elders to class or fostered dialog among students and local adults
	Use of lessons that include skills students can use or apply outside the classroom		Incorporated storytelling, oral history, or other indigenous culture activities
	Use of exercises that promote critical thinking		Encouraged cooperative group learning
	Provided students with opportunities and time for review, reflection, and extension		Included indigenous language terms or values in classroom instruction

Because a vast number of resources were created for ACMP, "How Fast is the Wind?" was evaluated as one part of a group of 14 lessons on weather. Before it was sent to Bering Strait schools, comments from scientists, master teachers and Elders were incorporated into the lesson. Along with other lessons in its group, the lesson was re-tested until the average rank of reviewing scientists and teachers was 4 or 5 in all categories. The "How Fast is the Wind?" lesson displayed in Appendix E is the final result of group collaboration and revision.

4.5.3 *A Brief Discussion of STEP and ACMP Examples*

The examples presented in the preceding section help clarify the methods used in STEP and ACMP to meet the GI framework professional development goal of preparing culturally responsive STEM teachers.

The STEP example details how Arctic scientist and master teacher (ASC fellow) collaboration resulted in the creation of a STEM professional development presentation aligned with GI framework learning goals. The STEP example demonstrates how a variety of research-based instructional strategies for engaging indigenous students were incorporated into STEP training and illustrates how discussion of authentic Arctic research processes was used to promote cross-curricular (subject) integration. In this example, the Arctic scientist provided teachers with specific guidelines for replicating STEM training (and related hands-on activities) in K-12 classrooms.

The ACMP example illustrates how collaboration among Arctic researchers, Native Elders, school district administrators, and master STEM teachers resulted in place-based, standard-aligned, integrated STEM professional development. The ACMP example emphasizes how curricular resources were used as mechanisms for transferring culturally responsive STEM training to K-12 STEM classroom instruction.

4.6 A COMPARISON OF STEP AND ACMP PILOT STUDIES

In both STEP and ACMP, pilot studies were conducted to determine how effective each of these GI framework-based programs were in delivering the instruction and tools rural Alaska teachers need to provide culturally responsive, place-based STEM instruction aligned with Alaska GLEs. This section summarizes and compares the pilot studies used in STEP and ACMP to test program effectiveness.

4.6.1 *Sample*

In ACMP, 165 teachers from one rural area—the Bering Strait School District—were involved in a three-year pilot study designed to determine the effectiveness of STEM professional development. In STEP, the pilot study used to determine the effectiveness of

STEM professional development was slightly larger and of slightly longer duration. In STEP, 175 teachers from 33 Alaska school districts attended four (2006-2009) STEP summer institutes; 85 teachers attended three (2006-2008) STEP yearlong follow-on courses; and 12 teachers participated in the 2009 sustainability workshop.

4.6.2 *Data Collection and Analysis*

To determine to what degree STEP and ACMP provided instruction and tools rural Alaska teachers need to provide culturally responsive, place-based, standard-aligned STEM instruction, data were collected for several outcomes: teacher participation rates; participant-reported impact of the program; and student outcomes measured in STEM assessments. In STEP, data also were collected for participant outcomes.

4.6.2.1 *Participation Rates*

In STEP, teacher training was offered in three distinct venues: (a) STEP summer institutes, (b) follow-on STEP field-test courses, and (c) the STEP sustainability workshop. In all three venues, teacher attendance was calculated directly. In ACMP, both direct and indirect methods were used to calculate participation. Due to challenges in providing training to teachers in the 15 schools scattered throughout this expansive, geographically isolated district, training was offered to Lead Teachers directly and then indirectly through a hierarchy of mentoring support to others. Participation was calculated directly for all in-person Lead Teacher professional development events and for introductory workshops open to all Bering Strait teachers during mandatory district in-service conferences. Participation at other training events open to all Bering Strait teachers was calculated indirectly.

4.6.2.2 *Participant-reported Impact*

Participant-reported impact of GI framework-based professional development was measured through online surveys and in-depth case study interviews in both STEP and ACMP. In ACMP, field-test documentation also was used in the form of Lead Teacher monthly reports. These emailed reports summarizing input from all teachers in each Bering Strait school contained a rich source of open-ended comments on ACMP training and resources.

In both STEP and ACMP, external evaluators administered online surveys at the conclusion of annual workshops. Online surveys prompted teachers to provide feedback about their satisfaction with GI framework-based professional development and to report on the extent to which training increased their knowledge of place-based STEM content and effective STEM instructional strategies. All responses were submitted anonymously. Online surveys contained questions that asked teachers to rank a variety of statements using a 1-5 Likert scale (ranging from strongly disagree to strongly agree, or from poor to excellent). In both STEP and ACMP, descriptive statistics were used to analyze feedback to Likert-scale questions on online surveys.

In STEP, online surveys were administered at the end of each summer institute and at the end of each follow-on STEP field-test course. STEP participants answered eight Likert-style survey questions each year. During the last three program years, additional survey questions were added. As a result, 2007-2009 STEP participants answered a total of 28 Likert-style survey questions.

In ACMP, online surveys contained 10 Likert-style questions and were administered at the end of annual STEM workshops. In both programs, online surveys also contained questions to which participants could provide open-ended responses of unlimited length.

In both STEP and ACMP, external evaluators conducted case study interviews in the final program year with teachers who had participated in GI framework-based professional development for two or more years. For research purposes, open-ended responses on online surveys were treated in the same way as open-ended responses that were spoken and then transcribed (verbatim) during case-study interviews. In both STEP and ACMP, external evaluators used a semi-structured interview protocol to prompt teachers to broadly describe if involvement in GI framework-based professional development had influenced their classroom instruction. In STEP, all 12 teachers attending the 2009 sustainability workshop were interviewed. In ACMP, 10 participating teachers, three Bering Strait school principals and three district administrators were randomly selected for interview.

In both STEP and ACMP, a grounded theory approach was used to analyze feedback to open-ended responses written on online surveys or spoken during case-study interviews. This approach involves analyzing qualitative data to search for emerging patterns. Rather than fit data into pre-determined themes, the goal of this approach is to derive themes from the data itself. To reduce bias in data analysis, multiple reviewers repeatedly analyzed all entries in all databases. Each reviewer independently analyzed each open-ended comment to determine the primary reason it had been written. Each reviewer assigned a primary-purpose code to each entry. Reviewers then compared and discussed primary-purpose codes until consensus was reached for each entry. When consensus could not be reached, the comment was not categorized. This process was repeated each time further breakdown of a category was merited.

For STEP analysis purposes, each sentence of every open-ended comment (written on surveys or transcribed from interviews) was input as a single entry into one of three databases, distinguished by training venue (i.e. summer institute, field-test course, or sustainability workshop). Because each entry was one sentence long, each entry received only one code.

For ACMP analysis purposes, three databases were developed, distinguished by source (i.e. Lead Teacher reports, case study interviews, or open-ended comments on STEM workshop surveys). Because the external evaluator considered the number of monthly reports from Lead Teachers important, entire monthly reports were input as single entries into the "Lead Teacher reports" database. Because each monthly report consists of two or more sentences, reviewers determined that some entries required two codes to correctly identify report purposes. No entry received more than two codes. To examine entries of comparative size, ACMP case study interviews were broken into paragraphs, and also received up to two codes. Again, no entry received more than two codes. Comments written on STEM workshop surveys were one sentence in length. For this reason, STEM workshop survey entries each received one code.

4.6.2.3 *Participant Outcomes*

Tests gauging teacher STEM content knowledge before and after GI framework-based training were administered in both STEP and ACMP. In both programs, completion of the pre- and post-tests was voluntary, but a higher percentage of teachers completed pre- and post-tests in STEP than in ACMP.

In STEP, teacher testing occurred in-person at UAF under proctor (external evaluator) supervision. In ACMP, teacher testing in rural schools was asynchronous. The external evaluator asked teachers to complete pre-tests online any time within the first month of the school year. Four years later, during the final program year, the external evaluator asked teachers to complete post-tests any time within the last month of school.

In STEP, pre-tests were given in hard copy at the beginning of 2007, 2008, and 2009 summer institutes. Post-tests were given in hard copy at the conclusion of each summer institute. Because the research focus was different for each STEP summer institute, scientists and ASC fellows designed different pre- and post-test questions to elicit teacher STEM content knowledge each year. In 2007, tests focused on climate; in 2008, tests focused on general earth science research; and in 2009, tests focused on Arctic volcanic research.

The STEP external evaluator used the Wilcoxon signed-rank test to determine if statistically significant differences occurred between pre and post-test scores. The Wilcoxon signed-rank test is a non-parametric test for the significance of the difference between the distributions of two related samples involving repeated measures or matched pairs. Like the t-test for correlated samples, the Wilcoxon signed-rank test applies to two-sample designs involving repeated measures, matched pairs, or "before" and "after" measures.

The evaluator used the Wilcoxon signed-rank test, rather than a t-test, because pre- and post-test data did not fit a normal distribution. An α-level of 0.01 was used to assess significance, meaning that the chances of obtaining a significant result when the underlying distributions were not significantly different is less than 1%. In both STEP and ACMP, teachers annually received graduate level credits for completing professional development training. In STEP, summer institute participants received letter grades. In ACMP, Bering Strait teachers received pass-fail grades.

4.6.2.4 *Student Outcomes*

Because both STEP and ACMP contained mechanisms for transferring STEM teacher training to classroom instruction, the external evaluator worked with scientist instructors and education researchers to develop pre- and post-tests that gauged student knowledge of STEM content and process prior to and after their teachers participated in GI framework-based professional development. In STEP and ACMP, student pre- and post-tests included a variety of multiple choice, fill-in-the-blank, and open-ended questions. In both programs, the external evaluator used the Wilcoxon signed-rank test to analyze pre- and post-test differences because pre- and post-test data did not fit a normal distribution.

In STEP, student testing was conducted during the academic year following the 2008 summer institute. Teachers from 24 districts across Alaska enrolled in this (final) STEP field-test course randomly selected about 10 percent of their students to take STEP pre- and post-tests. Tests were administered prior to, and then after, STEP-created lessons were field-tested in K-12 classrooms.

In ACMP, all Bering Strait students took pre-tests at the start of the program prior to field-testing STEM lessons. At the end of each program year, a random number of students were selected to complete post-test questions.

4.7 A COMPARISON OF STEP AND ACMP FINDINGS

4.7.1 *Participation*

Participation in both STEP and ACMP far exceeded expectations. Data sources for both programs reveal sustained high levels of teacher participation and little (to no) teacher attrition.

STEP summer institutes were designed for a maximum of 30 participants. However, teacher waiting lists were so long that two back-to-back sessions were held in 2007 and 2008 to accommodate twice as many teachers as anticipated each year. The final STEP summer institute was to have occurred in 2008, but teacher demand for continued training was so high that the Alaska Department of Education and Early Development authorized additional funding to hold one extra STEP summer institute in 2009. Funding for the last (2009) session became available after school had ended, less than a month prior to its occurrence. Despite limited time to advertise, the course enrollment limit of 30 was filled in less than a week. The waiting list was so extensive that an additional 11 were permitted to enroll and 12 others were re-directed to attend a concurrent sustainability workshop. Teachers in the sustainability workshop developed an online professional development course that was offered for the first time a year after grant funding ended in the fall of 2010. Interest in the STEP online course was so high, the course instructor had to cap enrollment.

Likewise, interest in ACMP professional development was so high that district administrators capped the number of teachers allowed to attend STEM training. This cap was the impetus behind the decision to select two Lead Teachers from each school to attend ACMP training sessions who then replicated training for other staff. ACMP did offer limited training for all Bering Strait teachers. All teachers were invited to view monthly live scientist and Elder video-streamed lectures and to participate in the online mentor network. Initially, all teachers also were invited to attend annual ACMP introductory (overview) workshops, which were held during district wide in-service meetings in Unalakleet, Alaska. However, teacher interest in attending annual ACMP introductory workshops was so high, district administration had to cap attendance and reassign teachers so other workshops offered at in-service conferences would be populated. To accommodate the overflow of teacher interest, ACMP offered extra evening sessions, which also attracted Unalakleet community members. The first grant year, 100 community residents attended; in the second, 650 attended; in the third, 400 attended. This is particularly impressive considering that the population of Unalakleet is only 752 (U.S. Census Bureau, 2000).

Widespread teacher enthusiasm for ACMP training also was evident in the hosting of local ACMP science camps showcasing student work for rural Bering Strait communities.

ACMP provided guidelines for hosting the camps in rural areas, but did not send staffing to rural locations to organize these daylong events. Teachers in each rural site were responsible for advertising and recruiting community members, and for all others aspects of local camp delivery and organization. Despite the labor intensive effort required by rural teachers, every Bering Strait school hosted local ACMP science camps each of the four years the program was offered. An average of 250 local residents annually attended local camps.

4.7.2. *Participant-reported Impact*

4.7.2.1 *Likert-scale Responses*

Responses to Likert-style questions on annually administered online surveys in both GI framework-based programs indicate overwhelming satisfaction with the STEM professional development offered each grant year. In ACMP, anonymous surveys were administered in 2006, 2007, and 2008 after the annual STEM workshop.[4] Each of these program years,

- 100% of ACMP workshop participants surveyed agreed or strongly agreed that the workshop was of high quality, that workshop activities were carefully planned, and that participant questions and answers were addressed;
- 97%-100% of ACMP teachers surveyed agreed or strongly agreed that workshop presenters were effective instructors, that their objectives were clear, and that they used presentation time effectively;
- 93%-97% of ACMP teachers surveyed agreed or strongly agreed that workshop presentations held their interest and that facilities were conducive to learning; and
- 90%-100% of ACMP teachers surveyed agreed or strongly agreed that a nice balance between presentation and interaction with other teachers was achieved.

Responses to Likert-style questions on annually administered STEP surveys indicate

[4] See data tables and more detail on Likert-scale participant-reported impact in ACMP in Chapter 2: The Arctic Climate Modeling Program: Professional Development for Teachers, p. 56.

similar satisfaction with the GI framework-based professional development.[5] At the conclusion of 2007-2009 STEP summer institute, teachers were asked to rate their overall experience in the STEP summer institute. The majority (96% to 100%) of participants ranked the course as good or excellent. At the conclusion of all 2006-2009 STEP summer institutes, teachers were asked to rank how they liked instruction provided by scientist presenters and ASC fellows. Each year, the majority of teachers agreed or strongly agreed that scientists and the ASC fellows were effective instructors (87%-100%), were well prepared (78%-100%), and conducted activities that were carefully planned (80%-100%). In addition, the majority of teachers believed that presentation time was used effectively by scientists (85%-100%) and by ASC fellows (67%-92%).

To delve into teachers' impressions of the course organizational structure and learning environment, 2007-2009 STEP summer institute participants ranked additional statements. The majority of teachers agreed or strongly agreed that: objectives were clear in scientist (91%-98%) and ASC (78%-92%) presentations; activities were geared at the correct level (85%-98%); instructors addressed teachers' questions and concerns (83%-100%); teacher interactions with scientists and ASC fellows were collegial (83%-100%); peer interactions were collegial (89%-100%); and an appropriate balance between content presentation and participant interaction was achieved (91%-98%).

STEP summer institute participants also ranked confidence in their ability to perform specific tasks before and after STEP summer institute involvement. These tasks included: using Alaska content standards to teach science and math and using GLEs to guide assessment of student knowledge of science and math; developing lessons based on locally relevant STEM content; and finding and selecting place-based STEM resources for classroom use. After STEP summer institute involvement the vast majority of teachers (93%-100%) felt well prepared or very well prepared to perform these tasks, and (88%-96%) agreed or strongly agreed that STEP involvement had improved their knowledge and use of Alaska science and math content standards and GLEs.

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[5] See data tables and more detail on Likert-scale participant-reported impact in STEP in Chapter 3: The Science Teacher Education Program: Uniting Arctic Scientists and Rural Alaskan Teachers, pp. 99-104.

STEP field-test courses instructed by ASC fellows held during the academic years following the 2006-2008 summer institutes also received high ratings. Each year, 100% of the participants agreed or strongly agreed that course activities were carefully planned, that an appropriate balance between presentation and interaction was achieved, and that participant questions and concerns were addressed. The vast majority (96%-100%) of field-test course participants agreed or strongly agreed: that ASC fellows were well prepared and effective, that course content was accurately and adequately delivered, and that course objectives were clear. On surveys administered at the conclusion of the 2007 and 2008 follow-on STEP field-test courses, participants also ranked how well they learned course content. The vast majority (95%-100%) of respondents ranked the STEP field-test courses as good or excellent in terms of improving their knowledge of how to apply STEM content learned at STEP summer institutes in their classrooms; improving their knowledge and use of the LCM to create standard-aligned STEM lessons; and improving their knowledge and use of Alaska content standards and GLEs.

4.7.2.2 *Open-ended Responses*

An analysis of open-ended responses in both GI framework-based programs support and clarify Likert-style survey findings. An overarching comparison of themes identified in STEP and ACMP teacher open-ended comments is valuable, however, direct comparison of STEP and ACMP findings is not possible for several reasons. First, because different teams of reviewers analyzed data in STEP and ACMP using the grounded theory approach, different terminology was used in codes describing findings emerging from datasets. Next, the total number of comments analyzed in each program differs. STEP databases contain a total of 2882 entries, while ACMP databases contain a total of 967 entries. Finally, the size of individual entries in program databases and the number of codes assigned differ. In ACMP, individual entries are 2 or more sentences long, therefore, up to two codes could be assigned to each entry. In STEP, individual entries are one sentence long, so only one code was assigned to each entry. Despite these differences, cross-program comparison of teacher open-ended comments in STEP and

ACMP reveals valuable information. Figures 4.4 and 4.5 illustrate that data comparison reveals remarkably similar themes and trends when viewed from a broad perspective.

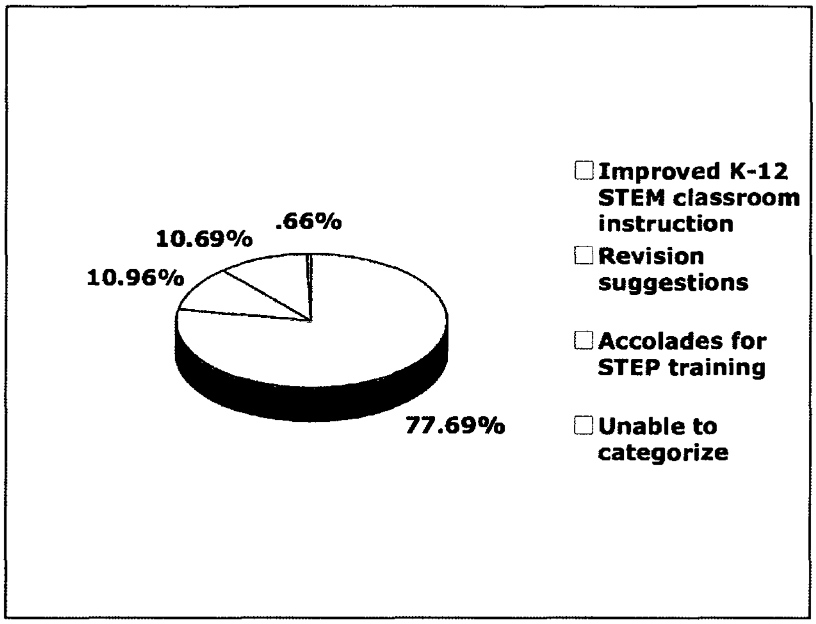

Figure 4.4
Primary Purpose Categories for STEP Open-ended Comments

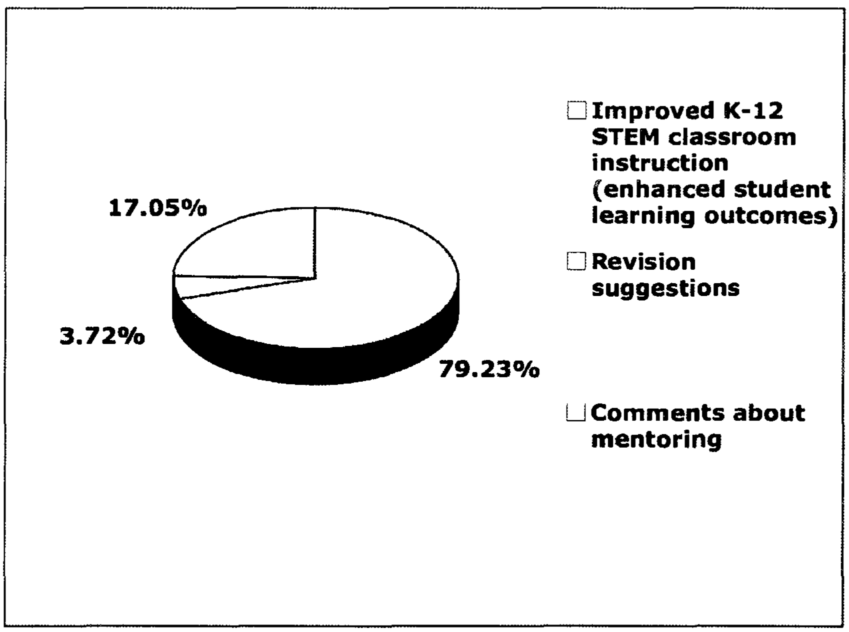

Figure 4.5
Primary Purpose Categories for ACMP Open-ended Comments

The primary purpose of 77.69% of all open-ended comments in STEP databases indicate that GI framework-based professional development improved teachers' K-12 STEM classroom instruction.[6] Similarly, the primary purpose of 79.23% of all open-ended comments in ACMP databases indicate that GI framework-based professional development improved teachers' K-12 STEM classroom instruction or enhanced student-learning outcomes.[7] Likewise, in STEP, 10.96% of all comments offered suggestions for revision; while in ACMP, 3.72% of all comments offered suggestions for revision. In STEP, 10.69% of all open-ended comments offered accolades or praises for STEP training. In ACMP, reviewers using the grounded theory approach did not include this category. Instead, 17.05% of all open-ended comments are dedicated to discussing mentoring support.

Because the primary purpose of the majority of both STEP and ACMP open-ended comments is to explain that GI framework-based professional development improved K-12 STEM classroom instruction (or enhanced student-learning outcomes), reviewers in both programs used a grounded theory approach to ferret out why this was so. In both STEP and ACMP, teachers name the following reasons why involvement in GI framework-based training improved STEM classroom instruction (or enhanced student-learning outcomes):

(a) Learning place-based STEM content, skills, and processes involved in conducting Arctic research;

(b) Learning research-based instructional strategies for increasing indigenous student engagement in STEM study;

(c) Use of "comprehensive curriculum" or multiple, flexible (Alaska-specific) resources that transfer STEM training to classroom instruction; and

(d) Developing mentorship networks of support.

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[6] See data tables and more detail on open-ended participant-reported impact in STEP in Chapter 3: The Science Teacher Education Program: Uniting Arctic Scientists and Rural Alaskan Teachers, pp. 104-114.

[7] See data tables and more detail on open-ended participant-reported impact in ACMP in Chapter 2: The Arctic Climate Modeling Program: Professional Development for Teachers, pp. 56-61.

Below is an overview comparing the percentages of comments in STEP and ACMP databases dedicated to the reasons teachers give for why GI framework-based instruction resulted in improved classroom instruction.

(a) In ACMP, learning place-based scientific content and processes along with the math and technology skills involved in conducting Arctic research is the main reason teachers give for improved STEM classroom instruction (or enhanced student outcomes) in open-ended comment databases. In ACMP, 47% of the codes whose primary purpose is to explain that GI framework-based training improved teachers' K-12 STEM instruction (or enhanced student outcomes) identify learning STEM content, skills and processes used in conducting Arctic research as a primary factor. In STEP, 21% of such comments name this reason.

(b) In STEP, learning a variety of research-based instructional strategies for increasing indigenous student engagement in STEM study is the main reason teachers give for improved STEM classroom instruction in open-ended comment databases. In STEP, 33% of the comments whose primary purpose is to explain that GI framework-based instruction improved teachers' K-12 STEM instruction identify learning best-practice skills as a primary factor. In ACMP, this is the second most frequently given reason for teacher and student improvement. Both STEP and ACMP reviewers used a grounded theory approach to identify the instructional strategies teachers named. In both STEP and ACMP, teachers identify four instructional strategies as being particularly valuable: learning to relate STEM content to local concerns; learning to incorporate tactile (hands-on) activities into STEM instruction; learning to align classroom STEM instruction to state standards; and learning how to infuse STEM into other subject areas (cross-curricular integration). In STEP, a fifth instructional strategy emerged: learning to guide student-driven inquiry, experimentation, and debate. Teachers referred to this in ACMP open-ended comments, reviewers did not identify this as an instructional strategy. Instead, reviewers grouped teacher comments about guiding student inquiry, research and experimentation under the broader, recently described category of "learning place-based STEM content, skills and processes involved in conducting Arctic research."

(c) The value of using comprehensive curriculum (or multiple, flexible Alaska-specific resources) to transfer STEM training to classroom instruction is frequently identified in ACMP and STEP teacher open-ended comment databases. In ACMP, 15% of the codes whose primary purpose is to explain that GI framework-based training improved teachers' K-12 STEM instruction (or enhanced student outcomes) identify the ability to use of "comprehensive curriculum" or multiple, flexible place-based (Alaska-specific) resources as a primary factor. In STEP, 7% of such comments name this reason.

Teacher comments about the value of being able to transfer STEM training into classroom instruction through use of comprehensive curricular resources is similar in STEP and ACMP, even though the origin of curricular resources in these programs differ. In STEP, teachers translated information provided by scientists into K-12 classroom lessons. Their lessons joined a vast array of other standard-aligned resources on place-based (Alaska-specific) themes accessible through the STEP database. In ACMP, scientists and curriculum developers provided teachers with a breadth of classroom resources created to help Lead Teachers provide STEM training to others in Bering Strait schools. Teachers provided input into these resources as they field-tested them with students in their classrooms. These lessons became part of the wide variety of standard-aligned resources accessible through the ACMP website.

(d) Developing mentorship networks of support is an additional reason STEP and ACMP teachers frequently give for improved STEM classroom instruction (or enhanced student outcomes) in open-ended comment databases. In ACMP, mentoring support was so frequently mentioned that reviewers elevated comments on this topic to inclusion in one of four main primary-purpose categories. In ACMP, reviewers reached consensus that the primary purpose of 17% of all comments (165 of 967 comments) discussed mentoring support. In ACMP, reviewers used a broad definition for mentoring support that includes teacher reference to interacting with scientists, Lead Teachers, and "administrators" (identified as the PI and the ACMP staff of education researchers, curriculum developers, and managers). A few ACMP comments in this primary-purpose category also refer to teachers "mentoring" administrators by serving as sources of STEM information for the Bering Strait district. STEP reviewers used a much narrower definition for mentoring. Open-ended comments in this category refer specifically to establishing long-term online and in-person mentorship networks with scientists, peer teachers, and ASC fellows. In STEP, 26% of the comments whose primary purpose is to explain that GI framework-based training improved teachers' K-12 STEM instruction (591 of 2239 such comments) identify developing mentoring networks of support as a primary factor.

In STEP, reviewers additionally identified increased self-efficacy in providing STEM classroom instruction and in working toward STEM goals as a reason teachers gave for improved in K-12 STEM instruction. In STEP, 13% of the comments whose primary purpose is to explain that GI framework-based training improved teachers' classroom instruction refer to increased confidence and ability to achieve STEM-related goals. STEP comments in this category describe the importance of earning credits toward achieving STEM-related goals and recommending STEP to peers so they can advance their goals. A post analysis of ACMP open-ended comments conducted during comparison of research findings indicates that ACMP teachers similarly discuss the value of earning credits, recommend the ACMP program to peers, and experience increased self-efficacy, however, ACMP reviewers did not break out comments on this theme into a separate category.

4.7.3 *Participant Outcomes*

Pre- and post-test comparisons of teacher STEM content knowledge was made prior to, and then after GI framework involvement in both STEP and ACMP. Completion of the pre- and post-tests was voluntary and anonymous. In STEP, pre- and post-testing occurred prior to, and then after each 2007, 2008, and 2009 STEP summer institute.[8] Data indicates that teachers participating in STEP made significant gains in their STEM content knowledge and understanding of Arctic research each year. Participant-reported

[8] See data tables and related detail on participant outcomes in STEP in Chapter 3: The Science Teacher Education Program: Uniting Arctic Scientists and Rural Alaskan Teachers, pp. 114-117.

evidence and feedback collected from online surveys and case study interviews strongly supports the results of these pre-post test findings. A Likert-style survey designed to reveal the degree of STEM content teachers believed they had learned indicates that the vast majority of respondents agreed or strongly agreed that STEP summer institute involvement improved their STEM content knowledge (95%-96% of respondents); enhanced their classroom application of STEM (91%-98%); and increased their interest in current geophysical research (95%-98%).

Pre- and post-testing of teacher knowledge of STEM content and processes also was conducted in ACMP. However, data is not available because so few teachers participated. In ACMP, the external evaluator made pre-tests available online for a limited time at the start of the program; 82 teachers completed online pre-tests. At program end (four years later), the evaluator offered the post-test online the last week of the school year; only 12 teachers completed it. Again, however, anecdotal evidence indicates teachers increased their understanding of STEM concepts. At the conclusion of each ACMP STEM workshop, the external evaluator randomly selected 10% of the teachers to participate in an online survey designed to ascertain the level of their understanding of geophysical research. Over the years, 44 Bering Strait teachers responded. Of these, 93% indicated that ACMP professional development training greatly enhanced their understanding of current climate research being conducted in the Arctic. In addition, as revealed in the previous section of this report, 47% of the open-ended comments whose primary purpose is to explain that GI framework-based training improved teachers' K-12 STEM instruction (or enhanced student outcomes) identify learning the scientific content and processes and the math and technology skills involved in conducting Arctic research as the primary reason for success.

4.7.4 *Student Outcomes*

In both programs, students were randomly selected to engage in pre- and post-tests of STEM content knowledge before and after their teachers transferred STEM training learned through GI framework-based professional development to the classroom.

In STEP, random testing was conducted by teachers participating in the final (2008) STEP field-test course. Random testing was conducted because 100% of the teachers participating in 2006 and 2007 STEP field-test courses stated on online surveys that they believed the STEM knowledge and skills they had acquired through STEP institute training would result in improved student achievement. A random sample of 2,341 students were given pre- and post-tests designed by teams of scientists and ASC fellows to assess student knowledge about Earth Science content and processes before, and then after, their teachers field-tested STEP-created lessons in their classrooms. The pre- and post-tests followed strands of learning evident in GLEs for students at all grade levels. Pre-post comparison indicates that students at all grade levels tested (K-12) showed statistically significant increases in STEM content knowledge.[9]

In ACMP, rural students also were randomly selected to engage in pre-post testing before, and then after interacting with classroom lessons designed to transfer GI framework-based STEM teacher training to students. During the three-year program, 867 students participated in pre-post testing. Analysis revealed significant student improvement from pre-test to post-test each year and overall.[10] Qualitative teacher reports also indicate that ACMP positively impacted student achievement on End of Level tests, which provides an additional measurement of change in student achievement as a result of teacher participation in ACMP. Teachers credited ACMP with improving student knowledge of test concepts and increasing student motivation to pass the exams. Examples (1)—(3) are typical of teacher open-ended comments gathered during ACMP case student interviews that reveal teacher impressions of how ACMP involvement impacted student achievement on End of Level tests.

(1) On the 'Earth and Universe' End of Level science test, students are asked to pick 3 things that affect the Earth and explain how it applies to their

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[9] See data tables and related detail on student outcomes in STEP in Chapter 3: The Science Teacher Education Program: Uniting Arctic Scientists and Rural Alaskan Teachers, pp. 117-118.

[10] See data tables and related detail on student outcomes in ACMP in Chapter 2: The Arctic Climate Modeling Program: Professional Development for Teachers, pp. 61-63.

communities. Before ACMP, students could not answer this question. We would feel extremely lucky if even one student picked one thing to write about. And, if they did write, it would be one or two sentences on the topic. This year, directly because of working with ACMP, all my high school students passed their 'Earth and Universe' End of Level science test for the first time. These kids all wrote on three topics related to climate and weather concepts they had learned in ACMP, pretty difficult concepts—such as the effect of the global ocean conveyer belt, ocean levels rising, and thawing permafrost—and they were able to apply these complex thoughts to effects in their local communities. And, the kids did not write just one or two sentences on each topic. Each kid wrote a book. ACMP really got them thinking."

(2) Everyone realizes that students are passing End-of-Level tests at an accelerated rate after being involved with ACMP, Just look at this example of a student test. Student engagement. When they come to the EOL test they are more comfortable doing the test because in ACMP they have done scientific experiments, they have seen the local impact of climate change, and they say, "Oh, this is a piece of cake." All five students who took the EOL this week got the answer about global warming right. One is an 8th grader, another a 9th grader, another a 10th grader, and two seniors. After work on ACMP, they thought the question was "easy."

(3) Another teacher added, "Two of my classes actually asked if they could work longer on their End of Level tests so that they could be sure they could pass. The reason? They told me, 'If we pass, then we can go on to the next level of ACMP and learn about permafrost next year, right?'"

4.7.5 *Unanticipated Outcomes*

Research in both GI framework-based programs revealed unanticipated research outcomes. In ACMP, a sustained high level of community interest was the most evident unanticipated research outcome. Local Bering Strait residents were interested in research being conducted by ACMP students and Arctic scientists and in STEM professional development on Arctic climate content and processes was. In addition to joining evening ACMP professional development sessions for teachers offered after district in-service meetings in Unalakleet, Alaska, local residents in Bering Strait communities used ACMP technology as a means of gathering information useful for village activities. For example, in the Bering Strait community of Shishmaref, the owner of the only grocery store daily retrieved data from the ACMP school weather station and accessed online satellite imagery to examine weather patterns and near real-time sea ice movement influencing the region. A data display in the grocery store helped others in the community determine when local weather and sea ice conditions were favorable for engaging in subsistence hunting activities central to the Native village culture. In the Bering Strait community of Savoonga, local airlines used data from the school weather station to determine when residents could use the small airstrip that served as the only way in and out of the village.

In STEP a sustained high level of Arctic scientist interest in offering STEM professional development was the most evident unanticipated research outcome. Realizing that STEP summer institutes were held in the middle of Alaska's relatively short summer field season and that a high level of scientist commitment to professional development was required, STEP's initial goal for scientist involvement in professional development was to recruit two Arctic researchers as co-instructors for each summer institute. Instead, unanticipated high levels of Arctic scientist interest in offering STEM professional development caused the PI to involve collaborative teams of up to 10 scientist instructors in each summer institute. Scientist commitment to STEP went beyond offering professional development for summer institutes. In an effort to continue STEP funding after program end, several Arctic researchers discussed the benefits of STEP involvement with the University of Alaska Board of Regents, and arranged for a STEP presentation at the Board's Academic and Student Affairs Committee in June 2010. Other scientists attributed their involvement in other organizations, such as governor panels on climate change, to their STEP involvement.

4.7.6 *A Brief Discussion of STEP and ACMP Findings*

A myriad of factors indicate that both STEP and ACMP provided professional development that effectively prepared culturally responsive teachers of science, technology, engineering, and math. In both GI framework-based programs, participation far exceeded expectations. Participant-reported impact indicates high teacher satisfaction with STEM training offered through STEP and ACMP. Participant-reported impact also reveals the specific reasons teachers believe STEM training offered through STEP and

ACMP resulted in improved STEM K-12 classroom instruction and increased student engagement. Random student testing in both programs supports this belief. Pre- and post-test comparison of student STEM content knowledge before and after their teachers were involved in STEP and ACMP training show statistically significant increases in student STEM content knowledge. Pre- and post-test comparison of teacher STEM content knowledge prior to, and then after GI framework involvement indicates similar statistically significant success.

Unanticipated outcomes of STEP and ACMP pilot studies reveal final measures of program success in different areas. For example, a sustained high level of interest by scientists in providing STEM instruction to teachers during busy summer research seasons offers subsidiary evidence that STEP was successful in providing training and information directly related to Arctic research content and processes. Likewise, a sustained high level of interest by rural Alaska Native residents in ACMP activities offers subsidiary evidence that ACMP was successful in providing training and information that was culturally relevant and locally significant.

An in-depth discussion of the STEP and ACMP findings briefly discussed here is contained in the thesis conclusion. The conclusion also offers evidence that the GI Framework for Professional Development is effective in preparing culturally responsive teachers of science, technology, engineering, and math under diverse circumstances.

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4.9 APPENDICES

Appendix A: Methane in the Arctic and the Role of Permafrost Thaw as a Positive Feedback to Climate Change: A Fact Sheet for STEP Teachers

Appendix B: How to Build a Methane Gas Trap

Appendix C: Examples of Methods used in ACMP to Engage Students in Critical Thinking

Appendix D: Sample Questions Teachers Can Use to Engage Students in Critical Thinking

Appendix E: How Fast is the Wind?

APPENDIX A

Methane in the Arctic and the Role of Permafrost Thaw as a Positive Feedback to Climate Change: A Fact Sheet for STEP Teachers

Prepared by: Aquatic Ecologist Katey Walter and ASC Fellow Gary Cooper

1) **Greenhouse Gases.** Methane (CH_4) and carbon dioxide (CO_2) are important greenhouse gases in the Earth's atmosphere because they contribute to global warming. Most of the heat energy emitted from the Earth's surface is absorbed by greenhouse gases which radiate heat back down to warm the lower atmosphere and the Earth's surface. Increasing the concentration of greenhouse gases increases the warming of the surface and slows the loss of heat energy to space. Methane is a much stronger greenhouse gas than CO_2, but today there is more CO_2 in the atmosphere than methane.

2) **Methane Cycle and Uncertainties.** Methane enters the Earth's atmosphere from different sources, with anthropogenic sources contributing ~60% and natural sources ~40%. Anthropogenic sources include rice agriculture, ruminant animal husbandry, land fills, and energy (coal, natural gas, industry). Natural sources include wetlands, termites, oceans, lakes, wildfires and gas hydrates. Wetlands are the largest source of methane to the atmosphere. Although most sources have been identified, there is large uncertainty in the exact magnitude of their emissions. Uncertainty in the magnitude of sources comes from variability in emissions between seasons and years and also across space. For instance, every wetland does not behave exactly the same: Some types of wetland plants emit more methane than others. Also, wetlands in different regions may be flooded for different periods of time and they only emit methane when they are flooded. So if a researcher measures a small number of wetlands and extrapolates their results to large regions, there can be large uncertainties. With all that methane going into

the atmosphere each year, there would be a runaway greenhouse affect if it were not for 'sinks' of atmospheric methane- or mechanisms that remove methane from the atmosphere. The main sink is oxidation of methane by the hydroxyl radical in the troposphere. Other more minor sinks are loss of methane to the stratosphere and uptake of methane by terrestrial soils.

3) **Permafrost and Thermokarst.** Many people think of ground ice when they hear the word permafrost, but that is not entirely true. Permafrost is defined as permanently frozen ground– rock, sediment or any other earth material with a temperature that remains below 0°C for two or more years. Permafrost does not necessarily contain ice, but ice is common in the surface permafrost of the Arctic and is an important feature of permafrost because when permafrost thaws and ice melts, the ground surface subsides, a process known as 'thermokarst'. When permafrost thaws inland, depressions that fill in with water form small thermokarst ponds that can expand into large thermokarst lakes. As you move from the high Arctic south towards the sub-Arctic, permafrost regimes shift from continuous permafrost, to discontinuous permafrost to sporadic and isolated permafrost. Recently permafrost has been warming and thawing, leading to more thermokarst activity.

4) **The Carbon Cycle and Vulnerabilities to Climate Change—Links between Permafrost and Greenhouse Gases.** The carbon (C) cycle will be presented in detail during the course to show how C moves between key pools such as the atmosphere, plant biomass, soils, permafrost, the ocean and its sediments, fossil fuel and natural gas reserves, and gas hydrates. Permafrost is an important and large pool of C. There is as much C locked up in a frozen state in permafrost in the Arctic in the form of organic matter (dead plant and animal remains) as there is in the atmosphere today; so, if all of permafrost were to warm and thaw, then the C would become available to microbes for decomposition. Decomposition of

organic matter in the presence of oxygen produces CO_2, and in the absence of oxygen it produces methane. Not all organic carbon is the same from a microbe's point of view. Some high-quality carbon, like sugar, will promote fast rates of methane production, while other poor-quality types of carbon, such as lignin in tree bark, will have slower rates of methane production. Production and emission of these greenhouse gases produced from organic matter as permafrost thaws contributes to global warming, which in turn causes further warming and thaw of permafrost constituting a positive feedback to climate warming.

5) **Methane Production and Emission**. Methane is produced under anaerobic (absence of oxygen) conditions of organic matter (dead plant and animal remains) decomposition by bacteria that live in lake and wetland sediments. Methane emission occurs via three pathways: molecular diffusion, through aquatic vascular plants, and by ebullition (bubbling). Ebullition is a very patchy process, but it dominates methane emissions from most lakes. Lakes are a prominent feature of the arctic landscape, so considering the amount of methane bubbling from all lakes results in a significant contribution to the global methane cycle (~6% of global sources is the first-order estimate).

6) **A Method for Measuring Methane Emission from Arctic Lakes.** A new method has been developed to quantify methane ebullition from lakes, taking into account its patchiness. This method involves counting the clusters of methane gas bubbles that get frozen into lake ice when lakes freeze in the fall and winter. Clusters of methane bubbles range from 25 cm^2 to 1 m^2 and represent discrete point sources and hotspots of bubbling. Bubbling hotspots do not refer to temperature, but rather to extremely high rates of bubbling from small openings in lake sediments. Constant high rates of bubbling result in ice-free holes in lake ice overhead, sometimes throughout the entire winter, contributing methane to the atmosphere year-round.

APPENDIX B

How to Build a Methane Gas Trap

Science Teacher Education Program

Materials:

- Waterproof adhesive and sealant
- Two-way stopcock
- 2 cm - 3/8" plastic tubing
- 3/8" drill bit
- Two-liter plastic bottle (no cap)
- 2 other plastic bottles of the same size with caps
- Nylon string
- Black electric tape
- 6 mil plastic sheeting, approximately 1 meter x 1 meter
- 2 meters 9 wire
- Scissors
- Permanent marker
- 1/2 pound weight

Note: Plastic tubing can be any size between 1/4 and 1/2 inches. The drill bit should be slightly smaller in size.

A finished methane gas trap, shown by its inventor, Katey Walter

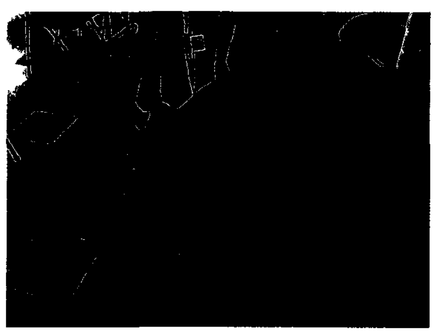
Directions for Assembly:

1. Place the stopcock onto the plastic tubing.

2. Drill a hole at the highest point on the bottom of the two-liter bottle. (NOTE: The hole should be slightly smaller than the outer diameter of the plastic tubing.)

3. Insert the plastic tubing into the hole. It should extend into the bottle only as far as needed to stay put (<1cm). Note: Inserting the tubing too far will result in dead air in the bulb.

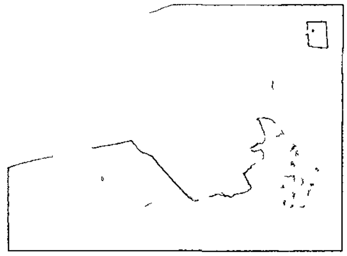
4. Glue around the tubing to secure it to the bottle and around the stopcock to secure it to the tubing to prevent leaks. Make sure there are no holes or air bubbles in the glue; this portion of the assembly should be watertight and airtight. Let sit overnight or several days to dry.



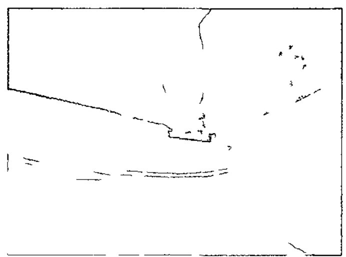
5. Using a permanent marker, mark a dot in the middle of the plastic sheet.

6. Cut a piece of string that is at least half the length of the plastic sheet. Hold one end of the string in the middle of the plastic sheet. Use the string as a compass and draw a rough circle on the sheet. The circle should extend as close to the edge of the plastic sheet so as to make as large a circle as possible.Cut out the circle.

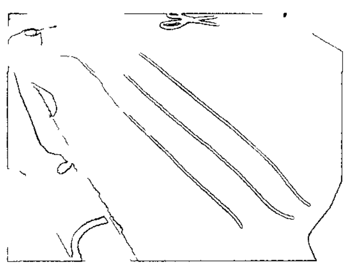
7. Cut a piece of wire, approximately 2 meterst in length. Strengthen the wire so that there are no bends or loops. Weave the wire through the plastic approximately one centimeter from the edge of the circle to form a loop.

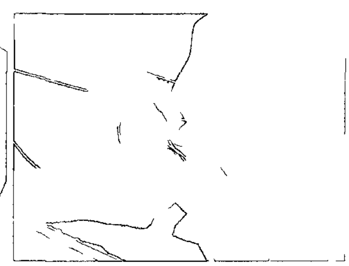


8. Overlap the ends of the wire by several inches and secure with black electrical tape, in two or three places.

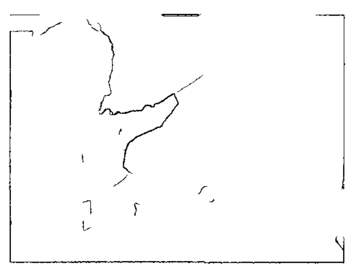


9. Cut three .75 meter long pieces of string. Tie them to the wire at semi-equidistant points along the hoop.

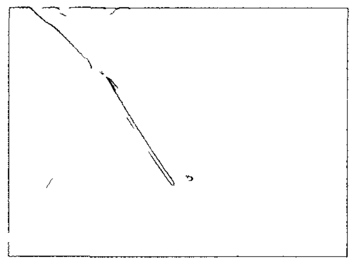




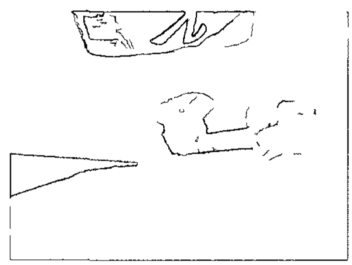
10. Pull the strings together so that the hoop shape is maintained, but there is a minimum of slack. Tie all three strings into a knot. Tie a second knot about 5 centimeters below the first. Cut off the excess string.



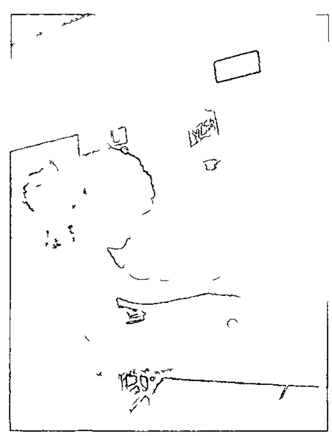
11. At the middle of the plastic sheet as marked, cut a very small hole, smaller than the mouth of the two-liter bottle.



12. Push the mouth of the bottle through the hole. Secure with tape. Be sure to wrap tape tightly; this portion of the assembly should be watertight and airtight.

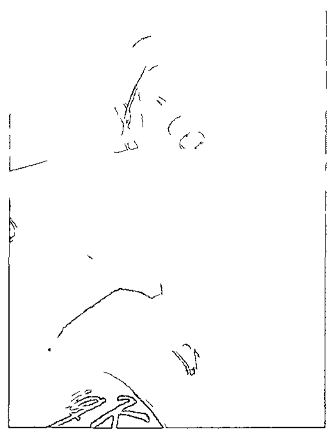


13. Cut another small piece of string and tie it to the weight. Tie the weight between the first and second knot on the strings that hang down from the wire hoop.



14. Cut two additional pieces of string, each approximately .75 meter. Tie one end to another capped plastic bottle and tie the other end to the neck of the two-liter bottle. Repeat with a second bottle and string. These bottles will act as floats in the water.

Note: See photo of finished methane gas trap on first page of instructions.



APPENDIX C

Examples of Methods used in ACMP to Engage Students in Critical Thinking

1. **The 3-minute Rule.** Ask a question and wait three minutes before providing an answer. This allows students to think through their replies and provides an opportunity for several students to answer and expand upon the question. Studies show that teachers often answer their own questions within 5 seconds when students do not respond immediately.

2. **Think-Pair-Share Method.** Distribute a critical thinking question (for example, what affect will shorter arctic winters have on walrus and polar bear?). Ask students to pair up and talk about the question. Once they have explored the question, ask students to share their ideas with the class.

3. **Information Processing Method.** Place a photo, slide or overhead up for the class to see (for example a satellite image from the GINA website of forest fires in interior Alaska). Ask students to break into small groups to discuss how they interpret the image and how it relates to the topic the class has been studying.

4. **The One-Minute Paper Method.** Check student progress and understanding by asking students an open-ended question or a specific statement and give them one minute to write down any ideas or knowledge they have on the topic (for example "describe the carbon cycle").

5. **Activity Response Method.** Ask students to write a paragraph describing their response to an activity or teacher-led demonstration. They can begin their response with "I was surprised to learn…" or "I learned that…" or "I wonder if…"

6. **Wait Time Method.** Explain that in order to give students time to think about their answers you will be asking a question but will not call on them for answers immediately. The wait time can be anywhere from15 seconds to 5 minutes. When the time is up ask for a show of hands or select a student to answer.

7. **The Fish Bowl Method.** Hand out one index card to each student. Ask students to write down one question about the classroom lesson. They may ask a question that will help to clarify something they don't understand about the material, or they may ask a broad question about the subject and its real world application. Ask students to place their questions in a fish bowl and at the end of the class period or at the beginning of the next period, draw out several questions for class discussion.

8. **Puzzle Method.** Develop students' critical thinking by providing clues to a puzzle or a paradox involving aspects of the day's topic. Ask them to find the solution without providing input.

9. **Discussion Method.** When students have completed a lesson, ask them to pair up to compare their answers and discuss how they came up with their answers (for example, they may discuss their findings from an experiment or conflicting information located during a web search).

10. **Concept Mapping Method.** A concept map illustrates connections between terms or concepts. Have students construct concept maps by writing words then drawing lines to connect terms or concepts that share a relationship. Some concept maps may indicate multiple connections (for example a concept map of the carbon cycle). Concept maps help students to determine relationships and organize information.

11. **Role Playing Method.** Ask students to play the role of the subject matter (for example, they may role play being part of the hydrologic cycle, with a drop of water (a clear marble) moving through the cycle and each student playing a part in moving it through the cycle).

12. **Letter Writing Method.** Ask students to write a letter asking questions regarding the subject matter. The letter should be addressed to a person involved in the subject matter. For example, if the students are studying DNA, they may write a letter to Francis Crick or James Watson, who discovered DNA. [The RAFT method of writing could be used here. In the RAFT method students pick a role (inventor, specific person, animal/object, etc.), an audience (specific community, fictional character, president, etc.), a format (poem, letter, diary, resume, article, etc.), and a topic (issue relevant to lesson). Teachers can provide a list of possible RAFTs for students to choose from or students can work independently or in partners to develop their own.]

13. **Debate Method.** Stage a classroom debate on a topic related to the lesson by dividing the class into two teams. Provide each team with approximately 5 minutes to discuss the argument they would like to present to prove their side of the issue. Give each student a chance to speak, taking turns from side to side.

14. **Case Study Method.** Read an article about a real event related to the class lesson. Discuss as a class the real-world situations, consequences, and methods for future improvement or prevention.

15. **What If? Method.** Before performing a demonstration, ask students what will happen if…

16. **How To Method.** After learning a technique or method for solving a problem in the classroom, ask students to write complete instructions for "how to…"

17. **Circle Discussion Method.** Divide students into two groups. The groups should form concentric circles. Assign the interior circle a discussion topic relevant to the lesson while the outside circle listens. Then, have the students reverse positions. This technique stimulates student interest and provokes discussion.

18. **Illustration Method.** Divide the class into groups. Assign each group a principle from the lesson to illustrate. Instruct students to share their illustrations within their group. Then, invite individual students to share their illustrations with the class as a whole.

19. **Anticipation Guide Method.** Before exploring a topic, ask students a series of true and false questions. After students have had a chance to answer independently, go through each question and ask for volunteers to provide an answer and defend it. Encourage debate among students. The anticipation guide will provoke thought and determine students' knowledge and misconceptions. Do not provide the correct answer, but allow students to find the answers throughout the subsequent lesson or activity. The anticipation guide can be used again as an assessment tool at the end of the lesson.

20. **K-W-L Method**. Create a three-column chart to be filled in during student discussion. The first column should be labeled "K (What I KNOW)," the second column "W (What I WANT to Know)," and the third column " L (What I LEARNED)." Fill in the first two columns of the chart by asking students what they know about the lesson topic and what they want to know. After the activity, fill in the third column of the chart.

21. **Question Exchange Method.** Ask each student to write a question regarding the content of the lesson. In pairs or small groups, ask students to answer each other's questions. When groups are finished, allow students the opportunity to ask their questions to the class.

22. **Voting Method.** Provide the class with various explanations or alternatives. Divide the class into small groups. Ask groups to debate the choices. As a class, ask students to vote between the alternatives. Discuss the results.

23. **Interview Method.** Divide students into pairs. Instruct each partner to ask the other questions within a role, or relating to the content; such as, "as a doctor, what you think about smoking?"

24. **Collaborative Story Telling Method.** Read a story or short book to the class. Divide students into teams of three or four. Ask each student to write a sentence to describe the first event in the story. Next, students will pass their sheets to a group member to the right, so that each student has a new sheet of paper. Each student will write a second sentence on the sheet describing the next event in the story. In the end, a complete retelling of the story will exist on each sheet of paper.

25. **Label Analysis Method.** Organize the class into group and provide each group with an empty package or label for a product. Instruct each group to write a description of what they know about the product based on the ingredients. Next, instruct students to make a list of what they don't know about the product. How can students find out what they don't know about the package? Based on what they know, would they recommend its use? Why or why not?

26. **News Clip Observations Method.** Play a clip of a news broadcast without the sound, which shows a topic relevant to the lesson (tsunami, earthquake, weather event, etc.). Ask students to write a script for the news broadcast using what they have learned about the weather event. After students are done, replay the clip with the sound and ask students to compare their script with the real news commentary.

27. **Headlines Method.** Ask students to write a short article, one to three paragraphs, using a headline as a prompt. A headline that is contradictory in nature will provoke more creative answers, such as "Beringia Melting – Flood Imminent."

28. **Venn Diagram Method.** Ask students to describe (and write down) all they know about a STEM topic before it is discussed in class. After they have completed lessons on this topic, ask students to describe (and write down) what they know about the topic. Helping students see how much of it overlaps often can spark meaningful classroom discussion.

29. **Jigsaw Method.** (To be used with class reading.) Divide students into groups of four; these are their home groups. Ask students to assign task within their group: vocabulary – list key scientific vocabulary from the text and define it; outline/summary – develop a framework or outline for the text; P (plus), M (minus), Q (questions) – lists all the scientific ideas in the text, list review concepts with a plus, new concepts with a minus, and questions with a question mark; and webbing – create a web or mind map of the concepts in the reading. After students have read the text together and assigned roles within their home group, ask groups to reform into task groups, with all the people assigned to vocabulary in one group, those assigned to outline in another group, and so on. Ask the task groups to complete their assigned tasks. When all groups have completed their tasks, instruct students to reform their home groups and review their findings.

30. **ABC Summary.** Divide students into small groups. Ask groups to come up with a word or phrase for each letter of the alphabet. Words and/or phrases should be related to the daily lesson. After a predetermined about of time (5-7 minutes), ask groups to read their answers one letter at a time. Groups get a point for each unique answer.

APPENDIX D

Sample Questions Teachers Can Use to Engage Students in Critical Thinking[1]

Analyzing

How could you break down…?

What are the parts of…?

What qualities/characteristics?

Applying

How is ______ an example of…?

What practical applications…?

What examples…?

How could you use…?

How does this apply to…?

In your life, how would you apply…?

Augmenting/Elaborating

What ideas might you add to…?

What more can you say about…?

How could you improve…?

Categorizing/Classifying/Organizing

How might you classify…?

What category does ______ belong to? Why?

What else could you add to this category?

How else could you organize…?

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[1] Adapted in part from "Higher Level Thinking Skills for Personal and Social Skills" www.KaganOnline.com

Comparing/Contrasting

How would you compare…?

What similarities…?

What are the differences between…?

How is ______ like ______?

How is ________ different from __________?

Connecting/Associating

What do you already know about…?

What connections can you make between…?

What things do you think of when you think of…?

Decision Making

What are the pluses and minuses of choosing…?

What would be a better decision…? Why?

Defining

How would you define…?

In your own words, what is…?

Describing/Summarizing

How could you summarize…?

If you were a reporter, how would you describe…?

Determining Cause/Effect

What are the causes of…?

How does ______ effect ______?

What impact might…?

Drawing Conclusions/Inferring Consequences

What conclusions can you draw from…?

What would happen if…?

What would have happened if…?

If you changes______, what might happen?

Eliminating

What part of ______ might you eliminate?

How could you get rid of…?

Evaluating/Assessing

What is your opinion about…?

Why did you like or dislike…?

How would you rate/grade…? Why?

Would you prefer/rather…? Why?

What is your favorite…? Why?

Do you agree or disagree with…? Why?

What are the positive and negative aspects of…?

What are the advantages and disadvantages of…?

Is it better or worse…? Why?

By what criteria would you assess…?

Explaining

How could you explain why…?

What reasons might explain…?

What are some alternative explanations for…?

Experimenting

How could you test…?

What experiment could you do to…?

Generalizing

What general rule can…?

What principle can you apply…?

What is common to all…?

Interpreting

What does _______ mean to you?

What is the significance of…?

What role…?

What is the moral of…?

Inventing

What could you invent to…?

What machine could…?

Investigating

How could you find out more about…?

If you wanted to know more about...?

Making Analogies/Similes/Metaphors

How is _____ like _____?

What similarities do _______ and ________ share?

What analogy/simile/metaphor can you invent for...?

Observing

What did you notice about...?

What observations did you make about...?

What changes...?

Patterning

What patterns can you find...?

How would you describe the organization of...?

If the pattern were to continue...?

Planning

What preparations would you...?

How would you plan to...?

Predicting/Hypothesizing

What would you predict...?

What is your theory about...?

What are some possible explanations why...?

If you were going to guess...?

Prioritizing

What is more important...?

How might you prioritize...?

In what order would you rank...?

Problem Solving

How would you approach the problem?

What are some possible ways to solve...?

Questioning

What questions do you have about...?

If you could ask a question of...?

Reducing/Simplifying

In a word/sentence, how would you describe...?

How can you simplify...?

Reflecting/Metacognition

What were you thinking when...?

How has your thinking changed...?

How could you describe what you thought about...?

Relating

How is ______ related to _______?

What is the relationship between...?

How does ______ depend on _______?

Reversing/Inversing

What is the opposite/antonym of...?

Role-Taking/Empathizing

If you were (someone/something else)...?

How does ______ look like to ______?

What would it feel like to be...?

Sequencing

How could you sequence...?

What steps are involved in...?

Substituting

What else could you use for/instead of...?

What is a synonym for...?

What is another way you could...?

Symbolizing

How could you express it with a drawing/symbol/song/movement/poem?

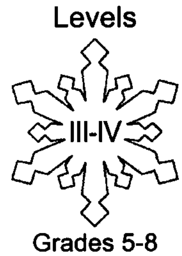
Synthesizing

How could you combine/put together...?

What could you make using...?

APPENDIX E

HOW FAST IS THE WIND?



Overview:

Traditional knowledge of wind is important to indigenous people for many reasons, including success in hunting and safety in travel. Knowledge of wind speed and direction are vital to many current professions, including accurate weather prediction. In this activity, students build an anemometer then measure wind speed in areas of differing topography to study how natural and man-made topography affects wind speed.

Objectives:

The student will·

- build an anemometer;
- measure wind speed at two different locations;
- compare wind speed measurements to determine if topography has an affect.

Targeted Alaska Grade Level Expectations:

Science

[7-8] SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring, and communicating.

[8] SD2 1 The student demonstrates an understanding of the forces that shape Earth by interpreting topographical maps to identify features (i.e., rivers, lakes, mountains, valleys, island, and tundra).

[8] SG2 1 The student demonstrates an understanding of the bases of the advancement of scientific knowledge by describing how repeating experiments improves the likelihood of accurate results.

Vocabulary:

anemometer – an instrument that measures the speed and force of the wind; the most basic type of anemometer consists of a series of cups mounted at the end of arms that rotate in the wind; the speed with which the cups rotate indicates the wind speed

revolution – the motion of an object around a point, especially around another object or a center of mass; a single complete cycle of such motion

topographic map – a map depicting local land features and elevation

topography – the shape, height, and depth of the land surface in a place or region, physical features that make up the topography of an area include mountains, valleys, plains, and bodies of water, man-made features such as roads, railroads, and landfills are also often considered part of a region's topography

wind speed – the speed at which the air in the atmosphere is moving

Whole Picture:

The term wind is used to describe the movement of air. Air moves from higher pressure toward lower pressure creating wind Wind can also be modified by mountains and turned by the spinning of Earth

An anemometer measures the force or speed of the wind A common anemometer, such as the one constructed in this lesson, uses cups mounted on four horizontal arms at equal distance from each other on a vertical shaft. The air flow past the cups turns the cups in proportion to the speed of the wind

Wind direction and speed are monitored by meteorologists, pilots, sailors, scientists, architects and others who need to know Earth's weather activity. From planning trips, to building sound structures, to understanding what shapes Earth, wind speed and direction are integral. For example, rural indigenous subsistence hunters need information on wind speed and direction to aid in travel safety and animal tracking success

HOW FAST IS THE WIND?

Many anemometers convert the revolutions per minute into wind speed measured in several different ways:

- ***Miles per hour (mph)*** – unit of speed measuring the number of miles covered in a period of one hour.
- ***Knots*** – unit of speed measuring one nautical mile per hour. A nautical mile is slightly longer than a mile, and corresponds to one arc minute of latitude along any meridian.
- ***Meters per second (m/s)*** – unit of speed measuring the number of meters covered in one second.
- ***Feet per second (f/s)*** – unit of speed that tells the number of feet covered in one second.
- ***Kilometers per hour (km/h)*** – unit of speed that tells the number of kilometers covered in one hour.

A crane operator, for example, needs to know wind speed and direction when he or she plans to operate a tall crane A landfill operator must know the behavior of the wind in order to maintain odor control.

The speed at which the wind is moving the clouds is especially important in forecasting (predicting) the weather. A scientist may study the way in which wind causes erosion.

Materials:

- Flexible straws (four per student)
- Condiment cups (four per student)
- Balsa wood or mat board (very thin) cut to 1½" square (two per student)
- Pencils with flat erasers (one per student)
- Washers (one per student)
- T-pins (one per student)
- Sticker (one per student)
- Stopwatch
- Computer with Internet access and multimedia projection capability
- DIGITAL LECTURE: "Chief Robert Charlie Talks About Wind" available on the UNITE US website (uniteusforclimate.org)
- STUDENT INSTRUCTION SHEET· "Build an Anemometer"
- STUDENT WORKSHEET. "Measuring Wind Speed"
- STUDENT WORKSHEET: "Wind Vocabulary"

Activity Preparation:

1. Bookmark DIGITAL LECTURE: "Chief Robert Charlie Talks About Wind" (uniteusforclimate.org).
2. Gather materials for "Build an Anemometer".
3. Plan ahead for students to take wind speed measurements at two different locations, with different topographic features. Examples might include a hillside versus a riverbank, a parking lot versus a wooded area, an open field versus a space between two buildings, etc. If possible, allow different groups to measure different data sets to add to later discussion

Activity Procedure:

1. Introduce DIGITAL LECTURE. "Chief Robert Charlie Talks About Wind" (uniteusforclimate.org). Students should listen and mentally note two important reasons wind is important in Alaska Native traditional knowledge When the video segment is over, ask students to review reasons traditional knowledge of wind is important. (Charlie discussed hunting and travel, however students may have additional comments from personal experience)
2. Explain students will build an anemometer, an instrument used to measure wind speed Using the STUDENT INSTRUCTION SHEET. "Build an Anemometer" as a guide, lead students through the process of building anemometers
3. Hand out the STUDENT WORKSHEET: "Measuring Wind Speed." Explain students will work in teams to measure the wind speed using handmade anemometers. Assign students to teams, then each team to one of the determined topographic locations Ask students to complete the Hypothesis section and read the procedure aloud as a class.

HOW FAST IS THE WIND?

4. Take students outside. Ask them to use the anemometers to measure wind speed. Using the stopwatch to keep time, students should count how many times their anemometer spins in 60 seconds and record their measurements in the data section of their worksheets. The procedure is repeated three times at each location
5. Bring students inside and instruct them to complete the "Analysis of Data" and "Conclusion" on their own or in teams.
6. As a class, look up the wind speed forecast at http.//climate gi.alaska.edu/Wx/forecast.html. Discuss how this data could be used to predict weather.
7. Ask students to complete the remainder of the worksheet, "Further Discussion"
8. Hand out STUDENT WORKSHEET: "Wind Vocabulary" and ask students to complete individually, in groups, or as a class.

Language Links:

Alaska Native people have always been careful observers of the weather. Their languages are rich in words describing weather. Ask a local Native language speaker to provide the words in the local dialect for the weather phenomenon listed in the chart below. The local dialect for these words may differ from the examples provided. Share the words with students to build fluency in local terms related to weather. Include local words in songs, stories and games when possible.

Bilingual Vocabulary Unit 2: Exploring the Land Around You

English	Gwich'in	Denaakk'e	Lower Tanana	Deg Xinag	Your Language
Rain / it's raining	Tsin / ahtsin	Kohn / yołee hødelaatlghaanh	Chonh	Chonh	
Wind / it's windy	Ahtr'aii	Ts'ehy	Eltr'eyh	Xidetr'iyh	
Snow'it's snowing	Zhah	Tseetl	Yeth	Yith	
Clouds / it's cloudy	Zhee k'oh / gwit'eh goo'aii	Kk'ul / yokk'uł hoolaanh	K'wth / k'wth xulanh	Q'uth	
Sun / it's sunny	Drin oozhrii	So / Soleł	Sro	No'oy	

Extension Ideas:

Study a topographic map of the entire state then compare statewide wind speed predictions on the National Weather Service site (http.//forecast.weather gov) to topographic features and see if any patterns emerge.

Using a topographic map of your community, study the features and discuss which could change over time (hills could erode, forests could burn in a fire, the town could grow much larger, streets could be paved, parking lots installed, etc). Make a model of how these changes could change wind directions, speed and patterns

Using a topographic map of your community, plan an overland snow machine route, round trip, within a 50-mile radius Plan for ease of access but account for protection from the wind and weather.

Critical Thinking Questions:

1. How is topography related to wind speed and direction?
2. What topographical features would you study if you were planning a moose hunt? An overland snow machine trip?
3. If you were going to build a wind powered generator, where would you put it?
4. How could you find out more about how landforms affect wind?
5. If you changed the altitude (height) of an anemometer at the same location, what would your wind speed reading show?

HOW FAST IS THE WIND?

6. How could you compare the reading on your hand made anemometer of revolutions per minute with the National Weather Service wind speed given in miles per hour?
7. If your community was surrounded by forest, then experienced a devastating forest fire that eliminated one quarter of the tree cover, how might the wind patterns change?

Answers:

STUDENT WORKSHEET: "Measuring Wind Speed"

Answers will vary.

STUDENT WORKSHEET: "Wind Vocabulary"

1. topography
2. anemometer, wind speed
3. topographic map
4. revolution

Answers to matching:

mph = unit of speed measuring the number of miles covered in a period of one hour
knots = unit of speed measuring one nautical mile per hour
m/s = unit of speed measuring the number of meters covered in one second
f/s = unit of speed that tells the number of feet covered in one second
km/h = unit of speed that tells the number of kilometers covered in one hour

BUILD AN ANEMOMETER

STUDENT INSTRUCTION SHEET

Materials:

- Flexible straws (four per student)
- Condiment cups (four per student)
- Balsa wood or mat board (very thin) cut to 1-1/2" square (two per student)
- Pencils with flat erasers (one per student)
- Washers (one per student)
- T-pins (one per student)
- Sticker (one per student)

Procedure:

1. Bend each straw at a 90 degree angle as shown in Figure 1.
2. Tape two of the straws together as shown in Figure 2.
3. Tape the remaining two straws together so there are two sets that look the same (Figure 3).
4. Tape the two sets of straws together to make the frame (Figure 4).
5. Tape a wood square to the center of the straws on each side of the frame (Figure 5).
6. Put a sticker in the bottom of one of the condiment cups.
7. Attach one cup to the end of each straw. Make sure they are all pointing the same direction (Figure 6).
8. Poke the pin through the center of the wooden squares in the center of the frame. Put the end of the pin through the washer, then push the pin into the pencil eraser (Figure 7).

Figure 1

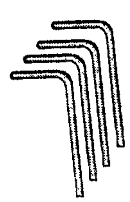


Figure 2

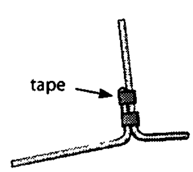


Figure 3

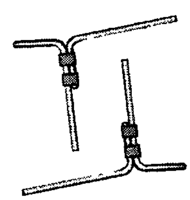


Figure 4

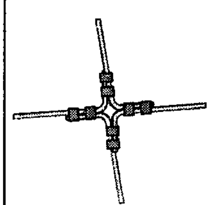


Figure 5

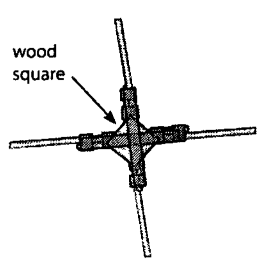


Figure 6

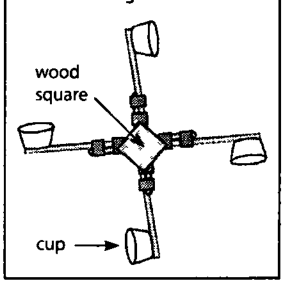
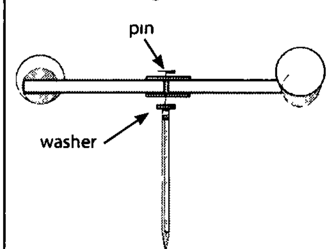
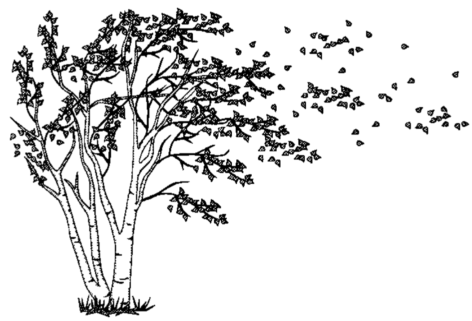


Figure 7



NAME: ______________________________ STUDENT WORKSHEET (page 1 of 2)

MEASURING WIND SPEED



Testable Question:

Does wind speed change due to differences in topography?

Hypothesis:

Write your choice.

Topography ___________________ influence wind speed.
does / does not

Experiment:

Materials:

- Anemometer
- Stopwatch

Preparation:

With the permission and/or direction of your teacher, choose two different locations to take wind speed measurements. The two places should have different topography, such as a hillside and a parking lot or a riverbank and wooded area.

Procedure:

1. Hold the anemometer so that the wind is blowing directly at it, causing it to spin around.
2. Work in teams. One student will serve as the timer, another as the counter.
3. **Counter**: watch the cups, looking for the one with the sticker. When it is visible, say "start."
4. **Timer**: when the counter says "start," start the stopwatch. When the stopwatch reaches 60 seconds, say "stop."
5. **Counter**: One revolution is a complete turn of the anemometer. Count revolutions by counting the number of times the sticker appears. After the timer says "stop," record the number of rotations in the Data section.
6. Switch positions and repeat.
7. Repeat steps 3 through 6 three times at location 1.
8. Move to location 2 then repeat the procedure.

Data:

In the chart below, record the number of times the anemometer rotated in the 60-second period.

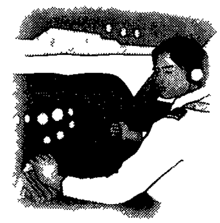
Location 1:		**Location 2:**	
Test	**Number of Revolutions**	**Test**	**Number of Revolutions**
1		1	
2		2	
3		3	

Analysis of Data:

Take an average of the three measurements for each location.

NAME: ____________________________ STUDENT WORKSHEET

MEASURING WIND SPEED (page 2 of 2)



Location 1:

(__________ + __________ + __________) ÷ 3 = __________ rotations per minute
test #1 test #2 test #3

Location 2:

(__________ + __________ + __________) ÷ 3 = __________ rotations per minute
test #1 test #2 test #3

Conclusion:

Circle the best answer below. Choose from the words in **bold.**

Compare results from Location 1 and Location 2.

There was **no difference / some difference / significant difference** in wind speed between the two locations.

Was your hypothesis proved or disproved? ____

Why do you think this is? ____

____

____

Further Discussion:

Visit the National Weather Service website and note the prediction for today's wind speed: __________ mph

Why do you think the National Weather Service often gives a range of possible wind speed?

____

____

Name two reasons that traditional knowledge of wind is important for Alaska Native People.

____

____

What kinds of professions need to know about wind speed? Name at least three.

____

____

____

NAME: ______________________ STUDENT WORKSHEET

WIND VOCABULARY

Directions: Using the word bank, fill in the blank with the correct term.

1. Mountains, rivers and roads are examples of ______________________.
2. A(n) ______________________ measures ______________________.
3. A(n) ______________________ identifies local landforms.
4. One complete turn of a wheel equals one ______________________.

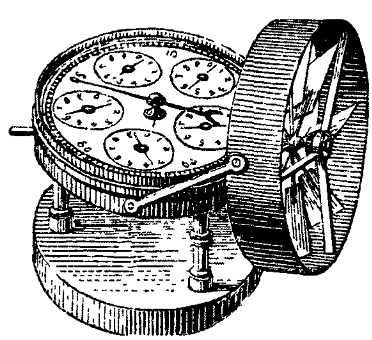
Word Bank

wind speed
topography
topographic map
anemometer
revolution

Directions: The following terms often are used to describe wind speed. Match the acronym or word to the corresponding definition.

mph	**unit of speed measuring one nautical mile per hour**
knots	**unit of speed that tells the number of kilometers covered in one hour**
m/s	**unit of speed measuring the number of meters covered in one second**
f/s	**unit of speed measuring the number of miles covered in a period of one hour**
km/h	**unit of speed that tells the number of feet covered in one second**

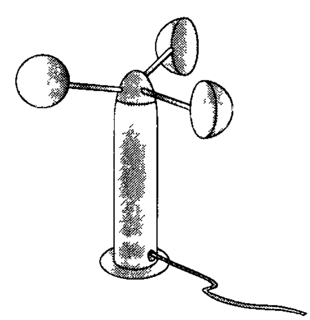
Early anemometer



Florida Center for Instructional Technology

"An instrument for indicating the velocity or pressure of the wind; a wind-gage." —Whitney, 1902

Modern anemometer



Wind speed and pressure is important information recorded by modern anemometers at weather stations worldwide.

CONCLUSION

C.1 OVERVIEW

Research conducted for this thesis provides evidence that the Geophysical Institute (GI) Framework for Professional Development is effective in preparing culturally responsive teachers of science, technology, engineering, and math (STEM) under diverse circumstances.

To test framework effectiveness, research was conducted on two STEM professional development programs based on the GI framework: the Arctic Climate Modeling Program (ACMP) and the Science Teacher Education Program (STEP). These programs were chosen because they offered two distinctly different venues for providing STEM professional development for K-12 teachers.

STEP offered summer institutes on the UAF campus, which were attended in person by more than 175 teachers from 33 Alaska school districts. By contrast, ACMP remotely served 165 teachers in one rural Alaska school district along the Bering Strait. Due to significant challenges in making professional development opportunities accessible to teachers in this geographically isolated district off the road system, ACMP offered unique "curriculum resource-based professional development" that provided a year-round mix of in-person, long-distance, online, and local training for rural teachers.

Chapter 2 presents findings from research conducted on ACMP. Chapter 3 presents findings from research conducted on STEP. Chapter 4 compares ACMP and STEP strategies for meeting GI framework cornerstones, research methodologies, and findings.

C.2 DISCUSSION

Consistently high teacher participation in both ACMP and STEP is one of the most obvious indicators of GI framework success. Both ACMP and STEP offered yearlong STEM professional development for four consecutive years. Rather than battle against attrition as many STEM professional programs do, participation in both ACMP and STEP far exceeded expectations each year. In STEP, teacher waiting lists to participate in professional development were so extensive, that extra summer institutes and workshops were added to accommodate the overflow. In ACMP, teacher waiting lists were so long, Bering Strait School District administrators had to cap attendance at STEM workshops. To ensure all teachers could receive STEM training without leaving their rural schools, Bering Strait administrators designated Lead Teacher representatives from each school in the district to attend ACMP professional development training and then provide the training to others in a hierarchy of support. ACMP added a variety of extra options to supplement STEM training provided by Lead Teachers for other staff. Training options that offered broad participation for staff unable to attend in-person STEM training included evening workshops, local science camps, live video-broadcast lectures offering synchronous communication with mentor instructors, and an online mentor network offering asynchronous communication with scientists.

Consistently high, sustained participation is critical to the success of STEM professional development programs that offer comprehensive yearlong training. The GI framework was designed primarily for Alaskan teachers in schools in which indigenous students compose a substantial part of the student population. For this reason, ACMP and STEP offered extensive training that was created by backward design to student learning goals based in both principles of indigenous ideology and Alaska standards. Place-based STEM professional development built from this foundation focused on Arctic geophysical topics relevant to Alaskan indigenous students presented in an integrated manner that mirrored processes used in authentic Arctic research and reflected principles of indigenous ideology.

Participant-reported impact data reveal that ACMP and STEP teachers believe they made significant gains in both their STEM content knowledge and in their ability to provide place-based, standard-aligned, culturally responsive STEM instruction. In STEP, pre- and post-tests of teacher content knowledge help substantiate this belief. For three consecutive years, pre- and post-tests administered to teachers attending STEP summer institutes before and after GI framework involvement indicate statistically significant increases in their place-based STEM content knowledge and in their understanding of processes used to conduct authentic Arctic research. To help transfer GI framework-based STEM training into K-12 classroom instruction, both ACMP and STEP provided teachers with multiple, flexible curricular resources. These resources encapsulated GI framework-based training and interwove STEM concepts and processes derived from Arctic researchers and indigenous knowledge bearers. ACMP and STEP comprehensive resources provided step-by-step guidelines to help teachers implement research-based instructional strategies for engaging indigenous students in STEM studies. Teachers received instruction in a variety of methods of engagement so they could tailor STEM instruction to meet their overall classroom needs and the needs of individual students.

In both ACMP and STEP, teachers were involved in the creation of sustainable resources used to transfer STEM training to the classroom. Teacher input was sought to ensure ACMP and STEP resources contained the elements needed to encapsulate GI framework-based instruction for future teachers.

In both ACMP and STEP, teacher involvement in the iterative design process promoted sustained yearlong teacher participation. This experience supports research indicating that involving teachers in curricular resource design builds teacher enthusiasm, pedagogical content knowledge, and ownership of the end product (Coenders, Terlouw, & Dijkstra, 2008; Hollon, Olson, Eierman, Havholm, & Hendrickson, 2002; White, 1992). It also supports research indicating that teacher ownership in the end product promotes continued implementation of the curriculum and enactment of the prescribed pedagogy (Coenders et al., 2008; Gess-Newsome, Southerland, Johnston, & Woodbury, 2003; Hollon et al., 2002).

Participant-reported impact data reveals that ACMP and STEP teachers believe GI framework-based training resulted in increased student STEM engagement and achievement. This finding supports research indicating that use of quality resources involving teachers as collaborators in development results in student gains (Gunckel & Moore, 2005; Hollon et al., 2002; White, 1992), and that teacher enthusiasm for STEM instruction increases student interest, engagement and achievement (Anderman, Patrick, & Ryan, 2004; Patrick, Hisley, & Kempler, 2000; Brigham, 1991). Student pre- and post-testing provides substance to this belief. Pre- and post-tests administered to randomly selected students before and after their teachers were involved in ACMP and STEP training reveals statistically significant increases in student STEM content knowledge. Random student testing was conducted in schools in which indigenous students compose a substantial part of the student population.

Participant-reported impact data reveal overwhelming satisfaction with GI framework-based professional development offered in ACMP and STEP. Likert-scale survey responses indicate consistently high ratings of ACMP and STEP workshops. Teachers in both programs believe their GI framework-based STEM instructors were effective, organized, and knowledgeable, and that the training they received was of high quality and carefully planned. Likert-scale survey responses also indicate that ACMP and STEP teachers strongly believe they are much better prepared to offer standard-aligned, place-based STEM instruction that engages indigenous students after GI framework-based professional development.

Open-ended comments support and clarify Likert-scale survey findings. In both ACMP and STEP, the primary purpose of more than three-quarters of open-ended comments in combined databases is to describe how involvement in GI framework-based professional development improved teachers' K-12 STEM classroom instruction (or enhanced student-learning outcomes). Detailed grounded theory research was conducted in both ACMP and STEP to discover what aspects of GI framework-based professional development were most instrumental in improving teachers' K-12 STEM classroom instruction (or in enhancing student-learning outcomes).

Data emerging from teacher comments in both ACMP and STEP synchronizes with core GI framework cornerstones. In both programs, teacher comments attribute improved STEM instruction and increased indigenous student engagement and achievement primarily to:

- learning place-based STEM content, skills, and processes involved in conducting Arctic research;
- learning research-based instructional strategies for increasing indigenous student engagement in STEM study; and

- use of "comprehensive curriculum" or multiple, flexible (Alaska-specific) resources that transfer STEM training to K-12 classroom instruction.

Teachers in both ACMP and STEP also attribute improved instruction and increased student engagement to developing sustainable mentorship networks of support with Arctic scientists, indigenous knowledge bearers, master teachers, and peer teachers. In ACMP, comments on mentoring expand to include support from the program staff of education researchers, curriculum developers, and managers. Both ACMP and STEP teachers also report that GI framework involvement resulted in increased self-efficacy in providing STEM instruction (in the classroom) and in working toward personal STEM-related goals (beyond the classroom).

GI framework-based programs emphasize a variety of research-based instructional strategies for engaging indigenous students in STEM instruction. It is interesting that the instructional strategies named in ACMP and STEP teacher open-ended comments as being most influential in engaging indigenous students in STEM study are synchronous with core GI framework learning goals. Instructional strategies named in ACMP and STEP teacher open-ended comments include: learning to relate STEM content to local concerns (i.e., to provide place-based and community-based instruction), learning how to infuse STEM into other subject areas (i.e., cross-curricular integration), and learning to incorporate tactile (hands-on) activities into STEM instruction. All of these strategies align with GI framework-based student learning goals rooted in principles of indigenous ideology. These findings lend support to research indicating that Alaska Native students succeed academically at higher rates when instruction is hands-on (Assembly of Alaska Native Elders, 1999; Wilson, 1997), addresses topics of local interest (Kawagley, 1995; Lipka, 1998; Battiste, 2000), and incorporates local knowledge and culture (Boyer, 2006).

Other instructional strategies emphasized in ACMP and STEP teacher open-ended comments as being influential in engaging indigenous students in STEM study align with GI framework-based student learning goals rooted in standards mandated by the state of Alaska. These instructional strategies include: learning to align classroom STEM instruction with Alaska grade level expectations (i.e., to provide instruction on concepts and processes that form the basis of Alaska standard-based assessments gauging student proficiency in science, math, and language arts) and learning to guide student-driven inquiry, experimentation, and debate (i.e., to provide instruction aligned with state-mandated scientific process skills).

C.2.1 *Unanticipated Outcomes*

Unanticipated outcomes of ACMP and STEP research also provide circumstantial evidence that the GI framework is effective in preparing culturally responsive teachers of science, technology, engineering, and math under diverse circumstances. In ACMP, STEM professional development was provided for teachers in the Bering Strait School District, which spans 80,000 square miles (an area larger than the state of Nebraska). Bering Strait schools are located in 15 well-established Alaska Native communities, most of which are accessible only by small aircraft or boat. These rural communities are not connected by roads and are isolated from each other and from urban centers. The Bering Strait School District serves a 98% Alaska Native student population; however, 94.5% of its teachers are non-Native, which is reflective of the state as a whole (Suderman, 2008). To address the cultural and experiential differences between teachers, students and their families, ACMP professional development included training in a variety of research-based skills shown to increase minority student STEM success.

One of the most significant unanticipated outcomes of ACMP research was sustained high interest by local Alaska Native residents in ACMP student schoolwork, in research being conducted by ACMP students and Arctic scientists, and in ACMP professional development on Arctic climate.

Community interest in research being conducted by ACMP students and Arctic scientists was demonstrated by local resident use of ACMP data and information. For example, in the Bering Strait community of Shishmaref, the owner of the only local grocery store daily retrieved and displayed data from the ACMP school weather station along with associated satellite imagery showing near real-time weather patterns and sea ice movement influencing the region. Others in the community consulted the display to help determine when local weather and sea ice conditions were favorable for engaging in subsistence hunting activities central to the Native village culture. In the Bering Strait community of Savoonga, local airlines used data from the school weather station to help determine when flights could take off and land in the village.

Community interest in ACMP STEM professional development was demonstrated by annual local resident attendance at evening ACMP introductory workshops for teachers. These ACMP workshops were designed to provide an overview of the activities teachers would offer students in the upcoming school year. Evening ACMP introductory workshops in Unalakleet, Alaska, were not publicized and local residents were not invited to attend. The evening workshops were created for teachers unable to attend introductory workshops during the working day. Even so, the first grant year, 100 local residents attended; in the second grant year, 650 attended; in the third grant year, 400 attended. This is impressive considering that the population of Unalakleet is only 752 (U.S. Census Bureau, 2000). Because Unalakleet is the site of school district headquarters, it is one of the larger communities in the district.

Community interest in student schoolwork on Arctic climate was demonstrated by high local attendance at annually held ACMP science camps. Remarkably, ACMP science camps were organized, publicized, and run solely by teachers and students in the villages. ACMP supplied only a guiding science camp manual and limited supplies (such as ribbons for community members who completed all student-offered STEM stations). An annual average of 250 local residents attended each camp. Again, this is notable attendance, considering the average population in a Bering Strait community is only 396 (Alaska Department of Commerce, Community, and Economic Development, 2009).

Another unanticipated outcome of ACMP training in the Bering Strait School District was an overall reduction in teacher turnover while the ACMP program was in place. During these years, average teacher turnover went from about 30% (at the start of ACMP) to 20% (Hill & Hirshberg, 2008) by program end. Also, during this time, Cheryl Silcox, a teacher in the Bering Strait community of White Mountain involved in ACMP, won a prestigious Presidential Award for Excellence in Mathematics and Science Teaching. This award is given annually to the 100 best pre-college-level science and math teachers from across the country.

In STEP, a high level of interest among Arctic scientists in offering STEM professional development was the most unanticipated outcome of research. STEP's initial goal for scientist involvement in professional development was to recruit two Arctic researchers as co-instructors for each summer institute. This concession was made to honor the fact that STEP summer institutes were held in the middle of Alaska's relatively short Arctic summer research field season and that a high level of scientist commitment to professional development was required. Despite these demands, unanticipated high numbers of Arctic scientists expressed interest in offering STEM professional development. For this reason, the PI revised initial goals to involve collaborative teams of up to 10 scientist instructors in each summer institute.

Scientist commitment to STEP went beyond offering professional development at summer institutes. In an effort to continue STEP funding after program end, several Arctic researchers discussed the benefits of STEP involvement with the University of Alaska Board of Regents, and arranged for a STEP presentation at the Board's Academic and Student Affairs Committee in June 2010.

Unanticipated outcomes of the STEP study also include scientist-reported benefits from interaction with K-12 teachers during STEP summer institutes, such as learning new instructional strategies professors continue to use in other teaching venues. In addition, scientists attribute STEP involvement with newly found participation in other STEM organizations, such as national STEM education committees and Alaska governor panels on scientific topics, such as climate change.

C.2.2 *Limitations*

To reduce bias, four people twice reviewed open-ended comments for every entry in ACMP and STEP qualitative databases. Even so, assigning codes is a subjective process, and it is possible that other reviewers could have detected other patterns. For example, different teams of reviewers were involved in analyzing open-ended comments in STEP and ACMP, which resulted in the use of different terminology when describing findings. Although the use of different terminology made difficult the direct comparison of open-ended comments, overarching comparison of themes identified in teacher comments was still possible and valuable.

Because scientists involved in STEP wanted to evaluate specific concepts taught during each summer institute, they created the pre- and post-test questions that gauged teacher-learning outcomes. Although these questions were pilot-tested by teachers outside the STEP program and reviewed by the PI and ASC fellow instructors, it would have been preferable to use validated, published tests instead. Unfortunately, such tests were not available. The same is true of the pre- and post-tests used to assess student-learning outcomes in both STEP and ACMP.

Student outcomes in both GI framework-based programs were conducted without control-group comparison. In ACMP, experimental design was forfeited at district administrator request. Once teachers (and their students) in the test group discovered the value of ACMP involvement, Bering Strait administrators requested that ACMP training be made available for all students and teachers in the district. In STEP, teachers from 33 districts across Alaska involved in GI framework-based instruction gave pre-tests to students before and after STEM training. STEP teachers were asked (and offered monetary incentives) to provide the same pre- and post-testing to a random number of students in parallel classrooms in the same school as a form of control-group comparison. When this did not work, school administrators were asked to provide the standard-based assessment scores of students in classrooms taught by STEP teachers and those of students in classrooms taught by teachers who were not involved in STEP. Two years later, these scores have not yet been made available.

C.2.3 *Implications*

Results of this study could provide data useful for broader educational research. Because pilot-study research provides evidence that the GI Framework for Professional

Development is effective in preparing culturally responsive STEM teachers under the two diverse circumstances described in this thesis, it is likely that the framework may be effective in other circumstances as well. Conducting full-scale research on GI framework-based programs in Alaska (using experimental design and control-group comparison) is a natural first step in painting a more complete picture of framework effectiveness and a more complete picture of its resulting impact on teacher and student outcomes. Testing programs based on the GI framework with other minority populations in even more diverse circumstances (e.g., rural versus urban schools in states other than Alaska) could result in data supporting broader, farther-reaching implications of the framework for nationwide use.

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APPENDIX F

Kathryn Berry Bertram Biosketch

Kathryn Berry Bertram has been the Education Director for the Geophysical Institute of the University of Alaska Fairbanks since 1991. She earned her B.A. in Environmental Science Education Outreach from Wittenberg University in Springfield, Ohio, her M.P.A. in Environmental Science Education Outreach from Indiana University in Bloomington, Indiana.