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INVESTIGATION OF STRATEGIES TO PROMOTE EFFECTIVE TEACHER PROFESSIONAL DEVELOPMENT EXPERIENCES IN EARTH SCIENCE

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INVESTIGATION OF STRATEGIES TO PROMOTE EFFECTIVE TEACHER PROFESSIONAL DEVELOPMENT EXPERIENCES IN EARTH SCIENCE

By

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A DISSERTATION

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This dissertation has been approved in partial fulfillment of the requirements for the Degree of DOCTOR OF PHILOSOPHY in Geology.

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Dedication

I dedicate this to my friends, the MiTEP teacher participants in Cohort 1, Cohort 2, Cohort 3, and Cohort 4, those urban teachers that get up and go to school every morning ready to make a difference in their student lives. You guys are amazing!

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Preface

Documentation for copyright permission is found in Appendix A. Chapter 4 was previously published as *Michigan Teacher Excellence Program (MiTEP): Using Lesson Study for Professional Development* [Engelmann, C., Hungwe, K., and Klawiter, M. 2013]. This paper appeared as Chapter 11 on pages 157-177 in the volume: *Exemplary science: best practices in professional development,* Second Edition, which was edited by Koba, S. and Wojnowski, B., and published by the NSTA Press. It is used here by permission. The approximate level of author contributions to this paper were: Engelmann, C. = 97% (collected the data, analyzed the data, wrote the paper); Hungwe, K. = editor (made suggestions for how to display data); Klawiter, M. = 3% (edited paper and contributed information about GRPS policies).

Documentation for copyright permission to reprint Figures 1 and 2 is found in Appendix B. The figures are used here by permission.

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Abstract

This dissertation serves as a call to geoscientists to share responsibility with K-12 educators for increasing Earth science literacy. When partnerships are created among K-12 educators and geoscientists, the synergy created can promote Earth science literacy in students, teachers, and the broader community. The research described here resulted in development of tools that can support effective professional development for teachers. One tool is used during the planning stages to structure a professional development program, another set of tools supports measurement of the effectiveness of a development program, and the third tool supports sustainability of professional development programs. The Michigan Teacher Excellence Program (MiTEP), a Math/Science Partnership project funded by the National Science Foundation, served as the test bed for developing and testing these tools.

The first tool, the planning tool, is the *Earth Science Literacy Principles* (ESLP). The ESLP served as a planning tool for the two-week summer field courses as part of the MiTEP program. The ESLP, published in 2009, clearly describe what an Earth science literate person should know. The ESLP consists of nine big ideas and their supporting fundamental concepts. Using the ESLP for planning a professional development program assisted both instructors and teacher-participants focus on important concepts throughout the professional development activity.

The measurement tools were developed to measure change in teachers' Earth science content-area knowledge and perceptions related to teaching and learning that result from participating in a professional development program. The first measurement tool, the Earth System Concept Inventory (ESCI), directly measures content-area knowledge through a succession of multiple-choice questions that are aligned with the content of the professional development experience. The second measurement, an exit survey, collects qualitative data

from teachers regarding their impression of the professional development. Both the ESCI and the exit survey were tested for validity and reliability.

Lesson study is discussed here as a strategy for sustaining professional development in a school or a district after the end of a professional development activity. Lesson study, as described here, was offered as a formal course. Teachers engaged in lesson study worked collaboratively to design and test lessons that improve the teachers' classroom practices. Data regarding the impact of the lesson study activity were acquired through surveys, written documents, and group interviews. The data are interpreted to indicate that the lesson study process improved teacher quality and classroom practices. In the case described here, the lesson study process was adopted by the teachers' district and currently serves as part of the district's work in Professional Learning Communities, resulting in ongoing professional development throughout the district.

1. Introduction

Scientists and K-12 educators need to form partnerships because both have a mutual interest and responsibility to improve student learning of Earth science content. A good model in which scientists and teachers function as partners is a teacher professional development program. All Earth science teacher professional development activities should strive to fulfill a universal goal; to make all high school graduates Earth science literate, which will ultimately lead to an Earth science literate society. As part of a teacher professional development program, scientists can share their time and expertise with teachers to improve the teachers' Earth science literacy, which will improve the Earth science literacy of their students and eventually the society as a whole. This dissertation reports on how Earth scientists can address some of the challenges that arise when developing partnerships with K-12 educators. This research was conducted so that Earth scientists will have reliable and proven tools as they plan science teacher professional development programs to elevate the level of Earth science education. This research has the potential to guide Earth scientists as they create partnerships with teachers in the development of exemplary lessons that can be used to support the national call for science education reform identified as the "Earth Science Core Ideas" in the National Research Council's (NRC) *Framework* and the *Next Generation Science Standards* (NGSS). All Earth scientists are positioned to support this reform and advance Earth science education along the pathway toward achieving the universal goal of Earth science literacy.

This dissertation explains how scientific evidence was collected and analyzed to determine the effectiveness of selected components of the Michigan Teacher Excellence Program (MiTEP). Over the course of the MiTEP program (from 2009 through 2013), multiple strategies have been employed with four cohorts of teacher participants. MiTEP, a Math-Science

Partnership (MSP) funded by the National Science Foundation (NSF), served as the test project. This research investigated three aspects of the MiTEP program: a strategy employed to promote communication among scientists and teachers as a means to increase the teachers' Earth science content knowledge, the development and testing of tools for measuring change in teachers' Earth science content knowledge and a process used to promote sustainable collaborative efforts among the teacher participants for ongoing improvement of teaching practices.

Chapter 2 of this dissertation is focused on investigating the use of the ESLP as the framework for structuring field courses that are designed to facilitate scientist and teacher partnerships. Partnerships between K-12 education and research scientists are often built through a scientist's interest in working to improve Earth science education by offering a professional development program for teachers. The *Earth Science Literacy Principles* (ESLP) were used and tested within the context of the MiTEP professional development program. They were tested to determine if they can provide common ground for communication between scientists and teacher participants through the use of the Earth science big ideas. Since planning is the first step an Earth scientist would take in designing a professional development experience, the research that supports the use of a particular structure in such planning is presented first in this dissertation. The MiTEP program used the ESLP to structure the two-week summer field courses as well as facilitate scientist and teacher communication. The results of this investigation are based on the perceptions of the program teacher participants, the geologists who served as the MiTEP Earth science field course instructors and the Michigan Tech graduate students who served as MiTEP program facilitators.

Chapter 3 is focused on development and testing of effective methods for determining the level of impact a professional development program has had on improving teachers' Earth science content knowledge. Designing an evaluation scheme is a major part of designing a professional development program. The evaluation scheme should include the selection of effective evaluative tools capable of testing the efficacy of the treatment. Evaluation is essential because measurement of changes that result from participation in a professional development program is required by most funding agencies. Evaluation also provides participating Earth scientists with evidence to judge whether or not their professional development program was an effective use of their time and effort. Throughout the implementation of the MiTEP program, the evaluation team administered various assessment instruments and applied various assessment methods in attempts to acquire an accurate picture of the impact of the program on the teachers. The methods chosen included both quantitative and qualitative data acquisition methods, and a multivariate comparison of the chosen methods and revealed strengths and weaknesses. The results from this research provide insight into what methods can serve as effective and efficient ways for program scientists, evaluators, and professional development strategists to measure the impact of their professional development programs.

Chapter 4 investigates a process that has potential to provide sustainability for a professional development program. This research was conducted to determine the effectiveness of a Lesson Study course in establishing a process among teachers for improving teacher practice. Lesson study is a self-directed, collaborative, professional development process that began in Japan and has undergone modifications to meet the needs of teachers in the United States. In Lesson Study, the teachers formed their own collaborative groups that developed, taught, observed, and evaluated the effectiveness of an exemplary Earth science lesson. Each exemplary Earth science lesson was designed to teach specific science skills while applying those skills to standards-based content. In addressing the universal goal of science literacy, the MiTEP program implemented an adaptation of Lesson Study. Lesson Study is self-directed, whereby a collaborative team of teachers decide the content and skills they want to improve within their students. This research investigates whether the MiTEP Lesson Study process was effective in improving teacher practice with the possibility of promoting sustainable improvement of teacher practice beyond the limited time frame of the MiTEP program.

2. Testing the Effectiveness of the Earth Science Literacy Principles as a Framework for Instruction

2.1 Introduction

The research described herein was conducted as part of the Michigan Teacher Excellence Program (MITEP) at Michigan Technological University. MITEP is a multi-year, National Science Foundation (NSF) funded, Math/Science Partnership (MSP) research program. The program's core partners are Michigan Technological University and three Michigan urban school districts: Grand Rapids Public Schools (GRPS), Jackson Public Schools (JPS), and Kalamazoo Public Schools (KPS). The program's supporting partners are Grand Valley State University, Western Michigan University, the Grand Rapids Area Pre-college Engineering Program, selected Midwest National Parks, and the American Geosciences Institute. Four cohorts of teachers participated in the MiTEP program. Each cohort consisted of between 12-24 teachers. The MiTEP activities included field courses, academic-year professional development days, on-line academic-year courses focusing on Earth science content and content pedagogy, leadership opportunities, and an intern experience at one of Michigan's National Parks.

Each cohort's three-year MiTEP experience began with a two-week summer field course, Earth Science Institute 1 (ESI-1). The first week of ESI-1 was spent in Michigan's Upper Peninsula exploring the geology of the Keweenaw and other Earth science concepts. The second week was spent in Michigan's Lower Peninsula exploring local geology and additional Earth science concepts. An Earth Science Literacy Principle (ESLP) [ESLI, 2009] served as the unifying theme for each day's activities. The first nine days of the two-week summer field course each addressed one of the nine ESLP big ideas, and the tenth and final field day was designated as a "synthesis of MiTEP". Each day of the field course was also correlated with curriculum from each of the participating districts, *Michigan's Earth Science High School Expectations* [MDE, 2006], and misconceptions related to the ESLP of the day.

During the first school year, teachers enrolled in a sequence of Michigan Technological University on-line courses and participated in quarterly workshops that focused on pedagogy, inquiry teaching, Earth science classroom activities and basic Earth and space science content. Two of the online courses addressed fundamental Earth and space science content that is required for preparation of teachers in Michigan who earn certification in Earth and space science (Huntoon and Baltensperger, 2012). In the third online course, Lesson Study, teams of teachers identify a student learning goal, select an existing lesson that supports the goal and collaboratively refine the lesson to improve student learning. The lesson is taught by a member of the team while the other members observe the lesson. Then the team reflects on the lesson and makes further modifications to improve the lesson. The team prepares a final report and an oral presentation to share what they learned with their colleagues. The Lesson Study process is examined in more detail in Chapter 4 of this dissertation.

Year two of the teachers' three-year program began with a second two-week summer field course, ESI-2, which was also split between Michigan's Upper and Lower Peninsulas and was similarly aligned with district curricula, and *Michigan Earth Science High School Expectations* [MDE, 2006]. Misconceptions and the ESLP were both explicitly incorporated into the instructional activities. Although misconceptions were not explicitly incorporated into the first-summer of the first cohort's programming, they were found to be useful during the second year of the MiTEP project and were used in all summer courses for all other cohorts throughout the remainder of the MiTEP program.

During the second school year, the teachers took additional on-line courses. The second-year online courses addressed issues related to effective teaching of Earth science content. The courses were: 1) STEM Learning Materials, Inquiry and Assessment, in which the MiTEP teachers examined learning materials that support inquiry-based teaching related specifically to the *Michigan High School Content Expectations* [MDE, 2006] and the *National Science Education Standards* [NSES, 1996]; and 2) Graduate Research in Education, in which the MiTEP teachers conducted an action research project as a capstone to an approved plan of study. The teachers worked with an education advisor as they designed their research, collected and analyzed the data, prepared a final report documenting their research. The MiTEP teachers defended the project/report in an oral presentation. Academic-year workshops during the second school year were led by MiTEP teachers who had accepted an invitation to serve as teacher-leaders in their districts. Teacher-leaders were initially nominated by administrators in the teachers' home districts and the nominations were reviewed by faculty and staff at the participating universities. In all cases, the teacher-leaders had outstanding leadership potential and were recognized by University personnel as having the skills necessary to effectively deliver a workshop focused on Earth science content and pedagogy.

The third and final summer in the MiTEP program, the teachers served an internship at Isle Royale National Park, Sleeping Bear Dunes National Lakeshore, Keweenaw National Historical Park, or Pictured Rocks National Lakeshore. As park interns, the teachers' developed educational materials for the parks and created activities they could use in their own classrooms. During the national park internships, Michigan Technological University faculty and graduate students visited the teachers and assisted the park staff in supporting the MiTEP interns in interpreting the Earth science in the park.

2.1.1 Research Question

The question investigated through the research describe here is: "Can the ESLP provide a sound basis for structuring a successful Earth science professional development program for teachers?" The research described here investigates the impact of using the ESLP as a framework for the design of the MiTEP Earth science professional development program. The perceptions of teachers, faculty, and graduate students who participated in the summer courses offered as part of the MiTEP program provide the data for the investigation. The teacher participants reported that the ESLP big ideas helped them learn Earth science content and they credit the big ideas with helping them to gain a deeper understanding of the Earth. The teachers also found that ESLP big ideas helped them think about the Earth as a system and understand the Earth's interrelated sub-systems. The geoscientists serving as ESI instructors found that the ESLP big ideas helped to create a comprehensive perspective of Earth science and they reported that this proved to be extremely valuable while working with the MiTEP teachers.

2.2 Teacher Professional Development

2.2.1 The Need for Teacher Professional Development

Professional development for science teachers is intended to improve science literacy among teachers as well as their students and the public at large. Research studies have shown that high-quality professional development for science teachers can improve teacher practices in their science classroom, resulting in improved student achievement in science [Kennedy, 1997]. An analysis of data from the 1996 National Assessment of Educational Progress in mathematics showed that when teachers learn to implement effective classroom practices, they can make a significant positive difference in student learning [Wenglinsky, 2002].

Since the 1970s, research has shown that classroom teachers play the most important role in contributing to student learning and achievement [Fennema, 1992]. As research has advanced, improving our understanding of how teachers impact the way students think about science and the role that teachers play in modeling scientific thinking, the role of the teacher has changed. In the past, an accepted practice for teachers to use was the “stand and deliver” or lecture approach. Schools at one time were considered to be teaching institutions. Today, schools are more often referred to as learning institutions. The teacher’s’ role is to create a sequence of activities to engage students so that they are able to construct new knowledge from their experiences. The *No Child Left Behind Act* (NCLB) of 2001, was founded on the idea that teacher quality is essential for student success [The Commission on No Child Left Behind, 2001]. Research conducted on teacher quality has shown a strong correlation between student achievement and teacher quality [Goldhaber et al., 1999; Goldhaber, 2002]. When students were assessed using standardized tests the research showed that students scored higher if they had an effective teacher [RAND, 2013]. For the RAND study, an effective teacher was identified as a teacher whose students demonstrated gains in science learning on standardized achievement tests.

According to the 2005 American Educational Research Association (AERA) publication, *Teaching Teachers: Professional Development to Improve Student Achievement*, high quality professional development incorporates many elements. One of the most important elements is building teachers’ deep understanding of the content they teach [AERA, 2005]. AERA’s *Essential Information for Education Policy* stated:

> *“Teacher professional development can improve student achievement when it focuses on teachers’ knowledge of the subject matter and how students understand and learn it.” [AERA, 2005]*

Research conducted in 2008 by Horizon Research, Inc. showed that teachers with a strong background in their content area were better at engaging students in learning and in improving student achievement. The classroom practices that teachers with deep knowledge typically employ include asking high-level questions, presenting alternative explanations, and helping students engage in inquiry. They found that teachers with weak content knowledge did not employ these practices. Horizon reported that teachers' mathematics/science content knowledge makes a difference in their instructional practice and their students' achievement, according to a number of research studies [Horizon, 2008].

Earth scientists are in a position to make a difference in student learning by providing Earth science professional development for teachers. If teacher Earth science content knowledge is increased, teachers will be able to improve their teaching practices so that their students can be more engaged, leading to higher student achievement. This is particularly true in the Earth sciences because so many Earth sciences teachers are not specifically trained in Earth science [Huntoon and Baltensperger, 2012].

2.2.2 Teacher Professional Development in Earth Science

Few students graduate from high school having taken a quality Earth science course because Earth science is not taught in many of the nation’s high schools’ [Ridky, 2002; Dodick and Orion, 2003; Lewis, 2008] and when it is taught, it is often by teachers that are certified in a different field of science. Since the late 1800’s, several national education policy groups have recommended that studying Earth science become a significant part of the high school science curriculum [NSES, 1996; Ridky, 2002; Dodick and Orion, 2003; Lewis, 2008]. Recently, the National Research Council’s *Framework for K-12 Science Education* [NRC, 2012] and the *Next Generation Science Standards* [Achieve, 2013] both recommend that Earth science play a major role in high school science curriculum. The most recent data available shows that most college bound students do not study Earth science, instead they take advanced placement courses along with high school biology, chemistry and physics. The *2012 Science and Engineering Indicators*, published by the National Science Foundation, demonstrate this to be true by providing the percent of high school graduates that completed various advanced science and engineering courses in 2009. The *2012 Science and Engineering Indicators* show that advanced biology was completed by 45% of the students, advanced chemistry was completed by 70% of the students, advanced physics was completed by 39% of the students and advanced environmental/Earth science was completed by 10% of students taking advanced science courses [NSF, 2012]. While national policy groups continue to recommend that Earth science be a significant part of the high school science curriculum, few college bound high school students, 10%, completed an Earth science course during the 2008-2009 school year [Ridky, 2002].

The lack of "highly qualified" Earth science teachers is often cited as a reason why Earth science is not taught in the nation's high schools [Ridky, 2002; Rutherford, 2008; Huntoon and Baltensperger, 2012]. One way to increase the amount of Earth science content taught in our nation's high schools is to increase our high school science teachers' knowledge of Earth science. This can be accomplished by providing in-service teachers teacher professional development in Earth science and/or university courses focused on Earth science for both pre-service and in-service teachers. Michigan Technological University, Eastern Michigan University and University of Maryland, are examples of undergraduate or graduate programs that have been implemented in which teachers can become certified to teach Earth science [Ridky, 2002; Rutherford, 2008; Huntoon and Baltensperger, 2012] and other institutions are in the process of designing programs [Ridky, 2002]. According to the "*Public School Teacher Data File*," published by the United States Department of Education, there were 53,100 high school Earth science courses taught during the 2007-2008 academic school year and only 23.7% of those classes were taught by an Earth science certified teacher or a teacher with a major in Earth science. The remaining 76.3% of the Earth science courses were taught by teachers that were teaching out-of-field; they were certified or majored in a science discipline other than Earth science [NCSES, 2009]. If these out-of-field teachers could participate in Earth science professional development opportunities, they could increase their knowledge of Earth science and increase the quantity and quality of Earth science courses taught in high schools.

To be most effective, a teacher Earth science professional development program should include a “learning in the field” component. Geoscientists refer to “learning in the field” as an extended period of time where a learner directly experiences the natural environment and actively interacts with it [Mogk and Goodwin, 2012]. While research continues to evolve about learning complex Earth science concepts in a laboratory setting compared to directly making observations of Earth materials and processes outside of the classroom, most university geoscience programs continue with tradition and require their geoscience majors to experience a field course [Mogk and Goodwin, 2012]. Learning in the field requires that the learner be immersed in the complex and uncertain world of the natural environment. In this natural environment, the learner makes careful and methodical observations that lead to the development of a historical understanding of the temporal and spatial changes that contributed to what can be seen in the field. Teachers of Earth science need to develop cognitive abilities to support their ability to make observations of complex rock outcrops and interpret their observations and then tell the history of the rocks over time [Mogk and Goodwin, 2012]. This is especially important for teachers without an Earth science certificate or major that are assigned to teach high school Earth science courses. Many geoscientists have reported that providing extended field experiences for Earth science teachers has been essential for the teachers’ to develop a deep understanding of Earth science concepts, thus increasing their ability to teach Earth science [Huntoon et al., 2001; O'Neal, 2003; Mattox and Babb, 2004; Hemler and Repine, 2006; Manduca and Carpenter, 2006; Marcum-Dietrich et al., 2011].

2.3 Earth System Science in Education

2.3.1 Science Literacy

Science literacy is important for the citizens of the United States if they are to be informed voters in our modern democratic society. Most geoscientists believe that science literacy is important and that science education can impact science literacy in our society [GSA, 2011]. In 2011, the Geological Society of America (GSA) published this position statement on Earth science education:

> *"The Geological Society of America (GSA) recognizes that basic knowledge of Earth science is essential to meeting the environmental challenges and natural resource limitations of the twenty-first century. It is critical that Earth-science education begin at the kindergarten level and include advanced offerings at the secondary school level, and that highly qualified Earth-science teachers provide the instruction. GSA recommends that the study of Earth science be an integral component of science education in public and private schools at all levels, from kindergarten through twelfth grade." [GSA, 2011]*

Advocacy for improving science education began in 1989, when the American Association for the Advancement of Science (AAAS) published *Science for All Americans*, in which they promoted the idea that science should not be taught in schools as though every student would eventually be moving into a science career. After Sputnik, science generally was taught as if everyone would be college bound and science education was directed at those students who would eventually become scientists. The AAAS publication began a discussion about whether every student should be asked to learn the same content. This publication indicated that learning "what science is" and "how science is done", rather than expecting memorization of science facts, is most important for most students. *Science for All Americans* asked the question, "What learning should take place in the science classroom so that every American could leave the 12th grade knowing and understanding science?" [AAAS, 1989].

The vision of AAAS, presented in *Science for All Americans*, was made more operational in 1996 when the *National Science Education Standards* (NSES) were published [NRC, 1996]. The NSES were the first attempt to explicitly express for United States science educators what science content every educated person should know and understand. The NSES prescribed the science skills that all students should possess by the time they graduate from high school [NRC, 1996]. The NSES emphasized the importance of learning Earth science content and described how Earth science should be taught through inquiry [NRC, 1996].

2.3.2 Earth System Science (ESS) Literacy

At the same time as the NSES was calling for Earth science to be a major part of science education, important changes were occurring within the Earth sciences as a new conceptual framework for studying the Earth, Earth System Science (ESS), was being embraced. The ESS concept originated in 1988, when the National Aeronautics and Space Administration (NASA) called for an integrated understanding of how the elements of the Earth's system interact, specifically how climate, hydrology, and the biosphere (including human activities) relate to each other. Once NASA began viewing the Earth from space, this new perspective of the planet demanded a holistic approach to the Earth sciences. During the 1990s, many Earth scientists began to accept ESS and started thinking of the Earth as a major system that is composed of subsystems. These subsystems, some of which can be conceptualized as the Earth's spheres, had always been studied independently, as if each was an independent field of study. The ESS perspective broadened Earth scientists' awareness of the relationships among the atmosphere, hydrosphere, geosphere, and biosphere. There are now fewer scientific studies that narrowly focus on one of the spheres without looking at its interaction with the other spheres [TERC, 2010].

As an example of the increased emphasis on ESS within the scientific community, one can look at a 2001 editorial in *Science* which highlighted the need for all of society to understand the interactions among the components of the Earth system [Lawton, 2001]. Also in in 2001, representatives of more than 100 countries attended the first *Global Change Open Science Conference* which asked for additional research and education efforts to better understand ESS [ESSP, 2009]. Later, authors such as Steffan et.al [2004], in their book *A Planet under Pressure,* echoed the need for ESS to support global sustainability. In more recent years, the focus of media attention on weather and climate change has renewed discussion of the importance of ESS education [Bostelman et. al, 2008]. As global climatic issues become topics of public discussion, meaningful responses to address local and global problems require better public understanding of ESS [Rankey and Ruzek, 2006]. What began in 1988 with NASA's request for divergent groups of scientists to work together and analyze pictures of the Earth from space continues to evolve. How Earth's spheres interact with each other and how a change in one causes changes in the others are important concepts for everyone to understand about the functionality of planet Earth.

Combining the ESS perspective with GSA's call to increase the role of Earth science in K-12 education suggests that geoscience education should be rooted in ESS. Teaching Earth science with an ESS approach can be highly effective for promoting general science literacy because ESS integrates biology, chemistry, and physics concepts. Citizens need to learn the basic principles within each of these science disciplines to have the knowledge required to understand the fundamental workings of the Earth system. Climate change is a good example of the interrelations among the Earth's spheres. Removing fossil fuels from storage in the geosphere and burning them releases carbon that had been sequestered in rock layers and increases the amount of carbon dioxide in the atmosphere. This increased amount of carbon dioxide contributes to an enhanced greenhouse effect, trapping more of the Sun's energy and raising the temperature of the Earth. Physicists, chemists, Earth scientists and life scientists all play a part in predicting what changes in the climate system will occur in the future and when they will occur. Input from all science disciplines will be needed as decisions will have to be made to accommodate the Earth's climate change.

ESS also provides concrete applications of concepts drawn from the other sciences, technology, engineering, and math (STEM) [GSA, 2011]. An example is provided by the impact plate tectonic processes have on humans. Understanding how and why plates move requires understanding of relevant concepts from physics, including gravity and friction. Chemistry concepts include the density differences between the oceanic and continental crust. Together, these basic principles help to explain the origin of mountain ranges and biology concepts explain why plants and animals live at specific elevations. Technology has played a key role in revealing the nature of plate tectonics, for example through the use of seismographs to detect earthquakes that originated from plate movement and to determine the velocity of relative plate motions. Engineering concepts are used to design structures such as bridges and buildings to minimize destruction caused by earthquakes. Mathematics is used to describe many plate tectonics processes and to predict the effects of plate movement. Thus all of science, technology, engineering and mathematics (STEM) taught with an ESS perspective promotes general science literacy because ESS understandings involve concepts that cut across all of the STEM disciplines. Earth scientists can promote understanding of the Earth and Earth science literacy by creating ESS professional development opportunities for science teachers who then can improve their teaching practices leading to improved science education for learners of all ages.

2.3.3 Literacy Principles in the Earth Science Domain

The research discussed in this chapter focuses on the use of the *Earth Science Literacy Principles* (ESLP) in conducting professional development for teachers. The Earth Science Literacy Initiative (ESLI) began in in 2008 at the request of NSF program officers. The NSF asked for a set of literacy principles for Earth science that would address the many challenges of the 21^{st} Century, such as managing Earth's limited resources, preparing for climate change and ensuring the Earth can provide clean water and fresh air to sustain humanity [Wysession et al., 2012].

The ESLP were written by Earth scientists and they focus on important and essential concepts in Earth science. The ESLP were written to guide educators to prepare people/citizens to make wise decisions about the Earth system [Wysession et al., 2012]. In order to produce a set of principles that Earth scientists in general could agree upon, the ESLP development included an on-line workshop, an in-person workshop, and an on-line peer review process that involved over 700 individuals from the education and science communities. The two-week on-line workshop provided the opportunity for about 350 Earth scientists and educators to communicate with their peers and identify what was considered important and essential Earth science information. By the end of the two-week workshop, the participants had come to agree on a group of Earth science big ideas. Next, a group of 36 individuals met face-to-face for a three-day writing workshop that formalized the products of the on-line workshop. This writing workshop produced the first draft of the Earth science big ideas and their supporting concepts. This framework was presented at the 2008 Geological Society of America (GSA) annual meeting.

The document underwent revision based on feedback that was obtained from geoscientists at GSA. The next draft was presented at the 2008 American Geophysical Union (AGU) annual meeting to obtain additional feedback. Further revisions were made based on the feedback obtained from the geoscientists at AGU. The review and revision process continued on-line until May 2009, when the ESLP were finalized [Wysession et al., 2012]. This extensive design and review process eventually produced the final draft which included nine big ideas and their supporting concepts. The ESLP were released to the public in 2009 defining what an Earth science literate society should know and understand.

The ESLP fully integrate the ESS perspective. The Chair of the Earth Science Literacy Initiative (ESLI) Committee, Michael Wysession, published this statement on the ESLI web-site which clearly addresses the need for an Earth System Science approach in science education:

> *"It is quite possible that, from the perspective of future civilizations, the 21st century will be defined by three things: climate change, water availability, and energy resources. These three are not independent, of course, and the fate of humanity will rest upon how they are addressed over the next 100 years. Importantly, all three are deeply rooted in the areas of Earth science. Many important political, legal, and ethical decisions are being made related to these issues that already severely affect the lives of all (people). The lack of clear, concise, and comprehensive community-driven guidelines puts (everyone) at risk of bad decisions made either through ignorance or self-interest. For example, the resistance within certain spheres to accept the relevance and validity of global climate change for as long as it did caused (the US) significant embarrassment at an international level, and severely delayed international attempts to address the matter." [ESLI, 2009]*

The ESLP were preceded by other literacy principles written with a focus on different specific content areas such as the ocean, the atmosphere, and climate. The impetus for the modern science literacy principles movement was the publication of the NSES. When the NSES were published and they did not include oceanography content, the ocean science community organized themselves to address that omission through the *Ocean Science Literacy Principles* [NOAA, 2004]. This was the first set of literacy principles developed, and their appearance prompted the development and publication of additional sets of "Science Literacy Principles". The format used to construct *The Ocean Science Literacy Principles* has been used as the template for all subsequent documents. This format highlights a series of big ideas, or the general understandings that scientists and educators have identified as important for developing a basic understanding of science. Each big idea is connected to specific fundamental concepts that clearly define what is deemed to be essential content related to the big idea. *The Essential Principles and Fundamental Concepts of Atmospheric Science* were released in 2007 [UCAR, 2007] and the *Essential Principles of Climate Literacy* were released in 2009 [CCSP, 2009]. The *Earth Science Literacy Principles* were released in 2009 [NSF, 2009] and the most recent set of principles to be developed, the *Energy Literacy: Essential Principles and Fundamental Concepts for Energy Education*, were released in 2011 [DOE and AAAS, 2011].

As new sets of the science literacy principles were designed, they incorporated good ideas from those that came before, and the ESLP were written to be more comprehensive than earlier sets of literacy principles [Wysession et al, 2012]. Each set of literacy principles was designed and edited collaboratively by a group of experts in relevant fields of study. Each community worked together virtually, taking advantage of virtual conferencing and sharing electronic documents during discussion, comment, and review cycles. Most communities included scientists, some included engineers, and some included other types of specialists, such as K-16 educators, science coordinators from school or state levels, education policymakers, and federal agency representatives. As the different literacy principles were created, a large set of big ideas along with an overwhelming number of fundamental concepts evolved. Not every big idea was unique to a specific field of science, and as a result many of the big ideas are repeated in at least two sets of literacy principles. Together, as a group, the literacy principles include over 37 big ideas and over 241 fundamental concepts. The multiple sets of literacy principles make for a very complicated “to-do list” for anyone interested in promoting science literacy.

Since one of the major goals of the MiTEP program was to increase the teachers’ Earth science content knowledge, the release of the ESLP in 2009 seemed to offer an effective way to structure the MiTEP two-week summer field courses. The ESLP appeared to match with the goals of the program and the Michigan HSCE [MDE, 2006], which is what was used by MiTEP to identify the important content that would be taught in the program. Because the Michigan HSCE are the standards that MiTEP participants are expected to understand and be able to teach to their students, it was important to structure the program in a way that aligned with these standards. The Michigan HSCE includes 132 content expectations that are organized by the five standards (table 1), resulting in another long and complicated “to-do-list”.

Table 1: Michigan Earth Science Standards, their sub-categories with the number of content expectations for each standard [MDE, 2006].

Standard	***Sub-Categories***	***Content Expectations***
E1 Inquiry, Reflection, and Social Implications	E1.1 Scientific Inquiry E1.2 Scientific Reflection and Social Implications	20
E2 Earth Systems	E2.1 Earth Systems Overview E2.2 Energy in Earth Systems E2.3 Biogeochemical Cycles E2.4 Resources and Human Impacts on Earth Systems	17
E3 Solid Earth	E3.p1 Landforms and Soils (prerequisite) E3.p2 Rocks and Minerals (prerequisite) E3.p3 Basic Plate Tectonics (prerequisite) E3.1 Advanced Rock Cycle E3.2 Interior of the Earth E3.3 Plate Tectonics Theory E3.4 Earthquakes and Volcanoes	29
E4 Fluid Earth	E4.p1 Water Cycle (prerequisite) E4.p2 Weather and the Atmosphere (prerequisite) E4.p3 Glaciers (prerequisite) E4.1 Hydrogeology E4.2 Oceans and Climate E4.3 Severe Weather	33
E5 The Earth in Space and Time	E5.p1 Sky Observations (prerequisite) E5.1 The Earth in Space E5.2 The Sun E5.2x Stellar Evolution E5.3 Earth History and Geologic Time E5.3x Geologic Dating E5.4 Climate Change	33

In designing the MiTEP professional development program, a great deal of attention was paid to the alignment between the curriculum for the professional development and the curricula that the participating teachers were required to address in their own classrooms. This was particularly true for the summer courses due to their extended timeframe and their focus on the applications of Earth science content to real-world situations. The strong correlation between the *Michigan High School Content Expectations* (HSCE) and the ESLP, which were used to structure the MiTEP summer two-week field courses, was essential to the success of the summer courses. Tables displaying the correlation between the five Michigan Earth science Standards and their HSCE to the nine ESLP show many similarities (Appendix E). The tables in

Appendix E show only connections to the Michigan Earth science standards; however, this correlation is applicable to many of the states' standards. When each state was expected to provide a set of standards of their own, most states, including Michigan, produced a modified version of the *National Science Education Standards* (NSES). If readers are interested in specific NSES and ESLP connections, they can be found on the ESLI website at http://www.earthscienceliteracy.org/ [ESLI, 2009].

The connections are strongest in the Earth Systems, Solid Earth, and the Fluid Earth categories of the HSCE. In addition, the ESLP can be connected to the Space and Time category in addressing the history of the Earth (time), but not in relation to formation of the universe, stars, and solar system. The MiTEP two-week field course did not place a strong emphasis on astronomy content expectations; however MiTEP did address Earth's history, the sun, and the sun/moon/Earth movements and the impact of these movements on our planet. The MiTEP program was able to address many of the ocean concept expectations by studying Lake Superior. Ocean life, density currents, and salt water chemistry were not addressed as part of the MiTEP program, although they are easily matched to ESLP big idea "#5- The Earth is the water planet."

2.3.4 Correlation between the Earth Science Literacy Principles (ESLP) and Other Geoscience Literacy Principles

It was clear from a cursory review of the ESLP, that they addressed ideas that had previously been included in the other geoscience literacy principles. Making the apparent overlap explicit would be beneficial to teachers, and for the purposes of teaching teachers, because it would further emphasize the truly big ideas in the geosciences.

Commonalities among the ESLP and the other geoscience literacy principles were identified through an iterative process. The ESLP provided the themes that were established while organizing all five sets of big ideas. Big ideas that articulated the same theme were grouped together. When necessary, the original ESLP big idea was modified to make the connections clearer to the reader (table 2). This exercise demonstrated that the ESLP, in slightly modified form, could be used to address Earth science content from an Earth system science perspective.

Table 2: Correlation among the five geoscience literacy principles and Earth system science themes (which are based on modified versions of the ESLP).

Earth Science 1:	***Ocean 7:***	***Atmosphere 6:***	***Climate 5:***	***Energy 5:***
Earth scientists use repeatable observations and testable ideas to understand and explain our planet.	The ocean is largely unexplored.	We seek to understand the past, present, and future behavior of Earth's atmosphere through scientific observation and reasoning.	Our understanding of the climate system is improved through observations, theoretical studies, and modeling.	Energy decisions are influenced by economic, political, environmental and social factors.
Earth System Science 1: Earth system scientists use repeatable observations and testable ideas to understand and explain the present and the future of the solid Earth, the Earth's ocean, the Earth's atmosphere, and the Earth's climate.				
Earth Science 2:	***Ocean 4:***	***Atmosphere 6:***	***Climate 4:***	***Energy 2:***
Earth is 4.6 billion years old.	The ocean made Earth habitable.	We seek to understand the past, present, and future behavior of Earth's atmosphere through scientific observation and reasoning.	Climate varies over space and time through both natural and man-made processes.	Physical processes on Earth are the result of energy flow through the Earth system.
Earth System Science 2: The Earth is 4.6 billion years old and scientists seek to understand the past behavior of the Earth's system through scientific observation, modeling and reasoning.				

Table 2 (continued):

Earth Science 3:	***Ocean 7:***	***Atmosphere 5:***	***Climate 1:***	***Energy 2:***
The Earth is a complex system of interacting rock, water, air, and life.	The Ocean is a major influence on weather and climate.	Earth's atmosphere continuously interacts with the other components of the Earth system.	The Sun is the primary source of energy for Earth's climate system.	Physical processes on Earth are the result of energy flow through the Earth system.
Earth System Science 3: The Earth system is a complex system of interacting rocks, water, air, and life and scientists seek to understand how inputs and outputs make changes within each of the spheres as well as between the spheres.				
Earth Science 4:	***Ocean 2:***	***Atmosphere 4:***	***Climate 7:***	***Energy 1:***
The Earth system is continuously changing.	The Ocean and the life in the ocean shape the features of the Earth.	Earth's atmosphere changes over time and space, giving rise to weather and climate.	Climate change will have consequences for the Earth system and human lives.	Energy is a physical quantity that follows precise natural laws.
Earth System Science 4: The Earth system is continuously changing and scientists seek to understand how changes occur over time and space within and between spheres.				
Earth Science 5:	***Ocean 1:***	***Atmosphere 3:***	***Climate 2:***	***Energy 2:***
The Earth is the water planet.	The Earth has one big ocean with many features.	Atmospheric circulations transport matter and energy.	Climate is regulated by complex interactions among components of the Earth system.	Energy processes on Earth are the result of energy flow through the Earth system.
Earth System Science 5: The Earth is the water planet and water plays a major role in all parts of the Earth system.				
Earth Science 6:	***Ocean 2:***	***Ocean 2:***	***Climate 3:***	***Energy 3:***
Life evolves on a dynamic Earth system and continuously modifies Earth.	The ocean and life in the ocean shape the features of Earth. Ocean 5: The ocean supports a great diversity of life and ecosystems.	Atmosphere 1: Earth has a thin atmosphere that sustains life.	Life on Earth depends on, is shaped by, and affects climate.	Biological processes depend on energy flow through the Earth system.
Earth System Science 6: Life on Earth depends on, is shaped by, and modifies the Earth system.				

Table 2 (continued):

<table>
<tr><th>Earth Science 7:</th><th>Ocean 5:</th><th>Atmosphere 2:</th><th>Climate 6:</th><th>Energy 4:</th></tr>
<tr><td>Humans depend on Earth for resources</td><td>The ocean supports a great diversity of life and ecosystems.</td><td>Energy from the Sun drives atmospheric processes.</td><td>Human activities are impacting the climate system.</td><td>Various sources of energy can be used to power human activities, and often this energy must be transferred from source to destination.</td></tr>
<tr><td colspan="5">Earth System Science 7: Human's removal and use of the Earth's finite natural resources cause changes in the Earth system natural processes.</td></tr>
<tr><td>Earth Science 8:</td><td>Ocean 6:</td><td>Atmosphere 7:</td><td>Climate 7:</td><td>Energy 7:</td></tr>
<tr><td>Natural hazards pose risks for humans.</td><td>The ocean is a major influence on weather and climate.</td><td>Earth's atmosphere and humans are inextricably linked.</td><td>Climate change will have consequences for the Earth system and human lives.</td><td>The quality of life of individuals and societies is affected by energy choices.</td></tr>
<tr><td colspan="5">Earth System Science 8: Earth system processes produce both sudden and gradual natural hazards that pose risks to humans.</td></tr>
<tr><td>Earth Science 9:</td><td>Ocean 6:</td><td>Atmosphere 7:</td><td>Climate 3:</td><td>Energy 6:</td></tr>
<tr><td>Humans significantly alter the Earth.</td><td>The ocean and humans are inextricably interconnected.</td><td>Earth's atmosphere and humans are inextricably linked.</td><td>Human activities are impacting the climate system.</td><td>The amount of energy used by human society depends on many factors.</td></tr>
<tr><td colspan="5">Earth System Science 9: The Earth system and humans are inextricably linked.</td></tr>
</table>

Once all of the big ideas had been matched with the newly crafted Earth system science themes, a final table was constructed that correlates each of the new Earth system science themes with the appropriate codes for all of the associated fundamental concepts in the other geoscience literacy principles (table 3). This comprehensive table makes it clear that there is a good match between the ESLP and all the other four sets of literacy principles. However, the original ESLP, numbers 1 through 9, did not identify the spheres of the Earth system, so they were added to the modified Earth system statements (table 3).

Table 3: Correlation between the new Earth system science themes and the other literacy principles. Each literacy principle or big idea is represented with the number which is followed by a decimal or letter. The decimal or letter portion of the identification indicates the relevant fundamental concepts. The established connections are based on ESLP [NSF, 2009], the *Ocean Science Literacy Principles* [NOAA, 2004], *the Essential Principles of Climate Literacy* [CCSP, 2009], the *Fundamental Concepts of Atmospheric Science* [UCAR, 2007], and the *Energy Literacy: Essential Principles and Fundamental Concepts for Energy Education* [DOE and AAAAS, 2011].

Earth System Science Theme	***ESLP***	***Ocean***	***Atmosphere***	***Climate***	***Energy***
ES 1 Earth scientists use repeatable observations and testable ideas to understand and explain our planet. to understand the present and the future of the solid Earth, the Earth's ocean, the Earth's atmosphere, and the Earth's climate.	#1.1-1.7	#7 a-f	#6.1-6.5	#5 A-E	#5.1-5.6
ES 2 Earth is 4.6 billion years oldand scientists seek to understand the past behavior of the Earth's system (lithosphere, hydrosphere, atmosphere, and biosphere) through scientific observation, modeling, and reasoning.	#2.1-2.7	#4 a-c	#6.1-6.5	#1 A-E	#2.1-2.7
ES 3 The Earth system is a complex system of interacting rock, water, air, and lifeand scientists seek to understand how inputs and outputs can make changes within each of the spheres (lithosphere, hydrosphere, atmosphere, and biosphere) as well as between these spheres.)	#3.1-3.8	#7 a-g	#5.1-5.4	#1 A-E	#2.1-2.7
ES 4 The Earth system is continuously changing. and scientists seek to understand how changes occur over time and space within and between the spheres.	#4.1-4.9	#2 a-e	#4.1-4.4	#7 A-F	#1.1-1.8
ES 5 Earth is the water planet. and water plays a major role in all parts of the Earth system (lithosphere, hydrosphere, atmosphere, and biosphere).	#5.1-5.8	#1 a-h	#3.1-3.5	#7 A-F	#2.1-2.7
ES 6 Life on Earth depends on, is shaped by, and modifies, the Earth system.	#6.1-6.9	#2 a-e	#1.1-1.4	#3 A-E	#3.1-3.6
ES 7 Removing and using the Earth's finite natural resources causes changes in the Earth system natural processes.	#7.1-7.10	#5 a-i	#2.1-2.5	#6 A-E	#6.1-6.8
ES 8 Earth system processes, within the lithosphere, hydrosphere, atmosphere, and biosphere, produce both sudden and gradual natural hazards that pose risks to humans.	#8.1-8.8	#3 a-g	#7.1-7.5	#7 A-F	#7.1-7.6
ES 9 The Earth system and humans are inextricably linked.	#9.1-9.9	#6 a-g	#7.1-7.5	#3 A-E	#3.1-3.6

2.3.5 Earth System Science (ESS) and the Next Generation Science Standards

Following the development of the literacy principles, ESS and systems thinking continued to be highlighted by important publications focused on bringing reform to science education, reform that would increase science literacy. In 2011, AAAS published the *Framework for K-12 Science Education* which was intended to create a new vision for science education in the United States. It proposed that science education be focused on what it called the "Three Dimensions of The Framework". These are: 1) Scientific and Engineering Practices, 2) Crosscutting Concepts (concepts/applications found throughout all fields of science), and 3) Core ideas in four disciplinary areas (Physical Sciences; Life Sciences; Earth and Space Sciences; and Engineering, Technology, and Applications of Science) [NRC 2011]. This publication calls for science teachers to use crosscutting ideas that bridge multiple sciences to introduce students to the concept that all science disciplines are interrelated and that cross-cutting concepts show those relationships. The first cross-cutting concept is "patterns." According to the Framework, "Observed patterns of form and events guide organization and classification, and they prompt questions about relationships and the factors that influence them." In Earth science, patterns of earthquakes are studied to understand plate tectonics and predict plate movement in the future, the forces that produce the stress and control eventual movement along the faults, and how the chemistry of the lithosphere determines where a deep earthquake will occur. Additional cross-cutting concepts identified within the Framework are "cause and effect", "scale, proportion, and quantity", "systems and systems models", "energy and matter", "structure and function" and "stability and change" [NRC, 2012]. All of these cross-cutting concepts can be addressed through ESS-based instruction. There are interactions among and within spheres that cause changes, sometimes slow and sometimes fast, and sometimes minor and sometimes major. Regardless of what causes a change in one sphere, that change causes other changes until the system as a whole reaches stability. An important ESS example is climate change, which requires integration of all “Three Dimensions of the Framework” 1) Scientific and Engineering Practices, 2) Crosscutting Concepts, and 3) Core ideas.

The ESLP are well aligned with the *Framework for K-12 Science Education*. That is, specific concepts listed in the ESLP correlate directly with many listed in the *Framework*. This is because they were used by the authors of the *Framework* to define the Earth science content that is listed as part of the “Dimension 3: Disciplinary Core Ideas: Earth and Space Sciences” [NRC, 2012]. Only “Core Idea ESS 1: Earth’s Place in the Universe” [NRC, 2012] is not well aligned with the ESLP because this core idea is focused on astronomy. These Core Ideas include a broad range of Earth science content that interrelates and promotes a deep understanding of our home planet from an ESS perspective. Both Core Idea 2 (Earth Systems) and Core Idea 3 (Earth and Human Activity) require examination of the interconnections within the Earth system. Core Idea 2 examines the processes that cause changes in the Earth system at both large scales, such as plate tectonics, as well as at small-scale, such as the chemistry of groundwater. The aligned ESLP big ideas are: “3- Earth is a complex system of interacting rock, water, air, and life”; “4- Earth is continuously changing”; “7- Humans depend on Earth for resources”; and “8- Natural hazards pose risks to humans.” Water, weather and climate are also interrelated in Core Idea 2 to demonstrate how water plays a major role in heat distribution as well as the role it plays in surface processes. The aligned ESLP big idea is: “5- Earth is the water planet.” Core Idea 3, focuses on how human actions impact the Earth system. The aligned ESLP big ideas are: “6- Life evolves on a dynamic Earth and continuously modifies Earth” and “9- Humans significantly alter the Earth” Through its ESS perspective, the *Framework* supports students’ learning that when humans cause changes in one sphere, the effect is that changes occur in all of the other spheres until the entire Earth system has found balance.

The *Next Generation Science Standards* (NGSS), based on the *Framework for K-12 Science Education*, were released in 2013 [Achieve, 2013]. As written, the NGSS asks teachers to teach crosscutting concepts, including many found in the ESLP such as: patterns, systems and system models, structure and function, and stability and change. The ESLP provide an excellent set of big ideas and fundamental concepts that support the understanding of ESS as well as the other sciences, math, engineering and technology. The big ideas and their fundamental concepts provide a comprehensive set of ideas that can demonstrate these crosscutting concepts in the Earth sciences, specifically from the ESS perspective [Achieve, 2013].

2.5 Methods

The question of whether the ESLP can provide a sound basis for structuring a successful Earth science professional development program for teachers was investigated in two ways. First, teachers' content-area knowledge was tested using the *Earth Science Concept Inventory* (ESCI) pilot test administered using a pre- post- intervention research design. The ESCI is described in more detail in the following chapter of this dissertation. Second, teachers', graduate students', and faculty members' perceptions of the effectiveness of the use of the ESLP was investigated through the use of surveys. Information collected through the surveys completed by teachers, graduate students and faculty were supplemented with information gleaned from review of teacher artifacts (journals and lesson plans), review of the website constructed in support of the summer courses, and from one-on-one interviews conducted after each group had submitted their survey responses.

2.5.1. Sample Description

The MiTEP program began in the summer of 2009 with Cohort 1 and then added a new Cohort of teachers every year through 2012. Cohorts 1 and 2 included teachers from one of the largest urban districts in Michigan. Cohorts 3 and 4 were composed of teachers from two geographically separated urban school districts. Each cohort contained teachers with a wide variety of backgrounds in science, math, and education. Assessment methods were being tested and developed throughout the program, so not all cohorts were assessed with the exact same instruments. However, all teacher participants experienced the same intervention; all teachers participated in a two-week field course for two summers and the same teacher workshops during the academic years.

2.5.2 Quantitative Data

One of the goals of the MiTEP program was to increase the teachers' understanding of Earth science content. A quantitative tool was used to determine if there was such a change. As part of the work conducted for this dissertation, *Earth Science Concept Inventory* (ESCI) test questions were developed to measure whether or not the teachers' knowledge had changed over the three years they participated in the MiTEP program. The ESCI set of test questions was needed specifically for the MiTEP program because no instrument could be found that had adequate resolution for the MiTEP program. The questions used on the ESCI pilot test, as administered in 2012, have been tested for validity and reliability (see Chapter 3).

The last group of teachers, Cohort 4, began the MiTEP program in summer 2012. At that time Cohorts 1, 2 and 3 had already completed part, if not all, of the MiTEP program. Cohort 4 was comparable to the other 3 Cohorts as far as educational backgrounds and teaching assignments (ranging from the elementary to the high school levels). Cohort 4 teachers were the only group to which we could administer the ESCI pilot as both a pre-test and post-test because the ESCI was not available earlier in the program. Therefore, only Cohort 4 scores are discussed here. The ESCI pilot test was administered in summer of 2012 to Cohort 4 teachers (N=14) as a pre-intervention test before they began the MiTEP program. The pre-intervention test was administered before the first summer field course. The same test was administered during the summer of 2013 to the same teachers as a post-intervention test on the last day of their second summer field course. The span of time between the pre- and post-intervention test was at least a year which provided an adequate span of time between them to minimize repeat-administration bias, which had to be considered because the pre- and post- intervention tests were identical.

A dependent-sample t-test was used to compare the scores on the pre- and post-intervention tests. A dependent-sample t-test was used, rather than the independent-sample t-test because there are two sets of scores for one set of participants. Since the expectation is that the teachers would score higher on the post-test, the one-tailed test was applied [Wagner, 2011]. Pre- and post-test scores on the ESCI were compared using the Statistical Package for Social Science (SPSS) [IBM, 2013]. SPSS provides the t-test statistic and degrees of freedom (df).

2.5.3 Qualitative Methods

Qualitative data were collected to determine if using the ESLP as the framework for the design of the summer field courses was viewed favorably. Data were collected from all participants in the two-week summer field courses (teachers, graduate students, and university faculty) that involved teacher Cohorts 1 and 2 (table 4). The qualitative data were analyzed by coding the responses from each group into categories and then creating a summary for each of the three groups. The grade-level teaching assignments of these teachers ranged from elementary to high-school seniors.

The second sample included graduate students that served as planners of the MiTEP program as well as facilitators of the activities in the field and faculty members from Michigan

Technological University, Grand Valley State University, and Western Michigan University that planned and delivered instruction for the MiTEP summer field courses. Two of the three graduate students came to the MiTEP program after being secondary-level educators. The third graduate student, had extensive experience working in the field, but was new to the field of education.

Table 4: Qualitative methods used to assess the use of the ESLP during the Michigan Teacher Excellence Program.

Group	***Methods***
Cohort 1 and 2 Teachers (N=22)	Review of daily field journals from summer field course. Analysis of responses to survey regarding use of ESLP. Survey follow-up phone interviews. Review of lessons created by the teachers.
Michigan Tech University Graduate Students (N=3) ***Geology Professors (N=4)***	Review of course website. Analysis of open-ended constructed response surveys. Survey follow-up phone interviews.

2.5.3.1 Teacher Daily Field Journals

The MiTEP teachers were provided notebooks to take field notes at each field stop during the summer courses. Teachers were instructed on how to take good field notes and how to sketch and label rock outcrops while in the field. After the completion of the first summer's two-week field course, when the teachers used a standard spiral notebook, MiTEP decided to change to Hayden McNeil Publisher's duplicate pages notebooks [Hayden-McNeil, 2013]. The first summer, in order to keep a copy of the notebooks for reference the teacher notebooks were scanned. After we began using the duplicate pages notebooks, the teachers turned in the top sheet and they had the duplicate bottom sheet to keep in the spiral for their own records. At the end of every field day, the teachers were asked to turn in their notebook pages. A member of the MiTEP evaluation team read through the teachers' notebook pages looking for detailed notes that showed understanding and/or misconceptions. At the end of some days the teachers were asked to reflect back on the big idea of the day and write down in their notebook a scientific claim they felt they could make related to the days field experiences. This was included because one of the themes stressed in the summer field courses was the nature of science. The teachers used a claim-evidence-reasoning model in their classrooms, so the teachers were instructed to use notebooks and do the following:

- *"state a claim related to today's big idea,"*
- *"provide evidence you gathered while in the field today, and"*
- *"explain the your reasoning in support of your claim."*

These questions are based on the *Disciplinary Literacy* approach [McNeil and Krajcik, 2008] which was emphasized by the district which was home to Cohort 1 and 2 teachers. Beyond analyzing the teachers' notebook pages for teacher understanding and/or misconceptions of Earth science concepts, the claim-evidence-reasoning provided insight into the teachers' understanding of the big idea assigned to the day. The journals were analyzed using a standard rubric (table 5) to ensure that all journals were reviewed in the same way.

Table 5: Rubric used to assess the Claim-Evidence-Reasoning Assignment the teachers placed in their journals.

	Satisfactory	***Excellent***	***Needs Improvement***
CLAIM	Proposes an answer to the scientific question	Proposes a valid answer to the scientific question	The claim is vaguely connected to the scientific question
	7 6 5	10 9 8	4 3 2
	The claim focuses on one idea but the statement could be clearer	The claim is stated clearly while focusing on one idea	The claim is confusing and complicated by including multiple ideas
	7 6 5	10 9 8	4 3 2
	The claim requires collection of scientific evidence	The claim facilitates scientific inquiry and the collection of quality evidence	The claim is based on beliefs and does not require scientific evidence
	7 6 5	10 9 8	4 3 2
	The claim is reasonable given the field course activities and information shared throughout the day	The claim can be supported or refuted with the evidence available to MiTEP teachers during field course	The claim is so far out that it cannot be answered without a lot of experimenting or research
	7 6 5	10 9 8	4 3 2

Table 5 (continued):

EVIDENCE	Most of the evidence presented is closely related to the claim	All of the evidence presented is directly related to the claim	There is more evidence that is not closely related to the claim than that which is
	7 6 5	10 9 8	4 3 2
	Includes a few observations or measurements from a field location	Includes multiple observations or measurements, data that was collected in the field	Did not include evidence related to one of the field locations
	7 6 5	10 9 8	4 3 2
	Presents evidence from at least three sources	Includes several pieces of evidence from multiple sources	The evidence presented came from one source
	7 6 5	10 9 8	4 3 2
	Most of the sources of evidence are cited	Each source of evidence is cited (ex. page #, URL, location, experience)	Only cited one source of evidence
	7 6 5	10 9 8	4 3 2
REASONING	A convincing argument is presented that shows that the claim is accurate and valid	Presents a clear argument as to why the claim is accurate and valid based on a general understanding of evidence	Argument is weak and not very convincing that the claim is accurate
	7 6 5	10 9 8	4 3 2
	Includes a few connections between the claim and most of the evidence	Clearly shows the connection between the claim and every piece of evidence	Did not show the connections between the claim and the evidence
	7 6 5	10 9 8	4 3 2
	Identifies a possible weakness in the argument	Identifies a possible weakness in the argument and supports this with evidence	Did not identify possible weakness in the argument
	7 6 5	10 9 8	4 3 2
	The "wrap up" or final statement of conclusion is present and convincing	Provides a "wrap up" or final statement of conclusion that is solid and convincing	Provides a weak "wrap up" or final statement of conclusion or it is missing
	7 6 5	10 9 8	4 3 2

Daily, the teachers were also assigned a set of questions that focused on specific field sites they visited throughout the day. Frequently, included in this assignment, the teachers were asked to reflect on a field site they had visited and explain how their experience related to the day's big idea (table 6).

Table 6: An example of typical assignment that required teachers to focus on a big idea. The big idea of interest was “Big Idea 9: Humans significantly alter the Earth.”

Big Idea Assignment
How did the Earth shape the human activities in this area and how did the humans shape the Earth?
By now you’ve witnessed lots of old rusty mining equipment lying around in the Keweenaw. How do you feel about that? Should it be cleaned up?
Explain why the following statement is NOT correct**. “**Earth and its systems are too big to be affected by human actions.”
Taken only from sites visited today prepare a list of ways in which *Humans have Significantly Altered the Earth* (ESLP Big Idea #9).

2.5.3.2 Teacher Survey Regarding Use of Earth Science Literacy Principles (ESLP)

The Earth Science Literacy Principles (ESLP) survey was administered to teachers from Cohorts 1 and 2 during the first of the full-day academic year workshops that took place during the 2010-2011 school year. Teachers completed the survey in a conference room at their home school district’s Professional Development Center. Teachers sat together around tables as they completed the survey. The survey structure required the teachers to read a statement regarding the use of the ESLP and then circle one of four possible choices: Strongly Agree, Agree, Disagree, or Strongly Disagree (table 7). The survey questions were designed to investigate the teachers’ experience related to the use of the big ideas. The goal was to obtain feedback about how the big ideas were used on a daily basis and whether or not the teachers found that the ESLP supported their learning of Earth science content. The survey questions were shared and edited by one of the MiTEP summer field course instructors, one of the MiTEP graduate students, and one of the MiTEP principal investigators. A total of 21 teachers responded to this survey.

Table 7: Teacher Survey regarding the use of *Earth Science Literacy Principles* “big ideas” to structure the summer field courses.

Teacher Survey				
Directions: Please circle the answer below that comes closest to what you think about each of the following statements regarding the use of the Earth Science Literacy Principles “Big Ideas” as part of the Earth Science Institute last summer. You are welcome to include comments.				
1. Talking about the day’s “Big Idea” every morning was useful to me.	Strongly Agree	Agree	Disagree	Strongly Disagree
Comments:				
2. I liked being given the day’s “Big Idea” written on a card to keep with me during the day.	Strongly Agree	Agree	Disagree	Strongly Disagree
Comments:				
3. The “Big Idea” helped me recognize which Earth science concepts are important.	Strongly Agree	Agree	Disagree	Strongly Disagree
Comments:				
4. The daily “Big Idea” enhanced my understanding that the Earth is a large complex system.	Strongly Agree	Agree	Disagree	Strongly Disagree
Comments:				
5. The “Big Idea” inspired me to want to learn about the difference sub-systems on Earth.	Strongly Agree	Agree	Disagree	Strongly Disagree
Comments:				
6. Learning that changes in one of Earth’s systems can cause changes in other systems was made clear through my understanding the “Big Ideas”.	Strongly Agree	Agree	Disagree	Strongly Disagree
Comments:				
7. The “Big Ideas” helped shape my understanding of how human actions impact our planet.	Strongly Agree	Agree	Disagree	Strongly Disagree
Comments:				
8. I think all citizens should learn about the “Big Idea” so that informed decisions can be made about the future of the Earth and its resources.	Strongly Agree	Agree	Disagree	Strongly Disagree
Comments:				
Free Response: Do you have any other comments or suggestions for how MiTEP could more effectively use the “Big Ideas” for the summer institute?				

The data collected on this survey was analyzed first by assigning a number value to the choices the teachers were presented with: Strongly Agree=4, Agree=3, Disagree=2 and Strongly

Disagree=1. The mean of the responses was calculated for each question. All comments and anything written in as an answer to the free response questions were analyzed for common themes.

2.5.3.3 Teacher Follow-Up Interviews

During the teacher workshop at which the teachers answered the survey, they were asked if they would be willing to answer a few more questions about the big ideas through a phone interview. Those teachers that volunteered were provided with a notecard to write the best time and a telephone number at which each could be reached to discuss the use of the ESLP. A follow-up phone interview was conducted with a small group of teachers who volunteered to participate in a phone interview.

Three teachers were interviewed by phone. The teachers were asked about their thoughts on MiTEP's use of the big ideas throughout their summer field courses. The purpose of the interviews was to dig deeper into how the teachers felt about using the ESLP and to have the teachers articulate whether or not the ESLP had made an impact on their learning of Earth science throughout the summer field courses.

2.5.3.4 Teacher Lesson Plans

The MiTEP teachers were asked to design a standards-based classroom lesson as one of the products to be assessed as part of their grade for one of the two week summer field courses. In addition to identifying the Michigan High School Content Expectation (HSCE) the lesson addressed, the teachers were asked to identify which of the nine ESLP it supported. These classroom lessons were assessed with a rubric (table 8) that was created collaboratively with teachers in Cohort 1.

Table 8: Rubric designed by Cohort 1 teachers to assess the MiTEP classroom lesson assignment.

	Excellent	***Satisfactory***	***Needs Improvement***
I. Knowledge Needed	A comprehensive list of content and resources with URL's is included along with an explanation.	A comprehensive list of content and resources with URL's is included	Content and resource list are minimal.
	20 18 16	14 12 10	8 6 4
II. Vocabulary	A comprehensive list of words that may cause difficulty for students are listed with their definitions	A comprehensive list of words that may cause difficulty for students are listed	Vocabulary word list is included, however, it is not comprehensive
	20 18 16	14 12 10	8 6 4
III. Goal of Lesson	The lesson's goal or purpose is clearly stated and importance supported by GRPS Standards and GRPS curriculum	Goal or purpose is stated and connected to GRPS Standards and GRPS curriculum	Only GRPS Standards or GRPS curriculum are provided in a list
	20 18 16	14 12 10	8 6 4
IV. Materials / *Tech	All materials are listed and are adequate, with possible location to find resources. Suggestions for cheaper alternatives provided when applicable.	All materials are listed and are adequate, with possible location to find resources.	A list of materials is provided without locations to find resources.
	20 18 16	14 12 10	8 6 4
V. Procedure / Instructions	Step by step instructions are provided in the 5 E format with details suggesting teacher moves, accountable talk and misconceptions to look for.	Step by step instructions are provided in the 5 E format with details suggesting teacher moves, accountable talk.	Step by step instructions are provided in the 5 E format.
	20 18 16	14 12 10	8 6 4
VI. Hands-on Connections	Detailed directions are provided with images or samples of what should be done or a prototype of final product.	Detailed directions are provided with a description of final product.	Directions are present but not detailed or does not have a description of the final product.
	20 18 16	14 12 10	8 6 4

Table 8 (continued):

VII. Assessment Rubric	A rubric is included that clearly shows students what the expectation is for high quality of the product along with student hints or suggestions for attaining an excellent designation.			A rubric is included that clearly shows students what the expectation is for high quality of the product			A rubric is included but it is not clearly written so students would not be able to understand what a high quality product would require.		
	20	18	16	14	12	10	8	6	4

The purpose of this assignment was to encourage teachers to bring something concrete from their field experiences back to students in their classrooms. By asking teachers which of the ESLP their lesson addressed, it was possible to determine whether and how they found ways to integrate the ESLP into their classroom teaching.

2.5.2.5 Field Course Website

The summer field courses were supported by an extensive website that included maps, images, illustrations and geologic information about each of the field stops the teachers visited. Analysis of this website was conducted to determine to what extent the ESLP were integrated into the MiTEP program. Also, the website provided insight into the way in which ESLP were used to structure the MiTEP program. The website for the MiTEP ESI-1 Course can be found on-line at http://www.geo.mtu.edu/~raman/SilverI/MiTEP_ESI-1/Welcome.html and MiTEP ESI- 2 can be found on-line at http://www.geo.mtu.edu/~raman/SilverI/MiTEP_ESI-2/Welcome.html.

2.5.2.6 Instructor and Graduate Student Survey and Follow-up Interviews

Field course instructors (faculty and graduate students) were asked to respond to an open-ended survey asking them about their thoughts related to using the ESLP as the framework for the MiTEP summer field courses (table 9). All were asked to describe their own personal observations of how using the ESLP impacted MiTEP teachers' learning, teachers' practices, and the depth of teachers' understanding of Earth science content (table 9). Follow-on non-structured interviews were conducted in person or by telephone when specific examples were not included in the e-mail response.

Table 9: Questions about using the Earth Science Literacy Principles e-mailed to Michigan Teacher Excellence Program graduate students and summer field course instructors.

Instructor and Graduate Student Survey
Directions: Please think back to working with the MiTEP teachers last summer. Based on your personal observations (seen or heard), please describe any impacts that using the ESLP may have had on the MiTEP teachers during the summer program.
1. Effect of ESLP Structure or Using the Big Ideas (BI) on Teacher Learning-
2. Effect of ESLP Structure or Using the Big Ideas (BI) on Teaching Practices-
3. Effect of ESLP Structure or Using the Big Ideas (BI) on Deepening Teacher Understanding-

2.6 Results

2.6.1 Content-Area Knowledge

The research question asked if the ESLP could be used as the framework of a successful professional development program. One aspect of success measured in this investigation is whether or not the teachers' Earth science knowledge changed as a result of participating in the summer courses. The scores of MiTEP's Cohort 4 teachers on the ESCI pre- and post-intervention tests revealed that the teachers made a significant gain in their Earth science content knowledge. The results of the dependent samples t-test on the ESCI pilot test (table 10) show a significant increase ($t_{(df=13)} = 5.29$; $p<.01$) in the post-test scores (Mean=31.3) as compared to the pre-test scores (Mean=25.9). Although this result cannot be attributed directly to the ESLP or the summer courses since the teachers experienced many other professional development activities as part of their MiTEP experience, it does appear to indicate the MiTEP program as a whole is effective in increasing teachers' content-area knowledge in Earth science.

Table 10: Dependent-sample t-test for Earth System Concept Inventory for pre- and post-Earth System Concept Inventory tests.

Mean	*Standard Deviation*	*Error*	*95% Confidence Interval*	*T statistic*	*Degrees of Freedom*	*Significance (1-tailed)*
5.44	3.84	1.03	Upper=3.22 Lower= -7.66	5.29	13	.000

2.6.2 Perceptions Regarding the ESLP as a Framework for Instruction

The teachers' daily field journals provided insights into how the big idea for a day could became part of a day's assignments. The daily sets of questions assigned to the teachers often asked reflection questions about specific field sites the teachers had visited throughout the day. When specifically asked, the teachers responded with answers that clearly showed that they made connections between the sites they had visited and the day's big idea. The big idea for the day was explained first thing every morning and the instructors continually related the field experiences to the big idea for that day. Although the teachers were not asked to explicitly make a connection between a day's activities and a big idea every day, on every day that the teachers were asked to make a connection, all of the teachers were able to provide an example. An example of such a question and a teacher's answer taken from a journal page is:

"Examples of ways Earth has been altered by the human activity observed today are:

- *Stamp sands dumped into Houghton Canal are damaging wetlands and shoreline environment.*
- *Tailing piles from mines that damage stream/forest/ plant communities resulting in erosion issues and threatening water quality."*

Responses to the teacher survey which targeted the use of the ESLP showed that the Cohort 1 and 2 teachers valued the use of the ESLP as part of the summer field courses (table 11). The responses indicated the teachers generally agreed with the statements in the survey that were stated in support of use of the ESLP (Strongly Agree=4, Agree=3, Disagree=2, Strongly Disagree=1). The mean of the responses to all of the questions was 3.28, somewhere between "agree" and "strongly agree." The percentages of teachers that selected each response was calculated.

Table 11: Teacher responses and the corresponding statements listed on the big ideas survey. The calculated means and counts of responses are also shown.

Item	*Strongly Agree*	*Agree*	*Disagree*	*Strongly Disagree*	*Mean*	*N*
1. Talking about the day's "Big Idea" every morning was useful to me.	60%	40%			3.6	20
2. I liked being given the day's "Big Idea" written on a card to keep with me during the day.	35%	55%	10%		3.25	20
3. The "Big Idea" helped me recognize which Earth science concepts are important.	37%	63%			3.2	19
4. The daily "Big Idea" enhanced my understanding that the Earth is a large complex system.	29%	62%	9%		3.35	21
5. The "Big Idea" inspired me to want to learn about the difference sub-systems on Earth.	26%	70%	4%		3.2	20
6. Learning that changes in one of Earth's systems can cause changes in other systems was made clear through my understanding the "Big Ideas".	29%	67%	4%		3.4	21
7. The "Big Ideas" helped shape my understanding of how human actions impact our planet.	15%	85%			3.15	20
8. I think all citizens should learn about the "Big Idea" so that informed decisions can be made about the future of the Earth and its resources.	15%	81%	4%		3.1	20
				Overall	3.28	20

The results show teachers found talking about the big idea every morning to be valuable. The set of responses indicated that the ESLP big ideas helped the teachers to advance their understanding of ESS. The teachers agreed that the big ideas helped them to recognize important Earth science concepts, to understand that the Earth is a large complex system, to learn more about the Earth's subsystems. The teachers agreed that the ESLP big ideas helped them understand how human actions impact the Earth and agreed with the statement that all citizens should learn about the big ideas so that informed decisions can be made about the future of the Earth and its resources. The responses to these questions showed the teachers placed value on having the ESLP big ideas as part of the MiTEP program.

The survey included one free response query. On this part of the survey, teachers were asked specifically to provide comments or suggestions for how the MiTEP program could more effectively use the big ideas in the two-week summer field courses. Responses from the teachers reinforced that they valued the ESLP. Thirteen of the teachers chose to respond to this question. Of the thirteen, eight of the responses included the word "focus", indicating that they valued having the ESLP to structure the field courses because it helped them to focus. None of the teachers provided a specific suggestion for changing their use as part of the MiTEP program (table 12).

Table 12: Teacher responses related to the use of the big ideas as part of the field courses. These were given in response to the question: "Do you have any other comments or suggestions for how MiTEP could more effectively use the big ideas (BI) for the summer institute?"

"Discussion of the BI was very helpful in outlining the day's activities!"
"The BI helped me to focus and outline the concepts that are part of studying the earth."
"Relationships with all of the sciences came out of the BI."
"The BI set the tone for the morning's lesson."
"I thought the BI added in our focus and learning throughout our field experiences."
"It was a great focus to come back to throughout the course of the day."
"I would definitely love to have it all- whole week in advance and even have time to prepare readings beforehand."
"It gave us a focus for the day and at the end we could put it all together."
"I think it was good to focus our thinking."
"I liked how it focused our thinking for the day."
"I liked having one thing to focus on every day."
"Helped me overview the topic in my mind prior to going into it. Allowed me to take new information and see how it applied to the BI."
"By having a focus it made it easier to connect the daily activities to the big picture."

During the interviews that were conducted after the teachers completed the survey additional information was obtained. These data provided insight into how teachers were planning to make use of the ESLP in their own classrooms and how the ESLP had impacted their overall learning experience in the field. At the time they were interviewed, the teachers were two months into their fall semester. At least two of the MiTEP teachers had already found applications for the big ideas in their classrooms. One teacher used big ideas to help students to know at the beginning of each class what they were expected to learn that day. A chemistry teacher brought the big idea that the "Earth is a water planet." into a chemistry lesson. When asked about the effect the ESLP had on deepening their understanding of Earth science, one teacher reported that the ESLP big ideas helped with the formulation of questions that were then asked of the geoscientists during the field course. This teacher found that organizing information around the big ideas helped them recognize when they didn't have a complete understanding of the Earth science content. Additional sample responses are representative of the information provided in the follow-up phone interviews (table 13).

Table 13: Teacher responses on the effect of Earth Science Literacy Principles collected during one-on-one interviews.

Effect of ESLP on Teacher Learning
"The big ideas focused the day for me; it really seemed to especially help those of us teachers without a solid Earth science background." "The big ideas helped me see why we were here and how this field site aligned with what we were learning, at times I found myself using the big ideas and telling myself "Oh-OK now I get it."" "It helped me in that it gave me background knowledge to help me understand a little more of what we were going to cover in the day."
Effect of ESLP on Teaching Practices
"I have already used the "Water big idea", when I was teaching about water in Chemistry class I used the big idea and pictures from MiTEP in the classroom." "I liked the way the big ideas provided a clear focus for me each day, so now I begin each of my classes with the BI for this lesson to help my students know my expectation for their learning that day." "It helped me to think about connections I can help students make concerning the big ideas as they relate to *EarthComm*."
Effect of ESLP on Deepening Understanding
"The BI prompted me to ask questions of the Geologists, it helped me formulate my questions so that it was clear what I wanted to know." "I found that I had holes in my understanding of ES concepts and the BI helped me identify those areas and engage in dialogue with the Geologists to gain more complete understanding." "It helped spur on prior knowledge and connect things I already knew, but might have been deeply buried in my brain! Kept a great focus for the day and helped narrow my thinking."

Teachers who participated in the summer field courses were required to submit a lesson plan related to their district's curriculum, tied to the Michigan HSCE, and connect to at least one of the ESLP big ideas. Most of the lessons submitted by the teachers showed connections to big ideas as well as specific supporting concepts. Since completing the lesson plan, and including information about how the lesson was connected to the ESLP was required, it is not surprising that all of the teachers included this information in their lessons. All lessons are available online at mitep.mtu.edu under the "conferences" tab. The MiTEP teachers presented their lessons at the Michigan Science Teacher Association as part of the leadership development activities. Two examples of the first pages of lesson plans are presented here as figures 1 and 2. Each of these figures demonstrate that each lesson plan included objectives and connects to the HSCE's and the ESLP. The teachers valued the ESLP connections because they found that the ESLP provided them with reasons for why their students should engage in the science lesson.

Investigating Stream Flow in your Local Watershed

Introduction:
A watershed is essentially an area where all the water drains to a common location. In the United States there are over 2,000 watersheds. These watersheds come in all shapes and sizes and greatly impact all living things within its boundaries. Humans have also both relied on watersheds as well as impacted them throughout history. This is true for your local watershed and can be explored in a way that helps students understand their local watershed and what impacts humans have had on it in the past and their responsibilities as responsible citizens in protecting and maintaining their watershed.

Grade Level:
6-8th Grade

Objectives:

1. Students will be able to describe the flow of water through a watershed and how the parts of the watershed are connected.
2. Students will be able to explain how human activities affect the watershed and change the surface of Earth.
3. Students will be able to describe the origins of pollution in a watershed and their impact on the quality of life found in the watershed.

MI Content Benchmarks met or partially met:

- **E.ES.07.82** Analyze the flow of water between the components of a watershed, including surface features (lakes, streams, rivers, wetlands) and groundwater.
- **E.ES.07.41** Explain how human activities (surface mining, deforestation, overpopulation, construction and urban development, farming, dams, landfills, and restoring natural areas) change the surface of the Earth and affected the survival of organisms.
- **E.ES.07.42** Describe the origins of pollution in the atmosphere, geosphere, and hydrosphere, (car exhaust, industrial emissions, acid rain, and natural sources), and how pollution impacts habitats, climatic change, threatens or endangers species.

Earth Science Literacy Principles met or partially met:

- 5.5 – Earth's water cycles among the reservoirs of the atmosphere, streams, lakes, ocean, glaciers, groundwater, and deep interior of the planet.
- 9.4 – Humans affect the quality, availability, and distribution of Earth's water through modification of streams, lakes, and groundwater.

Figure 1: Sample lesson plan (first page) written by Ernstes, A., 2012; used with permission.

Using Topographic Maps to Understand Watersheds and Stream Flow

Introduction:
A topographic map, also sometimes called a contour map, is an essential tool for earth scientists. Contour lines are used to connect points of equal elevation. Thus, topographic maps reveal vital information about the area, and can be used to determine the boundaries of the watershed and the direction of water flow.

Grade Level:
6th-8th Grade

Objectives:
1. Students will use topographic maps to describe the flow of water through a watershed and how the parts of the watershed are connected.
2. Students will explain how human activities affect the watershed and change the surface of Earth.

MI Content Benchmarks met or partially met:
- **E.ES.07.82** Analyze the flow of water between the components of a watershed, including surface features (lakes, streams, rivers, wetlands) and groundwater.
- **E.ES.07.41** Explain how human activities (surface mining, deforestation, overpopulation, construction and urban development, farming, dams, landfills, and restoring natural areas) change the surface of the Earth and affected the survival of organisms.

Earth Science Literacy Principles met or partially met:
- 8.3 – Human activities can contribute to the frequency and intensity of some natural hazards.
- 8.5 – Natural hazards can be local or global in origin.
- 8.8 – An Earth-science-literate public is essential for reducing risks from natural hazards.
- 9.5 – Human activities alter the natural land surface.

Figure 2: Sample lesson plan (first page) written by Ernstes, J., 2012; used with permission.

Observations of the two course websites[1] showed that a big idea and corresponding fundamental concepts are included as part of each day's introduction. Each day of the two-week field course had a unique introductory web-page which includes the ESLP big idea for that day. Additionally, each day's page provides a link to a list of common misconceptions related to the big idea for that day. By examining the MiTEP field course websites, it is clear that the ESLP big ideas were well integrated into the MiTEP program two-week summer field courses. Based on

[1] MiTEP ESI-1 Course at http://www.geo mtu.edu/~raman/SilverI/MiTEP ESI-1/Welcome.html and MiTEP ESI- 2 at http://www.geo mtu.edu/~raman/SilverI/MiTEP_ESI-2/Welcome.html

how the ESLP are displayed on the first page of the web-site for each day, they can be seen to have played a major role in MiTEP. The website provides evidence showing how the ESLP were used to structure the course

When asked for information related to the value of the ESLP, via email and a follow-up in-person interview, the geoscience faculty members who served as instructors for the field courses and the graduate students who assisted with the courses explained that from their perspective, the ESLP helped the students learn because they helped them make connections among their different field activities, among diverse types of knowledge, and encouraged them to think about how a day's experiences fit into one big picture in a holistic way. The ESI instructors liked that the big ideas helped them share a coherent big picture of Earth system science with the teachers. The graduate students concurred with the theme of coherence; they said that the big ideas helped put together the day's events (table 14).

Table 14: Responses from geoscientist and graduate student interview on the effect of Earth Science Literacy Principles teachers' learning, teaching practices, and depth of content-area knowledge.

Effect of Earth Science Literacy Principles on Teacher Learning	
Instructor	"I liked the way that the ESLP linked very diverse content in coherent ways." "Brought together the planning so we could focus on a BI and relate the field activities to a big picture."
Graduate Student	"I saw how the BI served as a "lens" for the teachers to experience and learn from the day's activities in a holistic way." "The ESLP served as a "guiding light" enabling teachers to thread together the day's observations."
Effect of Earth Science Literacy Principles on Teaching Practices	
Instructor	"Each day was focused on a BI and if you look at the web site, you can read where each day's BI and set of field activities are correlated to the GRPS 6-7 grade curricula." "The teachers' misconception assignment and C-E-R reinforced each of the BI and helped teachers relate back to these as they developed their GRPS MiTEP lesson."
Graduate Student	"Teachers used the BI cards; I heard them referring back to the BI while they were discussing GRPS curriculum and their classroom." "Teachers focused on the BI out in the field and then further to the misconception assignment. Teacher discussion often centered on the BI and student misconceptions and how to address them."
Effect of Earth Science Literacy Principles on Deepening Teacher Knowledge	
Instructor	"We found that using ESLP structure allowed the teachers to explore a diverse set of evidence and bring it all together using the BI each day." "Instead of having one day of earthquakes, one day of water, etc., these different fields were integrated. My impression is that this gave the teachers a deeper understanding of the big ideas because they were able to see them from different perspectives."
Graduate Student	"I observed that the MiTEP participants' understandings were enhanced as they focused their discussions on the BI." "The teachers were always using critical thinking skills throughout their field work as they were always relating the activities back to the BI for the day."

The graduate students and instructors and could not make direct observations of teaching practices because they were not able to observe teachers in the act of teaching. However, the graduate students explained that the ESLP were part of teacher discussions they were able to overhear during the two-week field courses (table 14). They heard teachers discussing how they planned to use the ESLP in their MiTEP lesson plans. Since the teachers developed the lessons for their classroom and were expected to connect these lessons to the ESLP, this was something that the teachers often discussed during meals and while riding in the vans between field stops. Both the instructors and the graduate students noted that the focus on misconceptions reinforced the importance of the big ideas. Instructor comments indicated that tying the course to the district's curriculum, using the claim-evidence-reasoning approach, along with both the ESLP and the misconceptions helped to reinforce the content presented during the field courses.

The instructor and the graduate students explained that the ESLP appeared to help the teachers to gain deeper understanding of the Earth system (table 14). They referred to how the big idea for the day supported the teachers' synthesis of activities that had occurred throughout the day. The teachers were observed discussing and reasoning critically as they began to see the Earth system as the integration of its parts. The instructor liked how the big ideas helped the teachers to integrate the different topics and find connections among and between systems. The graduate student proposed that there were effects, but did not provide details to support their proposition.

Although not specifically obtained either through the survey or as a response to a follow-on interview, an email was sent by one of the summer course faculty instructors that clearly demonstrates excitement and passion for using the ESLP. After having experienced using the ESLP during the two-week summer field course, this faculty member chose to introduce the ESLP to fellow geologists because it was very useful in helping "teachers develop deep Earth science understandings." This instructor updated a university-level course to make use of the ESLP, after working with them during the summer courses. An excerpt of the email (as quoted below) advocates for other geoscientists to do the same:

> *"The big ideas may also be thought of as drivers of our student of the earth, and the things that ground our work from becoming too abstract and removed from the real world. They also link all other areas of advanced knowledge, like math, physics, chemistry, biology, computer science, engineering, geography, psychology, art and English, to mention only some. Putting these ideas upfront helps clarify what we are doing."*

2.7 Discussion

With recent emphasis on the national need for improved Earth science literacy falling on the overburdened shoulders of K-12 educators, it is imperative that Earth scientists accept a share of the responsibility for actively communicating science information. There are many contributions that Earth scientists can make: they can write articles for a general public audience, they can volunteer to speak about science in their communities, and they can find ways to form partnerships with K-12 education. This last contribution is particularly attractive as it can potentially impact millions of students while assisting K-12 educators who are already grappling with multiple state and national testing programs, the *No Child Left Behind Act*, new state laws requiring accountability for pay, and concerns for the safety of children in the classroom.

Legislatively, the *No Child Left Behind Act* and more recently, "*The Common Core*" have insured that there is a strong focus on improving K-12 students' reading, writing and mathematics skills. With limited funding resources available to schools, these emphases have resulted in a diminished focus on science education. Through their involvement with K-12 teachers, Earth scientists can collaborate with teachers who will benefit from becoming more informed about cutting-edge science. Recent publications at the national level have asked for reform in science education to improve science literacy in society. Just this year, Achieve's 2013 publication of the *Next Generation Science Standards* along with National Research Council's 2012 publication of the *Framework for K-12 Science Education* advocate for the teaching of Earth science at all grades levels. Together, these documents have elevated the teaching of Earth science so that it is now of equal or greater importance to learning the standard high school biology, chemistry, and physics content. These important publications support the use of Earth science as a capstone course in high school that provides practical application for the concepts taught in the other sciences and in mathematics. To adequately address these prescribed reforms in Earth science education, Earth scientists will need to make connections with K-12 teachers to create partnerships which provide these teachers with opportunities to systematically and continuously update and improve their Earth science content knowledge. To support Earth scientists as they move in this direction, research identifying effective strategies is needed, including strategies that can help Earth scientists develop effective professional development programs

Recent educational research reveals that teachers are the most important variable when it comes to increasing student learning and achievement. One important characteristic of successful teachers is a strong content background in the subject(s) they are teaching. With the latest publications asking for an increase in the amount of Earth science that is taught in our schools, the importance of preparing teachers with a strong understanding in Earth science content knowledge is evident. High quality, research-based professional development can be an effective pathway through which Earth scientists can contribute their knowledge and expertise to address this need. For this effort to be successful, an opportunity for both the scientists and K-12 teachers to communicate and find common ground and common vocabulary must be provided. Use of the ESLP, which were specifically written to describe what an Earth science literate person should know and understand, appears to assist both faculty members and participants to focus on key topics during field-based professional development activities. This is important because knowing about successful strategies, has the potential to increase the number of Earth scientists reaching out to improve K-12 education.

The data collected in this study show that teachers felt the ESLP helped them focus and understand Earth science content. Because the teachers' responses are self-reported, all that can be said is that it is likely that the ESLP played a role in the increase in teachers' Earth science knowledge that was measured through administration of the pre- and post-intervention content-area tests. Graduate students reported that the big ideas within the ESLP served to help the teachers see how all the different field activities and field stops were all connected. Additionally, they explained the ESLP helped the teachers connect everything they learned into a big picture of a holistic Earth system. The instructors reported that they found it easy to teach Earth science content within the ESLP structure because it helped the teachers understand the content and how it all fits together. The use of a framework to structure field-based professional development activities is not new [e.g., Huntoon et al., 2001; O'Neal, 2003; Mattox and Babb, 2004; Hemler and Repine, 2006; Marcum-Dietrich et al., 2011], but the research presented here indicates that the ESLP may provide such a structure and they are easy for any professional geologist to understand and use. The fact that the ESLP were developed through the collaborative work of many scientists indicates that they have broad acceptance throughout the geoscience community. The breadth of coverage of the ESLP also makes them an ideal framework for structuring professional development because they emphasize the most important concepts (big ideas) and also demonstrate that these concepts are based on data and logical inferences.

Additional findings are that the instructors, and to some extent the graduate students also valued the use of misconceptions, the claim-evidence-reasoning approach, and the fact that the field courses' curricula was specifically tied to the curricula that teachers were teaching in their home district. Based on this research, the ESLP can be recommended for use by other Earth scientists as they work on developing field-based professional development programs. In addition, paying explicit attention to misconceptions, emphasizing the use of reasoning, and connecting the content of field-based professional development activities to the topics that the teachers themselves are asked to teach appear to be very useful as has been shown previously

[Choi et al., 2010; Burgoon et al., 2011; Penuel et al. 2011; Loughran et al., 2012; Reiser, 2013]. Finally, giving teachers the opportunity to think and practice science, in the case here through the use of the claim-evidence-reasoning approach, appears to help bridge the gap between knowing facts and understanding their meaning.

2.8 Conclusion

Many positive insights about the ESLP were discovered while investigating their effectiveness as a tool for teacher professional development. The ESLP provided the teachers and the geologists with a common standard that focused each day's instruction during the summer courses. The MiTEP program was successful at increasing teacher Earth science content knowledge as measured by the ESCI test and the field-based courses that incorporated the ESLP were a major component of the MiTEP program. Qualitative data collected from teachers, graduate students, and geoscience faculty members supports the conclusion that the ESLP are effective in designing and administering a field-based Earth science professional development program for teachers. The teacher participants indicated that the ESLP big ideas helped them learn Earth science content and gain a deeper understanding of that content. Teachers also indicated that ESLP big ideas helped them think about the Earth as a system and facilitated their understanding of the Earth's interrelated sub-systems. The geoscientists serving as instructors in the field courses provided positive feedback about their experiences using the ESLP as well as misconceptions, the claim-evidence-reasoning approach, and tying the professional development to the teachers' district Earth science curriculum. The geoscientists reported they found the way that the ESLP big ideas helped create a comprehensive perspective of Earth science was extremely valuable. They found the structure helped them to communicate with the teachers.

The ESLP provide a framework to understand how difference concepts relate to one another. The concept of emphasizing interrelationships between science concepts is emphasized in the *Next Generation Science Standards* as cross-cutting concepts. In summary, this research indicates that the ESLP can support communication among geoscientists and teachers during teacher professional development, and that they will likely be useful in the future as the *Next Generation Science Standards* are more widely accepted and implemented.

3. Measuring the Impact of an Earth Science Professional Development Program

3.1 Introduction

This research was conducted as part of the Michigan Teacher Excellence Program (MiTEP) and its goal is to identify an effective methodology for measuring the impact of a professional development program in Earth science. When Michigan Technological University began the MiTEP professional development program, assumptions were made about the methods and instruments that would be used for assessment and evaluation of the program. Existing instruments with proven reliability and validity were selected and implemented. Unfortunately, the data obtained with these instruments was contradicted by observations made by geoscience faculty and graduate students who worked with the teachers during the professional development program. The research described here was undertaken to find and test a method or combination of methods that would provide the program with an accurate measurement of its impact on the teachers.

Both quantitative and qualitative methods were ultimately used to measure impact. A mixed-methods approach was required so that the weaknesses inherent to any one method could be overcome through a system of checks and comparisons. Development of two new instruments along with reliability and validity testing was completed. Analysis of data collected through the use of the newly developed qualitative and quantitative instruments showed that they are effective in identifying the program’s effect. The methods described here, as well as the instruments themselves (in modified form) will likely be useful to other geoscientists who conduct professional development activities with teachers and need or want to measure the impact of their efforts.

The new instruments include an Earth Science Concept Inventory (ESCI) test and a comprehensive exit survey. The ESCI provided reliable quantitative data showing that MiTEP teachers' knowledge increased significantly during the program. The exit survey provided reliable qualitative data confirming the ESCI test results and identifying which parts of the program teachers found most effective. It is no surprise to geoscientists that the teachers said that the field courses were the most effective learning experiences.

3.1.1 About the Michigan Teacher Excellence Program (MiTEP)

MiTEP is a National Science Foundation funded Math/Science Partnership (MSP) project that began in 2009 and will end in 2014. MiTEP's core partners include Michigan Technological University and three urban public school districts. Faculty members from Grand Valley State University and Western Michigan University, as well as staff at the American Geoscience Institute and some Midwestern National Parks have also contributed to the project. One of the most important goals of the MiTEP intervention is to increase teachers' Earth science content knowledge. MiTEP and other geoscience K-12 partnerships need accurate methods for measuring the impact of their efforts.

Four cohorts participated in a staggered three-year MiTEP program. Each cohort contained between 12 and 24 teachers. The MiTEP activities included summer field experiences, professional development days, online courses, leadership opportunities, and an intern experience at one of Michigan's National Parks. Each cohort's MiTEP program began with a two-week summer field course, Earth Science Institute I (ESI-I). The first week of ESI-I was spent in Michigan's Upper Peninsula exploring the geology of the Keweenaw and basic Earth science concepts. The second week was spent in Michigan's Lower Peninsula exploring local geology and additional Earth Science concepts. Each day of ESI-I was correlated with district curriculum, Michigan's Earth Science High School Expectations [MDE, 2006], misconceptions, and one of the nine *Earth Science Literacy Principles* (ESLP) [NSF, 2009]. During the school year, teachers enrolled in Michigan Technological University online courses and participated in four teacher workshops that focused on pedagogy, inquiry teaching, Earth science classroom activities and basic Earth and Space science content. The second year for the teachers in the program began with a second two-week summer field course (ESI-II), which also was split between the Upper and Lower Peninsulas and was aligned with district curriculum and Michigan's Earth Science High School Expectations [MDE, 2006]. Misconceptions and the ESLP [ESLI, 2009] were again addressed, as in the previous year. This experience was followed by a second school year of online courses and four teacher workshops that were led by MiTEP teacher-leaders. During the third and final summer in the MiTEP program, teachers interned at Isle Royale National Park, Sleeping Bear Dunes National Lakeshore, Keweenaw National Historical Park or Pictured Rocks National Lakeshore. During their internships they developed educational materials for the parks.

3.1.2 Research Question

The goal of this research project was to determine an effective method for assessing the effectiveness of a professional development program on building teachers' Earth science content knowledge. The research question is, "Can a quantitative, qualitative, or mixed-methods approach determine the impact of an Earth science professional development program on teachers' Earth science content knowledge?"

3.2 Background and Context

Promoting understanding of the *Earth Science Literacy Principles* (ESLP) [NSF, 2009] and correcting the many common Earth science misconceptions is of utmost importance in preparing society to effectively deal with challenges that our planet will be facing in the future and the many natural hazards we face every day. Geoscientists and Earth science educators play an important role in teaching the general public about geoscience concepts. Collaborations between geoscientists and K-12 science educators can make the general public more aware of geoscience by introducing students to geoscience concepts, processes, and careers. Unfortunately, although many geoscientists are experts in their field, they are unprepared and ill-equipped to engage teachers in partnerships. Workshops with scientists and K-12 educators have shown that scientists want to build partnerships, but that they need support to do this [Andrew, 2005].

Since the 1970s, research has shown that classroom teachers play the most important role in contributing to student learning and achievement [Fennema, 1992]. As research has progressed and improved our understanding of how teachers impact the way students think about science and the role that teachers play in modeling scientific thinking, the role of the teacher has changed. Research studies have shown that by providing high-quality professional development for science teachers, one can improve teacher practices in their science classrooms and can improve student achievement in science [Kennedy, 1997]. According to the 2005 American Educational Research Association's (AERA) publication, *Teaching Teachers: Professional Development to Improve Student Achievement*, high quality professional development must incorporate many specific elements. One of the most important is building teachers' deep understanding of the content they teach [AERA, 2005]. When they published the AERA's *Essential Information for Education Policy*, they stated:

> *"Teacher professional development can improve student achievement when it focuses on teachers' knowledge of the subject matter and how students understand and learn it."* [AERA, 2005]

The research described here has the potential to inform geoscientists about how to measure changes in teachers' Earth science content knowledge. When geoscientists give their time and expertise to improve teachers' Earth science content knowledge through professional development, they expect to be able to measure to what extent their efforts have been successful. If geoscientists know that their efforts have made a difference and they have improved teacher quality, they are more likely to take an active role in continuing to reach out to the K-12 community by building additional partnerships that can eventually lead to an Earth science literate society.

This is an important time for science education reform in the United States. Several recent publications should be on the radar of all geoscientists. In 2009, the *Earth Science Literacy Principles* (ESLP) [ESLI, 2009] were released. The ESLP identified the most important big ideas and fundamental concepts that a scientifically literate member of society should understand about the geosciences [Wysession et al., 2012]. In 2011, the National Research Council (NRC) released the *Framework for K-12 Science Education* which identified the science content knowledge and engineering concepts that students should know by the time they finish high school. In the NRC's *Framework*, Earth and Space Science became one of four major science domains along with the physical sciences, life sciences, and engineering, technology and applications of science. The *Framework* also describes a set of important "Disciplinary Core Ideas" within each domain [NAS, 2011], with one-fourth of all the "Disciplinary Core Ideas" coming from the geosciences. The ESLP and *Framework* alone have increased awareness among geoscientists of the importance of geoscience in K-12 education, and have increased concern about teachers being prepared to teach the "Earth Science Disciplinary Core Ideas" [NAS, 2011]. In 2013, teams from 26 states worked with Achieve and a 41-member writing team along with science experts drawn from each of the *Framework's* four domains to develop the *Next Generation Science Standards* (NGSS) [Achieve, 2013]. For grades K-5, 13 out of 37 or 35% of the standards are related to Earth science. In the middle grades (6-8) and in high school (9-12), 3 out of 12 NGSS or 25%, of the science standards are based on Earth science. As of September 2013, seven states have already adopted the NGSS, and other states have begun the process [NCSE, 2013]. This is an important time for all geoscientists to contribute to the work that needs to be done to improve teacher Earth science content knowledge.

3.3 MiTEP Assessment

Both quantitative and qualitative methods were employed during the course of the MiTEP Program (2009-2014) to assess the program's impact.

3.3.1 Initial Assessment Strategies

The initial assessment strategies were selected based on the best information available when MiTEP began. Beyond knowing that the program made a difference, assessments were intended to identify the specific nature and magnitude of any impacts. The following describes the initial strategies, explaining what methods and instruments were used and why.

The original instrument selected to assess changes in the Earth science content knowledge of teachers participating in the MiTEP program was the middle school level Misconceptions-Oriented Standards-Based Assessment Resources for Teachers (MOSART) Earth Science Instrument [MOSART, 2006]. The MOSART project was funded by the National Science Foundation (NSF) to provide no-cost assessment support to NSF-funded Math Science Partnership (MSP) projects. MOSART project tests are free and can be accessed by anyone upon completion of an online tutorial [MOSART, 2006]. The MOSART test was chosen because of its reliability and validity [Sadler et.al, 2010]. The MiTEP team expected that this instrument could provide a quantitative measure of changes in content knowledge among the teachers participating in the MiTEP program.

The MOSART was administered to MiTEP teacher participants as a pre-test and a post-test (table 15). The pre-test was administered at the beginning of the first summer session, prior to any instructional activities. The post-test was administered at the end of the second summer session, following the last instructional activity. Both the pre-test and the post-test were the same version of the MOSART Earth science test. Due to the fact that the pre- test and post-test were administered one year apart, there was little potential for repeat-administration bias.

Table 15: Schedule for administering Misconception-Oriented Standards-Based Assessments for Teachers all cohorts.

Cohort	***Pre-Intervention***	***Post-Intervention***
Cohort 1	Summer 2009	Summer 2010
Cohort 2	Summer 2010	Summer 2011
Cohort 3	Summer 2011	Summer 2012
Cohort 4	Summer 2012	Summer 2013

Pre- and post-intervention test scores on the MOSART were compared using the Statistical Package for the Social Sciences [IBM, 2012]. The paired t-test is a parametric statistical test used when there are two repeated measures with one sample. When the same subjects take pre- and post-intervention tests, the t-test tells how far apart the means are in standard error units [Wagner, 2011]. The scores were typed into a spread sheet as the independent and dependent variables. SPSS provided the t-test statistic, degrees of freedom (df), and critical t value at the specified level of significance ($p<0.05$) [Salkind, 2008].

Both of the two-week summer field courses required the teachers to maintain a field journal and to complete daily assignments which were often related to misconceptions and the ESLP [ESLI, 2009]. The field journals were scanned daily for misconceptions and the daily assignments were also reviewed each day. Review of the journals and daily assignments, and observations of the teachers' field work, provided some formative assessment information to the MiTEP team. An additional formative assessment was a weekly survey that asked the teachers to self-reflect on the past week's field experiences. These surveys provided immediate feedback so changes could be implemented to improve the field courses.

The surveys asked teachers to mark one of five choices for each statement: Not True, Slightly True, Moderately True, Mostly True, and Very True. To analyze the results, each response was assigned a nominal value and the mean response was calculated for each statement. Only the portion of the survey related to teacher learning is shown in table 16 and analyzed here because the research described here focused only on measuring one of the goals of the MiTEP program, that is, change in teachers' Earth science content knowledge. Other components of the survey addressed different goals.

Table 16: Questions on field course formative assessment related to teacher learning administered at the end of each week.

Survey Statement	***Not True***	***Slightly True***	***Moderately True***	***Mostly True***	***Very True***
As I have gone through the workshop, I have felt confident that I know what I am supposed to learn and do.					
Doing the workshop and completing the assigned tasks has given me a feeling of accomplishment.					
The workshop content is relevant to my work as a teacher.					
The workshop has stimulated my desire to learn more.					
The workshop has been building my confidence to learn new concepts.					
The workshop experience has challenged me to consider new ideas and approaches to teaching.					
My understanding of the subject content has increased.					
The technology that has been used has helped me to learn.					
The course has provided me with opportunities to learn through hands on practical experience.					
The technology that has been used can also be used in my own work.					

The teachers self-assessed their leadership skills and practices on a pre-intervention survey administered prior to beginning the MiTEP program. The same survey was used as a post-intervention assessment. Teachers also created a "Leadership Portfolio" that was collected and used as an additional measure of the extent to which the teachers met the MiTEP expectations in leadership growth. Portfolios provided teachers with the opportunity to demonstrate leadership in communicating with students and parents, improving classroom instruction within the school and the district, and serving as leaders in their local communities. Teachers were encouraged to take on formal leadership roles in local and state educational professional organizations.

MiTEP teachers gave professional presentations at local teacher workshops. Cohort 1 teachers presented posters at the 2011 Geological Society of America (GSA) Conference. Each of the MiTEP teacher cohorts shared their work at Share-A-Thon presentations at the Michigan Science Teacher Association (MSTA) annual conference in the spring of their second year in the MiTEP Program. Additionally, some of the teacher participants gave presentations about their National Park Internship experience at the MSTA annual conference held during the year after they had completed the MiTEP program. The MiTEP Principal Investigators, MiTEP ESI instructors, MiTEP external evaluators, and MiTEP graduate students regularly attended the MSTA conferences to observe the MiTEP teachers' presentations. These observations provided information about what teachers learned while being a participant in the MiTEP program. Participation as a presenter at a conference such as MSTA was considered evidence of leadership in the teachers' professional community.

Four Michigan Tech University faculty members who had been involved with MiTEP were interviewed about their experiences working with the MiTEP teacher participants. The four interviewees were randomly selected. In order to perform the random selection, the names of all MiTEP guest instructors were placed into a beaker. The first four names drawn were asked to participate in an interview. These individual semi-structured interviews took place in an office on the Michigan Technological University campus. Five basic questions (table 17) were asked and then the interviewer encouraged the faculty members to explain their answers and provide more information about their experience with the MiTEP program. The faculty interviews were not recorded but the interviewer took notes while conducting the interview.

Table 17: Interview questions asked of four faculty members that had served as guest speakers.

Interview questions
1. How often did you participate in educational sessions with K12 teachers prior to working with the MiTEP program?
2. Since working with MiTEP, has the frequency of your participation with K12 teachers increased, decreased or stayed the same? Why do you think that is?
3. Did working with the MiTEP teacher participants impact your interest in finding additional ways to work with K12 teachers and students? Please explain why or why not.
4. Did you develop any new insights as a result of your work with the K12 MiTEP teacher participants? Please describe any insights that came from working with the teachers.
5. Did you change your own teaching practices as a result of working with the MiTEP program? If so, please describe the changes and what aspects of MiTEP caused these changes.

Additional assessments also were conducted but are not discussed further in this document. For example, teachers completed surveys and typical course assignments for the Michigan Technological University online and field courses. Typical course assignments included reports, quizzes, etc. Additionally, the teachers were required to produce products for specific courses such as standards-based lesson plans, lesson-study research lessons, slideshows of digital images from a National Park connected to the ESLP, and geology kits and trail guides for the National Park where they interned.

Also not discussed further is the MiTEP evaluation team's assessment of the teacher participants' teaching skills. A pre-intervention observation was conducted during the spring semester prior to a teacher's entry into the MiTEP program. A post-intervention observation was conducted during the spring semester just before the teachers completed their last summer in the MiTEP program. The *Science and Mathematics Program Improvement* (SAMPI) *Lesson Observation System* [SAMPI, 2008] developed by Western Michigan University's Michigan Mathematics and Science Leadership Collaborative [MMSTLC, 2009] was used to measure changes in the use of inquiry in the MiTEP teacher participants' classrooms [Schuster et al., 2007].

3.3.2 Analysis of Initial Strategies

The MOSART test proved to be an inadequate instrument for measuring the impact of the MiTEP program. Analysis of the teachers' scores on the MOSART test indicated that the MiTEP program made no impact or produced no change in the MiTEP teacher participants' Earth science content knowledge. The mean of the teachers' scores from Cohorts 1, 2, 3, and 4 show a gain of one point on the post-test after completing the MiTEP program. Table 18 shows the descriptive statistics.

Table 18: Misconception-Oriented Standards-Based Assessment Resources for Teachers pre-intervention and post-intervention test descriptive statistics for combined scores of cohorts 1-4.

MOSART	***N***	***Mean***	***Standard Deviation***
Pretest	54	22.59	4.760
Posttest	54	23.56	5.315

As one would expect given the descriptive statistic data, the dependent samples t-test results show no difference ($t_{(df=53)} = 2.306; p<.05$) between the post-intervention MOSART test mean scores (Mean=23.59) and the pre-intervention test mean scores (Mean=22.59). According to these statistics, the MOSART results provided no evidence of change.

Teachers' responses to the formative surveys that were administered each week during the summer field courses contrasted with the MOSART results. Data analyzed here came from

Cohorts 1 (years 2009-2010), 2 (years 2010-2011), 3 (years 2011-2012), and 4 (2012-2013). Each of the responses were assigned a number Not True=1, Slightly True=2, Moderately True=3, Mostly True=4, and Very True=5. The first ten statements on the survey related to learning; only those statements have been analyzed (table 19). The means for all ten questions are high. The three highest are: 1) My understanding of the subject content has increased; 2) The course has provided me with opportunities to learn through hands on practical experience; and 3) The workshop has stimulated my desire to learn more. The responses on these surveys were in direct conflict with the scores on the MOSART.

Table 19: Analysis of responses to questions about teacher learning on the weekly formative surveys.

Survey Statement	***Mean***
As I have gone through the workshop, I have felt confident that I know what I am supposed to learn and do.	4.16
Doing the workshop and completing the assigned tasks has given me a feeling of accomplishment.	4.47
The workshop content is relevant to my work as a teacher.	4.39
The workshop has stimulated my desire to learn more.	4.61
The workshop has been building my confidence to learn new concepts.	4.55
The workshop experience has challenged me to consider new ideas and approaches to teaching.	4.54
My understanding of the subject content has increased.	4.72
The technology that has been used has helped me to learn.	4.37
The course has provided me with opportunities to learn through hands on practical experience.	4.68
The technology that has been used can also be used in my own work.	4.11

Another bit of conflicting data came from observations of the teachers' presentations. Many MiTEP teachers' presentations were observed from 2010-2012. In each presentation the same theme was voiced. The teacher participants gave testimony that they had learned a great deal of Earth science content during their participation in the MiTEP program. The presenters often referred to topics that they had learned while in the field and how their internship experience at a Michigan National Park helped them use what they learned during the MiTEP project.

Other information, aside from the observations and formative survey data, was also in conflict with the MOSART results. One summer faculty member reported that the teachers working in the field during the ESI-I and ESI-II courses had asked difficult questions about Earth science content. This faculty member reported that there was a difference between these teachers and typical undergraduate students in regular on-campus geology courses. The faculty member said that typical college students were mostly interested in a basic understanding; they wanted to learn enough to do well on their tests. In contrast, the MiTEP teachers wanted to develop a deep understanding of the Earth science content. During the experience with the MiTEP teachers, the faculty member said that the teachers asked many questions checking to be sure their newly acquired understandings were accurate.

By 2011, there was ample evidence that the MiTEP program had impacted the teachers' Earth science content knowledge, even though it was not apparent from the MOSART results.

3.4 Developing Improved Assessments

3.4.1 Quantitative Methods

In spring 2012, development of a set of test questions began with the intent of piloting a test with Cohorts 3 and 4 that summer, in June 2012. The Earth System Concept Inventory (ESCI) development began with a group of undergraduate and graduate geoscience students writing test questions based on the High School Content Expectations (HSCEs) for the State of Michigan. Each student was assigned a category of HSCE's and were instructed to write at least two comparable multiple-choice questions, labeled A and B, for each HSCE that was assigned to them. A professional geoscientist met with the students in spring 2012 while they worked on this writing process and instructed students on how to conduct a content validity test on their questions. These students asked undergraduate geoscience students and K-12 teachers to participate in this validation activity. The test question writers instructed their subjects to answer each question and then explain why they answered as they did. The question writers determined if their subjects answered correctly or incorrectly for the "right" or "wrong" reason in order to determine if they understood the question and if the question addressed the appropriate and intended content. When the writers found problems, they revised the questions. The tested questions were reviewed by another geoscientist for construct and content validity review. The students improved their questions based on the review and submitted the final versions of their questions to the MiTEP evaluation team, both as digital documents and in hard copy. These sets of questions served as the foundation for writing the new pilot ESCI.

Construction of a pilot test began with the selection of 20 sets of questions (a version "A" question and a version "B" question formed a set of questions) from each of the four HSCE categories: The Earth's System, The Solid Earth, The Fluid Earth, and The Earth and Space. The 80 sets of questions were directly related to the HSCE covered during the two summer field courses. These questions were reviewed by a committee to select 40 A and B version questions as the ESCI pilot test. The committee decided that 40 multiple choice questions would adequately cover the content taught during the summer field courses. The 40 A/B questions were selected according to the criteria shown in table 20. The committee tried to limit the total number of questions to the minimum number required in order to ensure that the test could be completed within an hour.

Table 20: Criteria for selecting questions to place on the Earth Science Concept Inventory pilot test.

Selection Criteria
1. Does the question focus on one of the HSCEs addressed during the MiTEP ESI 1 or 2 summer field courses?
2. Is the question written too easy, or posed in such a way that we would expect any 8th grade Earth science student to know the answer?
3. Does answering the question require deeper thinking beyond rote memorization of a definition?
4. Are there A and B questions that are equal in content and difficulty?
5. Are the answer choices for the question reasonable and likely to be considered as possible answers, including common misconceptions?

Reviewing the questions according to the selection criteria required that several questions be partially re-written so that the A and B questions were of equal difficulty. Several new questions were added that specifically related to Michigan geology. Michigan geology was important because place-based science was stressed throughout the MiTEP Program. The two different versions were then reviewed further for content and construct validity by a third professional geoscientist. Two versions of the test were constructed because of the possible threat to internal validity when the pre-tests and post-tests are the same. This threat can manifest when the pre- and post-tests are administered during a relatively short time period.

During the summer of 2012, the version A was administered to the Cohort 3 and Cohort 4 teachers' prior to the beginning of the summer two-week field course. The summer 2012 field course was the second and last field course that the Cohort 3 teachers participated in and the first field course for the Cohort 4 teachers. Both cohorts were administered the B version as a post-test at the completion of the two-week field course. If the two versions of the test were identical, any gains (or losses) in the teachers' scores could potentially be attributable to the summer field course experience. However, at the time the tests were administered in 2012, equivalence of the two versions of the test had not yet been established. During the summer of 2013, Cohort 4 teachers took (for the second time) version A of the ESCI pilot test. This small sample of 14 teachers were therefore pre-tested (at the start of their first field course) and post-tested (at the end of the second field course) with the same version of the ESCI pilot test. The gains (or losses) exhibited by the Cohort 4 teachers, as measured by version A of the ESCI pilot test were assumed to be attributable to all components of the MiTEP program to which the teachers had been exposed during the intervening year. It was assumed that repeat-administration bias would not be a problem because more than one year had elapsed between the two administrations of the test. A dependent samples t-test was used to compare the pre- and post-intervention test scores for the Cohort 4 teachers.

Multiple comparisons of the version A post-test and version B post-test data were used to investigate the equivalency of the two tests. The two versions of the post-tests were administered to two different cohorts of teachers who had completed the same components of the MiTEP program as of the last day of their ESI-2 field course (Cohort 3 took version B in 2012 and Cohort 4 took version A in 2013). Therefore these two groups of teachers, while not exactly the same, could serve as comparison groups for each other. If the two versions of the ESCI pilot test were equivalent, it was expected that the two sets of post-test results would be equivalent. Unfortunately, the sample sizes of these two groups of teachers were small, 17 and 14 respectively. An independent sample t-test was used to investigate the equivalency of the two tests. The result of the independent-samples t-test indicated that there was no significant difference ($t_{(df=29)} = .5$; $p>.05$) between the mean scores (table 21). This statistical analysis indicates that any difference was due to chance. Because the sample sizes are small for this t-test statistical analysis, additional groups of teachers were also used to test for the equivalency of the A and B versions of the pilot test.

Table 21: Descriptive statistics for Earth System Concept Inventory post-intervention test scores for Cohort 3 (version B) and Cohort 4 (version A).

ESCI	***Sample Size***	***Mean***	***Standard Deviation***
Cohort 3 Post-test (B)	17	30.05	5.42
Cohort 4 Post-test (A)	14	31.0	4.94

A second test for the equivalence of the A and B versions of the pilot test was conducted using a convenience sample of 33 individuals taking classes through the University of Nebraska at Omaha's Education Department. This same group of individuals was used to establish the criterion-referenced validity of the ESCI pilot tests. Some members of the sample had strong science backgrounds; some had taken very little science in college. Some were classroom teachers, some had moved into administration and some were school nurses. The A and B versions of the test were administered to this diverse group using SurveyMonkey [SuveyMonkey, Inc, 2013]. Each individual's score on the A version of the pilot test was compared to their score on the B version (figure 3). As can be seen in figure 3, scores for the different types of individuals who took the test can be grouped. Practicing teachers certified to teach Earth science and teachers who had experience teaching Earth science (Group D) earned the highest scores on both versions of the pilot tests. Group C includes teachers with a background in a science other than Earth science, that is, chemistry, physics or biology. Group B consists of nurses and elementary teachers. Group A includes school administrators with the least amount of background knowledge in any area of science. Figure 3 shows that the teachers with strong Earth science backgrounds (top right, group D) scored high on both version of the tests. Individuals with progressively less knowledge of Earth science and science scored progressively worse on the two versions of the test. Thus the test appears to measure what it is intended to measure: Earth science content-area knowledge. Since the people with more exposure to the requisite content knowledge scored higher and the results are not random, these tests may have future use for predictive validity.

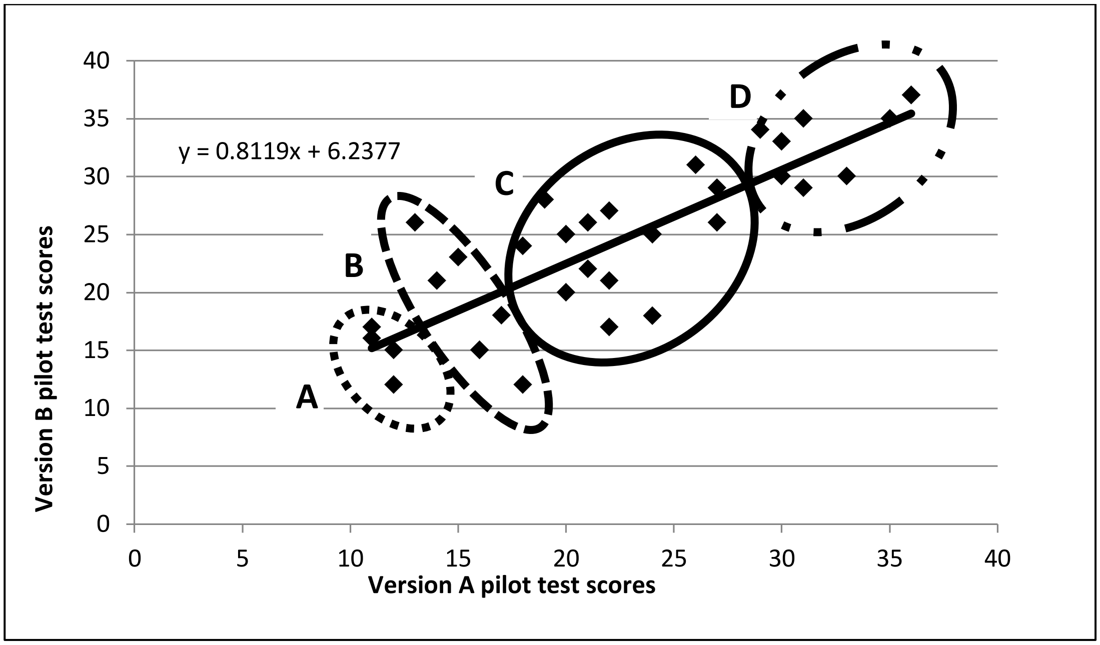

Figure 3: Criterion-referenced validity test (n=30) of the Earth System Concept Inventory pilot test, versions A and B. Equation of best-fit line is shown along with four fields that correspond to different types of test takers.

The scores on the A and B pilot tests from this set of 33 individuals were also used to examine the relationship between the two versions of the test using the Pearson Product Moment Correlation (PPMC). A correlation coefficient is a calculated value that reflects the relationship between two variables [Abu-Bader, 2006]. The value of this descriptive statistic ranges between -1 and +1, with 1 being a perfect linear correlation, that is, a very strong correlation. When the calculated value is equal to zero, this indicates that there is no relationship between the variables. Using the scores on the A and B pilot tests of the 33 individuals with highly variable backgrounds in science, the correlation was r_{AB}= 0.828, $p<.05$ (table 22) when all 33 individuals were included. This indicates a relatively strong positive relationship between the scores on the A and B versions of the tests.

Table 22: Correlation statistics using Pearson Product Moment Correlation between version A and version B test scores of Nebraska educators with a wide range of Earth science backgrounds (including Groups A, B, C, and D in figure 3 (n=33).

Correlation Statistics		
	A-Test	B-Test
Mean	22.3	24.3
Standard Deviation	7.43	7.03
Pearson Reliability Coefficient	0.828	

It is also important to note that of this sample, the teachers who had experience in Earth science, either through their own education or because of their teaching assignments, as well as those with the least experience in any science, tended to have scores that were approximately identical on the two versions of the test. Comparison of these subgroups (group D, n=7; group A, n=4; and group B, n=6; as shown in figure 3) also provides some evidence of the equivalency of the two versions of the test. The Pearson Product Moment Correlation between members of group D (teachers with a strong Earth science background) was r_{AB}= 0.810, $p<.05$ (table 23). This indicates a relatively strong positive relationship between the scores on the A and B versions of the tests for all of the group D individuals. The Pearson Product Moment Correlation between members of group A (teachers with the weakest science background) was r_{AB}= 0.762, $p<.05$ (table 23). Similarly the Pearson Product Moment Correlation for group B was r_{AB}= 0.896, $p<.05$ (table 23). This indicates a relatively strong positive correlation between the scores on the A and B versions of the tests for all of the individuals with weak science backgrounds. Group C was found to have a weak positive correlation; group C included teachers with backgrounds in a science other than Earth science. Due to the small sample sizes there is a high probability of error, particularly for groups A, B, and D, but the correlation coefficient can still be considered strong [Abu-Bader, 2006].

Table 23: Correlation statistics using Pearson Product Moment Correlation between all individuals in groups A, B, C, and D in figure 3.

Correlation Statistics								
Group	A (n=4)		B (n=6)		C (n=15)		D (n=7)	
Pearson	0.762		0.896		0.301		0.810	
Version	A	B	A	B	A	B	A	B
Mean	11.5	14.7	15.5	19.1	22.53	24.26	32.8	32.7

An important small subgroup of the group D master teachers is a group of three nationally recognized Earth science teachers who scored very high on both the A test and the B test. For individuals in all four groups in figure 3 (Groups A, B, C, and D) the correlation is not as strong as the correlation for this very small elite subgroup. Because the group is very small, n=3, it is meaningless to calculate a correlation coefficient, however, descriptive statistics demonstrate that their scores were very close (table 24). The calculated means of these teachers' scores on version A (35.67) and versions B (36.33) of only 0 .66, less than one individuals earned high scores (table 24).

Table 24: Descriptive statistics for scores on version A and version B earned by three nationally recognized Earth Science teachers.

Descriptive statistics		
	A-Test	B-Test
Mean	35.67	36.33
Standard Deviation	0.577	1.154
Range of Scores	35-36	36-37

Although tables 21-24 provide some evidence of alternate forms reliability, this was further tested through the participation of members of the Michigan Earth Science Teachers Association (MESTA) who volunteered to be on-line test takers, again using SurveyMonkey. Forty-four Earth science teachers volunteered to participate. Twenty-two of the MESTA test responded to questions 1-40 on the A version and questions 41-80 on the B version, while the other twenty-two of the MESTA teachers responded to questions 1-40 on the B version and questions 41-80 on the A version. Thus every teacher responded to a total of 80 questions (40 from the A version and 40 from the B version). A total of two scores was calculated for each teacher. The first score was based on their responses to items 1-40 and their second score was based on their responses to items 41-80. Their score on the A version was then compared to their score on the B version. The MESTA teachers' scores were again analyzed using the Pearson Product Moment Calculation (table 24). The A and B pilot tests' correlation is $r_{AB} = .838$, $p < .01$), indicating a relatively strong positive relationship between scores on the A and B versions of the test [Abu-Bader, 2006].

Table 25: Correlation statistics using Pearson Product Moment Correlation between pilot test version A and version B scores for Michigan Earth Science Teacher Association test takers (n=44).

Correlation Statistics		
	A-Test	B-Test
Mean	22.58	24.28
Standard Deviation	7.23	6.94
Pearson Reliability Coefficient	0.838	
Significance: Correlation is significant at the 0.01 level	.000	

The t-test conducted with the MiTEP teachers' post-intervention scores, the calculated correlations with the University of Nebraska Educator students' scores and the Michigan Earth Science Teacher Association volunteer test-takers' scores, all showed that the A version and the B version of the pilot test are nearly equivalent. However, small sample sizes could introduce error when using these statistics. Visual inspection of figure 3 suggests that test B may be somewhat easier than test A, more so for students with the weakest science background. The equation of the best-fit line through all of the data (shown in figure 3) supports this interpretation as well as the calculated mean of the version A test scores and the version B test scores for Groups A, B, C, and D (table 23). Groups A and B have a greater difference (three out of forty questions) between their means than Group C (one question out of forty questions) and Group D (less than one question out of forty questions) (table 23).

Based on the results shown in tables 22-25, it appears that the two versions of the test are approximately equivalent. These tests also appear to be reliable in that for test subjects classified according to specified criteria, people with similar backgrounds all score the same on both of the instruments [Abu-Bader, 2006]. More analysis and refinement of the test is needed however. In the future, as additional data become available, each individual pair of questions will be compared and if necessary, the questions will be further modified in order to improve their equivalency in terms of difficulty.

The three award-winning "Master" Earth science teachers were also asked to assess the tests' face validity. Face validity addresses whether or not the instrument appears to measure what it is intended to measure. These teachers were asked to determine whether or not the two versions measured only Earth science knowledge. Each of the seven teachers in this elite sub-group reported both versions met the criteria for an Earth science test [McLeod, 2013].

3.4.2 Qualitative Methods

The MiTEP evaluation team decided that a comprehensive exit survey could be used to gauge the impact of the MiTEP program. In the spring of 2012, an on-line search was conducted to locate surveys that were already developed and validated. Nothing was found to meet the needs of the MiTEP program. While looking for a more effective qualitative instrument, the evaluation team talked about a survey that teachers had taken prior to the beginning of the MiTEP program. The MiTEP teachers had self-assessed their Earth science content knowledge on a survey that was based on the *Michigan High School Content Expectations* [MDE, 2006]. The original survey instrument listed all of the content expectations every Earth science teacher in Michigan is required to teach. It was decided that repurposing this instrument to gather post-intervention data could either confirm or refute the evidence collected through the MOSART and observations. The plan became to administer the survey again and compare the teacher's responses on the pre- and post-intervention surveys. The sample size was small because only six of the teachers that had taken the pre- intervention survey remained in MiTEP until the end of the three year program. Copies of the surveys were mailed to these six teachers, along with a postage-paid return envelope. Since these teachers had already completed the MiTEP program, they were provided with an incentive to promote completion of the survey.

The teachers used a Likert scale (E=Excellent; VG=Very Good; G=Good; F=Fair; P=Poor) to self-reflect on their 1) personal understanding of the Earth science content , 2) their skills for teaching the content, and 3) their student's understanding after being taught. The MiTEP evaluation team assigned each of the letters a numeric value (E=5, VG=4, G=3, F=2, and P=1). A mean score was calculated for each teacher for their personal understanding of Earth science content. Upon comparing the responses on these teachers' initial and later self-report surveys, the MiTEP evaluation team decided more explanation was needed because the results showed very little change and the changes were not always positive. Therefore, interview questions were created based on the results from this survey. The six teachers that completed both the pre-intervention survey and the repurposed survey were asked to participate in individual interviews.

A set of interview questions was designed to complement the sets of survey questions that focused on the teacher's Earth science content knowledge, teaching practices, and students' learning outcomes (table 26). The teachers were invited to participate in an interview through an e-mail invitation. Each teacher selected the time and location for the interview to take place. Three interviews took place in a restaurant or coffee shop because the MiTEP evaluation team offered to pay for a snack or meal as an incentive. Two interviews took place after school in the teacher's classroom. Each teacher was shown their scores on both the pre-intervention survey and the repurposed survey. During these semi-structured interviews, each teacher was asked the interview questions and then encouraged to talk about their background, teaching experiences and their experiences in the MiTEP program. The interviews were recorded and later transcribed with the help of *Dragon Naturally Speaking Software* (Nuance, 2011). The teachers' responses were analyzed and coded according to 1) kinds of MiTEP learning activities that the teachers thought were important, 2) conditions of their current employment, and 3) reasons for such low responses on the survey.

Table 26: Interview questions asked of Michigan Teacher Excellence Program teachers regarding their responses on the repurposed survey.

Interview Questions
1. Focusing on your personal experience, do you believe that the program improved your knowledge? If so, can you give examples of <u>aspects of your knowledge</u> that were improved?
2. Can you identify specific <u>activities</u> in the project that had an impact on your knowledge?
3. I would like to talk to you about your <u>responses to the survey.</u> How did you interpret the following questions? (Interviewer shows them the questions on content knowledge). • Follow up questions: o Option A: Your responses appear to show that you did not gain in knowledge as a result of participation in the program. Can you help me understand how you have thought about your experience? o Option B: Your responses appear to show that you gained in knowledge as a result of participation in the program. Can you help me understand how you have thought about your experience?
4. Do you have suggestions of what else could have been done to better support your learning?

After the interviews took place, the evaluation team decided an additional instrument was needed to capture specific information, the kind of information that the interviewees had shared. The decision was made to develop a new exit survey for the program. The questions were developed with attention paid to the goals of the MiTEP program. All the components of the program were addressed on the final version of the exit survey (Appendix C).

The MiTEP exit survey went through multiple cycles of review and revision. Once the review and revision process was completed, two graduate students working on the MiTEP program took the survey. They judged the questions to be valid and to request the information that was needed. The survey was finalized in the summer of 2012. The final exit survey is present in Appendix C.

While the majority of survey questions on this new instrument provided teachers with a Lickert scale to rate the effectiveness of various MiTEP learning activities, the teachers were asked to rank which activities they perceived to be the top activities that supported their learning. The instrument included a section for the teachers to write constructed responses so that we could capture additional information. The face validity of the exit survey had been established by graduate students when they responded to the survey as if they were teacher participants. The survey committee that worked on creating the survey instrument established context validity by carefully examining and discussing each individual question. It was expected that teachers' responses on this new MiTEP exit survey would provide valid qualitative evidence showing whether or not the MiTEP program made an impact on the participants' Earth science content knowledge and which aspects of the program were most effective.

Even though the teachers were once again providing us with their self-assessment, as they previously had done on the repurposed survey, the exit survey questions were structured to minimize bias. The survey's Likert scale included negative options to promote serious reflection. A scale from -10 to +10 was employed in some instances so that responses would require deeper thinking and hopefully avoid general and superficial responses. Experience had shown that the teachers often felt rushed when completing a survey, so the teachers were given an extended period of time to think and respond to the questions. The surveys were sent to the teachers with a due date three weeks in the future, telling them they should take their time and provide thoughtful responses.

3.5 Results

3.5.1. Results of Quantitative Data Analysis

Cohort 4 was the only cohort to take the new ESCI pilot test prior to beginning their first-two week MiTEP summer field course. Because everyone in Cohort 4 took version A of the ESCI as their pre- and post-intervention tests, the “alternative forms reliability” concern does not apply. Due to the fact that the pre- test and post-test were administered one year apart, there was little potential for repeat-administration bias. The average gain was 5.4 points on the post-test after completing the MiTEP program (table 27). The results of the dependent-samples t-test on the ESCI pilot test (table 28) show a significant difference ($t_{(df=13)} = 5.29$; $p<.01$).

Table 27: Descriptive statistics for Earth System Concept Inventory pre-intervention and post-intervention test scores for Cohort 4.

ESCI	*Sample Size*	*Mean*	*Standard Deviation*
Pre-test	14	25.9	7.05
Post-test	14	31.3	4.58

Table 28: Dependent-samples t-test on Earth System Concept Inventory pre-intervention and post-intervention test scores for Cohort 4.

ESCI	*Mean*	*Standard Deviation*	*95% Confidence Interval*	*T value*	*Degrees of freedom*	*Significance (1-tailed)*
Pre-Post	5.44	3.84	Upper=-3.22 Lower=-7.66	5.29	13	.000

A gain-scores plot was made to illustrate the changes in the Cohort 4 teachers’ scores from when they took the pre-intervention (A test) and the post-intervention (A test). When gain scores are plotted graphically, the graph can provide insight via visual interpretation not easily inferred using only values from tables. The average gain for the Cohort 4 teachers, assumed to be due to participation in the MiTEP program, was 5.4 points (out of 40 points possible) or 13.5%. This average gain implies that all of the teachers showed improvement in their understanding of Earth science. Nevertheless, the gain plot (figure 4) clearly shows that not all teachers exhibited gains. One teacher exhibited a substantial loss, which is surprising given the other results. It is possible that this individual purposefully provided incorrect answers on the post-test due to frustration with the test, with MiTEP, or for some other (unknown) reason. The average gain in scores was found to be statistically significant, and the gain-score plot clearly shows that [May and Hittner, 2010], on average, teachers participating in MiTEP increased their understanding of Earth science content. The small sample size, 14 teachers, limits the potential generalizability of these results; they are encouraging however.

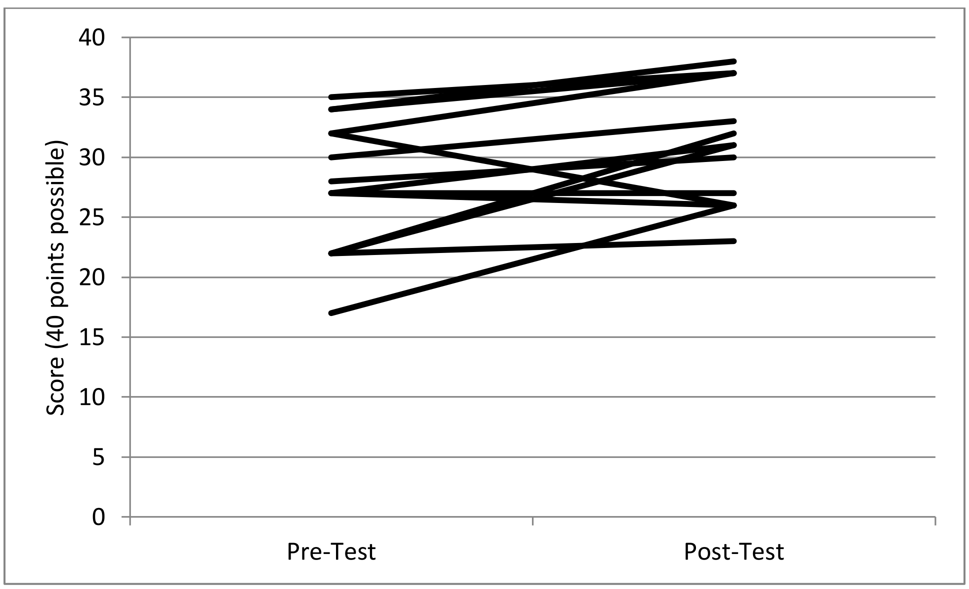

Figure 4: Gain-score plot of Cohort 4 teachers' on the Earth Science Concept Inventory pilot test, version A.

Once the ESCI pilot A and B versions were ready in the summer of 2012. They were administered to Cohorts 3 and 4. Only the data from Cohort 4 could be used to measure the MiTEP program's impact. It was later realized that a better method for administering tests when there are two versions is the "split-half" method. Had the evaluation team given half of the teachers the A version while the other half took the B version for the pre-intervention test and then reversed this process for the post-intervention test, any difference in difficulty between the two tests could have been controlled for. Use of the split-half method would have allowed MiTEP to accept that the difference between the pre- intervention and post-intervention scores represented a real difference in Earth science content knowledge. This would not have eliminated other reliability and validity testing described in section 3.4.1.1.

3.5.2 Results of Qualitative Data Analysis

Observing the teachers as they participated in the program provided valuable information about changes in their Earth science content knowledge. Although this kind of information alone is insufficient for assessment of the program, it revealed the weakness of the MOSART instrument and has been of value in formative evaluation and the development of improved assessment methods.

The repurposed survey was considered as an option for obtaining better evidence, so it was administered at the end of the program to compare these responses from teachers who had also provided responses before they entered the MiTEP program. Since teachers identified weaknesses the first time they took the survey, it was thought that they had fewer weaknesses after participating in MiTEP. When the results came in and were analyzed, they appeared to yield a negative outcome, and the decision was made to conduct interviews. Conducting the interviews was very important because that is how we learned that self-reflection distorted the teachers' responses. After the program, the teachers viewed themselves and their Earth science knowledge through a new lens. They had learned a lot of content, but working in the field with geologists and taking online classes made them realize how much more there is to learn about Earth science. Initially, they felt overconfident. Later, after they had been introduced to expert geoscientists, they lacked confidence. During the interviews, the teachers revealed that the more they learned, the more they realized how much more there is to know. The negative self-assessment responses were the result of their increase in content knowledge.

The new MiTEP exit survey asked the MiTEP teacher participants in Cohorts 1 and 2 to provide feedback in multiple areas. Increasing Earth science content knowledge was one of the areas, and the others were: teacher leadership, pedagogy skills, attitudes about teacher learning, and the use of specific teaching strategies. Table 29 shows teacher responses in the area of Earth science content knowledge on the yes/no questions.

Table 29: Results from Michigan Teacher Excellence Program exit survey related to Earth science content (Cohorts 1 and 2).

Survey Question	***# Yes***	***N=14***	***% Yes***
Did MiTEP change your understanding of the nature of science and/or how scientists do science?	9	14	64%
Did MiTEP change your understanding of how the Earth works?	13	14	93%
Has MiTEP influenced your attitude about the societal importance of earth science literacy?	14	14	100%

These results indicate that the MiTEP teachers believe that the MiTEP program was responsible for changes in their understanding of the nature of science and how the Earth works. The results on this section of the exit survey are consistent with observations made of MiTEP teachers in the field and MiTEP teachers' presentations at state and national professional conferences. They are in conflict with the results obtained through the administration of the MOSART test instrument, which did not measure a change in teachers' content-area knowledge. These results support the ESCI pilot test results, although these questions only specify that change occurred, but they do not indicate whether or not the change was positive (as was shown by the ESCI test).

When the teachers were asked to examine a list of types of activities that were part of the MiTEP program, they were asked to identify which four made the greatest impact on their learning of Earth science content knowledge. Table 30 shows the activities that were listed by the greatest number of teachers as having the greatest impact.

Table 30: Michigan Teacher Excellence Program activities identified by teachers as having the greatest impact on learning Earth science content from Cohorts 1 and 2. The potential choices included on the list were: Fieldwork in the Upper Peninsula; Fieldwork in the Lower Peninsula; Michigan Geography and Geology Text; Pedagogy days; Lesson Study Course; Earth System Science Content On-line Course; Science Learning Materials, Inquiry, and Assessment On-line Course; Scientists on Call; National Park Internship; Vernier LabQuest Pro probe devices; Commercial posters, booklets, pamphlets; MiTEP grants for classroom supplies; Membership in MSTA; Attendance at the MSTA Conference; Presenting at the MSTA Conference; Membership in NSTA; Participation in GSA National Conference; MiTEP Field Course Website; Classroom visits by colleagues; and Classroom visits by MiTEP personnel.

Activity	***Included in Top Four***
Field Work in UP	100%
Field Work in LP	93%
National Park Internship	93%
Pedagogy Work Days	43%

Few Earth scientists would be surprised by the fact that the teachers identified field experiences as having a great impact. Every teacher listed working in the field in the Upper Peninsula among their top four activities. Most geology programs in the US include fieldwork and/or a field camp. Teachers engage in an internship of "Student Teaching" in most education programs, but are seldom involved in doing field work at interesting geological locations. Based on the feedback from the MiTEP teachers, professional development programs for Earth science teachers should include a major field component.

Additional support for including field work comes from a different part of the exit survey where the teachers were asked to use a Likert scale ranging from one to ten to rank the extent to which specific MiTEP activities contributed to their learning. The mean of the responses for each of the activities was calculated. The top eight choices are found in table 31. The table lists the top eight because there were eight choices clustered together and there was a wide gap between these top eight and all of the other activities. The top three selections again identified doing fieldwork as most important in advancing teachers' learning. The fourth selection, MiTEP grants program, was an element of the MiTEP program that was added after the project started at the request of the participating teachers. During the program, several MiTEP participants complained of budget issues in their schools and the lack of adequate equipment. To help the teachers obtain equipment for their classrooms, as well as teach the teachers grant writing skills, the teachers were provided a MiTEP "Request for Proposals". Many teachers took advantage of this opportunity and acquired equipment that improved both their teaching practice and student learning. The remaining items indicate that MiTEP's practice of providing opportunities for the teachers to become members of professional organizations and to actively participate in those organizations was highly valued.

Table 31: Activity scores showing most important to advance Michigan Teacher Excellence Program teacher learning.

Michigan Teacher Excellence Program Activity	***Mean Score***
UP Fieldwork	9.94
Nat'l Park Internship	9.88
LP Fieldwork	9.44
MiTEP Grants	8.00
GSA Conf. Participation	8.00
MSTA Conf. Participation	7.67
MSTA Conference	7.53
MSTA Membership	7.27

Information about which aspects of the MiTEP program were found to be most effective by the teachers is important information for prioritizing effort. The MiTEP exit survey provided valuable information that has contributed to being able to judge the effectiveness of MiTEP's Earth science professional development experience.

While the Lickert scale options and ranking of the most important activities allowed us to get the teachers opinions in a form that could be quantified, they limited teachers' responses. The evaluation team wanted to provide teachers the opportunity to speak more freely about their MiTEP experience, so the teachers were asked to respond to free response questions. The first question asked whether MiTEP changed the teachers' understanding of the nature of science. Sixty-four percent of the teachers responded positively (table 32). The teachers found working in the field, especially in Michigan's Upper Peninsula, to be the most important activity for changing their understanding of the nature of science and/or how scientists do science. Taking teachers out of their classrooms and exposing them to awe-inspiring locations seems to have been a major contributor to changing their perspective, however, having Earth science instructors that were able to share their passion for science seems to have been equally important. Research has previously shown that the teacher is the most important variable when it comes to student learning [RAND, 2013, Wenglinsky, 2002, [Fennema, 1992]. The teacher response that praised the field course instructors indicated that this was also true within the MiTEP program.

Table 32: Constructed responses (Cohorts 1 and 2) to the question, “Did the Michigan Teacher Excellence Program change your understanding of the nature of science and/or how scientists do science?”

Cohorts 1 and 2 Constructed Responses
Summary of Responses (n=14): • 64% reported that MiTEP **did change** their understanding of the nature of science and/or how scientists do science. • 36% reported that MiTEP **did not change** their understanding of the nature of science and/or how scientists do science.
Specific Examples: • Five examples provided by teachers were related to their field experiences in Michigan’s Upper Peninsula. They complimented the MiTEP instructors who modeled how science is done and credited some of their learning to listening to the guest scientists explain their research projects. • One teacher discussed the impact that a particular field site had on their thinking: “The Gay Sands trip opened my eyes to the need of our society to create true thinkers to undo the harm we have done to the Earth. Knowledge of the nature of science is an important part, but "scientists" need to have the ability to think outside the box to figure out remedies to sustain our Earth.” **Three examples related to teaching practices:** • “I now understand that how teaching should be, does not exist where I teach. I know that I have to be the one who crosses the line to make changes when it comes to student and professional learning.” • “I was able to understand the vast number of misconceptions that students come to the classroom with.” • “I have a better understanding of inquiry due to MiTEP.” **Example related to why it did NOT change understanding:** • “I don't think MiTEP changed this- new for me. I worked as a development engineer and scientist before I was a teacher.”

All but one teacher claimed that the MiTEP program changed their understanding of how the Earth works (table 33) and most of them identified learning about the Earth system science perspective as instrumental in changing their understanding. The teachers included examples of working in the field as well as their National Park Internship as the experiences responsible for the most profound changes in their understanding.

Table 33: Constructed responses (Cohorts 1 and 2) to the question, “Did the Michigan Teacher Excellence Program change your understanding of how the Earth works?”

Cohorts 1 and 2 Constructed Responses
Summary of Responses (n=14): • 93% reported that MiTEP **did change** their understanding of how the Earth works. • 7% reported that MiTEP **did not change** their understanding of how the Earth works.
Specific Examples: • Four examples provided by teachers were related to learning about the complexity of the Earth system and the dynamic nature of the spheres. • Three examples provided by teachers were related to learning about the geologic history of the Earth. Two examples were the age of the Earth, tied to the rocks in the Keweenaw and the National Parks. Another example was the “Snowball Earth” construct, and another teacher specified unconformities and rock layers. One specific example was: “One of the biggest "ahas" was realizing that the lava flows occurred and stopped over a long period of time. Not one big constant eruption.“ • “MiTEP gave me more visuals and hands-on understanding of how the Earth works.” • “I did not know about the plasticity of the crust, or the convection currents in the magma.” • “Experience at Sleeping Bear Dunes changed my understanding of the amount of movement of sand due to wind and water.” **Examples related to teaching practices:** • “I never quite understood the science behind the seasons. It wasn't until a pedagogy day where we modeled different things in the solar system and discussed different misconceptions (of which I had one.) Also, the retreat of glaciers. Whenever I thought of this, I imagined this huge thing of ice moving backward and I guess I just accepted this without thinking about it. I feel somewhat stupid for thinking this way for years, I did realize that some students may be thinking the same thing.”

All but one teacher claimed that the MiTEP program influenced their attitude about the societal importance of Earth science literacy. The specific examples listed in table 34 shows that the teachers related science literacy with the ways that people can make a difference to society. The teachers support the inclusion of more science literacy curriculum in schools.

Table 34: Constructed responses (Cohorts 1 and 2) to the question, "Has the Michigan Teacher Excellence Program influenced your attitude about the societal importance of earth science literacy?"

Cohorts 1 and 2 Constructed Responses
Summary of Responses (n=13): • 93% reported that MiTEP **influenced** their attitude about the societal importance of earth science literacy. • 7% reported that MiTEP **did not influence** their attitude about the societal importance of earth science literacy.
Specific Examples: • "MiTEP exposed me to new scientifically literate groups of people. I found these groups to be intellectually stimulating and healthy to be around." • "MiTEP offered so many hands-on inquiries based activities at places such as Copper Harbor, which to the naked, un-trained eye is just simply a beautiful place, but upon closer look hold vital information about the Earth's past. Knowing this has helped me to look deeper at my surroundings and to appreciate the changes the Earth has undertaken to allow us to function today." • "To stay informed of current events. In particular the increase in wind energy and the debates it has caused." • "I think we need to take Earth science back to high school and look at it as the foundation for good citizenship. We did water source and looked at the landfill with methane use for electricity." • "Really… it is important for our students to be taught how this world works and how we need to care for it. My own growth in Earth science Literacy has changed my own habits and actions."

The teacher responses show that many teachers did not find that MiTEP changed their attitude about improving their teaching skills (table 35). This is expected because the teachers that would apply to attend a professional development program such as MiTEP would already be interested in being the best teacher they can be. Even those that made the claim that it did not change their attitude provided positive feedback as to supplies and lessons that were obtained through the program.

Table 35: Constructed responses (Cohorts 1 and 2) to the question, "Did the Michigan Teacher Excellence Program change your attitude about improving your teaching skills?"

Cohorts 1 and 2 Constructed Responses
Summary of Responses (n=14): • 79% reported that MiTEP **did change** their attitude about improving your teaching skills. • 11% reported that MiTEP **did not change** their attitude about improving your teaching skills.
Specific Examples: • Three teachers indicated they always want to improve their teaching and the MiTEP program helped them do just that. • "MiTEP did not change my attitude, but MiTEP provided me with supplies and lessons to live my already positive attitude to improve my teaching skills." • "I think a lot of my attitude change was just a result of being inspired by the professors in MiTEP." • "The value of being observed by peers and observing peers." • "Incorporate more local/state examples." • "After practicing experiments on pedagogy days, I felt more confident in my abilities to make the labs more meaningful. I found that the students were better behaved during labs than most other parts of the day- and they learned more as well." **Example related to why it did NOT change attitude about improving their teaching skills:** • "MiTEP did not change my attitude, but MiTEP provided me with supplies and lessons to live my already positive attitude to improve my teaching skills." • "Uh, not to toot my own horn, but I rock as an innovative and diverse-styles teacher. I can take subject material and make it exciting and interesting for students. What MiTEP did for me in this aspect, was re-new my passion, and give energy to my own learning so I could share it. "

All but one teacher claimed that they had made changes in how they teach as a result of their participation in the MiTEP program (table 36). Many of the examples the teachers provided were related to themes that the MiTEP program incorporated. Fostering inquiry by asking the right questions was stressed during the two-week summer field courses; teachers cited this technique as one of their examples. Investigating the local and regional geology of an area was part of the program's emphasis on "place-based" education. While in Michigan's Upper Peninsula, the summer field courses focused on the geology of the Upper Peninsula. While in the Lower Peninsula, the summer field courses focused on rivers, lakes, and glacial deposits near the teachers' homes. The online courses used the geology of Michigan as a springboard for developing an understanding of basic geological concepts that underpin the "*Big Ideas*" of the *Earth Science Literacy Principles* [NSF, 2009]. The summer field courses were also structured around the ESLP; and one teacher cited an example of using the ESLP big ideas as a second textbook for their classes.

Table 36: Constructed responses (Cohorts 1 and 2) to the question, “Did you make changes in how you teach as a result of participation in Michigan Teacher Excellence Program?”

Cohorts 1 and 2 Constructed Responses
Summary of Responses (n=14): • 93% reported that they **made changes** in how they teach as a result of participation in the MiTEP program. • 7% reported that they **did not make changes** in how they teach as a result of participation in the MiTEP program.
“Specific Examples: • “As a result of MiTEP, I use a lot more questioning within my classroom. I try to foster inquiry through questioning and learning occurs through group discussions. MiTEP helped me to see that providing just the right piece of information can stir the mind, and create questions for the student to explore on their own. Having students take ownership for their learning and making discoveries on their own has created and much richer learning environment. “ • “This year I am all projects based. This was a direct outcome of the lesson study, where we made an interactive discovery lesson and recorded each other.” • “More labs. Used more internet sites that were interactive. Demos using the density flow tank that I obtained with a grant through MiTEP.” • “Used more local, state references while teaching Earth science. Used pedagogy day activities in my teaching as well.” • “I am definitely more focused on incorporating more place-based learning as much as possible. Currently we are studying the Grand River Watershed and will be canoeing The Grand the next two school days (in partnership with Think GRAND- a grant with Great Lakes Lifeways Institute.” • “My secondary "text" for 8th grade is the big ideas pamphlet that we used throughout the program. I'm very excited about the students using it to develop a similar project to my summer Park requirement (pictures depicting the 9 big ideas). Can't wait to see what I get from my students.”

The teachers that responded to this survey (Cohorts 1 and 2) all worked for the same urban school district. Some background helps to understand the responses in table 37. When our first two cohorts of teachers applied to become participants in the MiTEP program, the majority of these 23 teachers were either Earth science teachers or were co-teachers in Earth science classrooms. The teaching assignments were drastically changed every year the teachers were in the program. Of the 23 original teachers, there are only two still teaching Earth science in that district. Sixteen of the original 23 and three teachers were required to take involuntary transfers and three have moved out of the district. The turmoil in urban school districts due to moving teachers from position to position was not anticipated when the program began so a change was implemented when MiTEP expanded and new school districts were added. When MiTEP was ready to bring in new school districts for Cohorts 3 and 4, the districts were asked to protect the MiTEP participants from being transferred to different teaching positions. It seems that this has provided the MiTEP program teachers in Cohorts 3 and 4 more stability than was experienced by the Cohort 1 and 2 teachers.

Table 37: Constructed responses (Cohorts 1 and 2) to the question, "Did being part of Michigan Teacher Excellence Program encourage you to take any actions that may improve earth science education in your school or district?"

Cohorts 1 and 2 Constructed Responses
Summary of Responses (n=14): • 53% reported that MiTEP **did not take actions** improve Earth science education in their school or district. • 47% reported that MiTEP **did take actions** improve Earth science education in their school or district.
Specific Examples: • Six examples provided by teachers that indicated they did not take action reported that they were not able to teach Earth science. • "I developed a Geology Unit to incorporate into my curriculum throughout the year**.**" • "I joined a committee and have begun to write curriculum." **Examples related to why they did NOT make changes in teaching practices:** • Six examples were provided by teachers indicating they did not take action because they were not able to teach Earth science. • "Each year in our district I have had to teach 3 grade levels. I have to use a lot of my personal time to plan, so I don't have the opportunity to take any actions during the school year. • "No, because I teach SPED and not Science (frown emoticom)." • "I don't teach Earth Science and I have no influence on this." • "No- due to moving to the Math Department."

One of the MiTEP program goals was to "improve Earth science education in the schools and the districts" making up the partnership. An important insight that came from the teachers that responded to this survey was that the teachers did not have much power to be able to improve Earth science education in their schools or districts. During the MiTEP program pedagogy workshops, the teachers often brought up issues that made it difficult to implement changes that they wanted to make. Table 38 shows that 93% of the MiTEP teachers in Cohorts 1 and 2 felt that they encountered obstacles that prevented them from improving Earth science education. Additional research is needed to determine the best ways to overcome these obstacles faced by teachers in urban districts.

Table 38: Constructed responses (Cohorts 1 and 2) to the question, "Have you encountered obstacles that have prevented you from improving earth science education in your school or district?"

Cohorts 1 and 2 Constructed Responses
Summary of Responses (n=14): • 93%reported they **encountered obstacles** that have prevented them from improving earth science education in your school or district. • 7% reported that they **did not encounter obstacles**.
Specific Examples: • "Each year there is an increase of students at beginning reading levels or lower elementary reading skills. We also get large classroom sizes with 40-50% special education students who also are beginning readers or read at an early elementary reading level. I am teaching 6-8th science. This happens in all grade levels." • "Due to my certifications. I was unable to teach Earth science, even though I am certified in Earth science. However, I did include Earth science concepts in my other science classes." • "Four teachers reported that the district moves teachers around to different building and several reported they are yearly assigned new teaching assignments." • "$$ to change."

The MiTEP program influenced the teachers by helping them see themselves as professionals (table 39). The program also seems to have encouraged the teachers to want to keep learning about Earth science and science literacy. MiTEP provided the opportunity for teachers to work side-by-side with both scientists and other excellent teachers. Thus, the program brought together a group of teachers that shared a passion for learning and then took them out in the field and introduced them to some amazing geology. The MiTEP instructors used the inquiry approach to stimulate thinking and help the teachers to develop observation skills and use logic to make interpretations based upon their own observations. Classroom teachers often feel isolated and do not have many opportunities to collaborate or work with peers that have the same levels of curiosity about the world around them and how it works. One teacher described their MiTEP experience as "intellectually stimulating" and found the program introduced them to “new scientifically literate groups of people”. Another teacher found an interesting way to explain how the MiTEP program encouraged them to see the world through a new lens. The teacher explained about Copper Harbor on the Keweenaw Peninsula, “which to the naked, untrained eye is just simply a beautiful place, but upon closer look holds vital information about the Earth's past. Knowing this has helped me to look deeper at my surroundings and to appreciate the changes the Earth has undertaken.” The program also introduced the MiTEP teachers to scientists and their cutting-edge research. Few classroom teachers have the time or ability to read peer-reviewed science journals and most teachers are not aware of the exciting new advances in science. One of the MiTEP teachers plans “to stay informed of current events, in particular the increase in wind energy and the debates it has caused.” The MiTEP program’s focus on one of the big ideas each day immersed the teachers in the ESLP frame of mind. One teacher wrote on the survey, “it is important for our students to be taught how this world works and how we need to care for it. My own growth in Earth science literacy has changed my own habits and actions.” The teacher comments show that the MiTEP program introduced these teachers to new ways of looking at the world around them and encouraged them to want to keep learning about Earth science and science literacy.

Table 39: Constructed responses (Cohorts 1 and 2) to the question, “Did your participation in the Michigan Teacher Excellence program influence how you see yourself as a professional?”

Cohorts 1 and 2 Constructed Responses
Summary of Responses (n=14): • 79% reported their participation in the MiTEP program **has influenced** how they see themselves as a professional. • 21% reported that the MiTEP program **has not influenced** how they see themselves as a professional.
Specific Examples: • “MiTEP helped me to further realize that learning never ends and we can all benefit from maximizing the learning opportunities around us. As a professional, I also found that I came to realize that working with and getting feedback from colleagues develops a strong working environment.” • “After completing my work at the National Park (Isle Royale), I feel very good about my ability to keep learning and creating materials that were actually published. First time I have ever published anything.” • “This transformed me into a grounded professional who wants to continually learn, question, and work together for the better of our students. That means that I lead when I need to and LOVE the journey of being a teacher and a learner.” • “Yes, I am more aware of what I am capable of and MiTEP has opened many doors for me. Presenting at conferences, networking with NPS staff and professors, and being viewed as a leader among my peers.”

The most drastic change of a teacher’s personal view occurred with the teacher that provided the last example on the list in table 40. This teacher, over the three year MiTEP program, evolved from having a religion-based creationist perspective of the Earth to having a broader understanding of how the Earth has undergone many changes and has experienced a much longer history than she had originally believed. Initially, one of the teachers announced at a teacher workshop during the school year that they thought that Earth science was boring. They said that the summer field program had them staring at rocks and wondering who cares. This teacher has also made a drastic change and now has said, “I like Earth science more now.” Forty-seven percent reported that MiTEP did not change their personal views, but they did not provide any explanations along with their response. One teacher explained that while her/his views where not changed, “the program helped to verify that my methods arnd views are on the right track." It is possible that the other teachers whose views did not change were interested in Earth science prior to joining the MiTEP program.

Table 40: Constructed responses (Cohorts 1 and 2) to the question, "Did your participation in the MiTEP program change your personal views?"

Cohorts 1 and 2 Constructed Responses
Summary of Responses (n=14): • 53% reported the MiTEP program **has changed** their personal views. • 47% reported that the MiTEP program **has not changed** their personal views.
Specific Examples: • "Not so much changed my views but the program helped to verify that my methods and views are on the right track." • "My attitude toward Earth science changed. Although I still don't find it the most exciting thing or aspect of science, I do find it interesting seeing earth science in the news and being able to explain in more depth what happened to students and also my own children." • "Yes, I like Earth science more now." • "MiTEP. Claim-Evidence-Reasoning! Our Earth is billions of yrs old!! My God still cares for me and is one awesome Being! To Infinity and Beyond!"

The entire exit survey is available as Appendix C. This survey has proven to be an effective tool for measuring change due to a professional development activity and could be adopted in its current or a modified form, by geoscientists that are designing Earth science professional development experiences for teachers.

3.7 Discussion

Geoscientists and Earth science educators play an important role in teaching the general public about geoscience concepts. Collaborations between geoscientists and K-12 science educators can make the general public more aware of geoscience by introducing students to geoscience concepts, processes, and careers. Unfortunately, many geoscientists, although experts in their field, are unprepared and ill-equipped to engage teachers in partnerships. Workshops with scientists and K-12 educators have shown that scientists want to build partnerships, but that they need support to do this [Andrew, 2005]. This research makes a contribution to building these partnerships by identifying ways to measure the effectiveness of a geoscience-teacher partnership that engages teachers in professional development for the purpose of increasing Earth science content knowledge. MiTEP contributes two products for measuring efficacy of a program, the ESCI data bank and the exit survey.

Since the 1970s, research has shown that classroom teachers play the most important role in contributing to student learning and achievement [Fennema, 1992]. As research has progressed and improved our understanding of how teachers impact the way students think about science and the role that teachers play in modeling scientific thinking, the role of the teacher has changed. Research studies have shown that by providing high-quality professional development for science teachers, one can improve teacher practices in their science classrooms and can improve student achievement in science [Kennedy, 1997]. Geoscientists can improve science education in our country by taking an active role in improving teacher knowledge of Earth science content. This research provides geoscientists with tools to effectively identify gains made through their work with K-12 educators. As was stated previously, according to the 2005 American Educational Research Association's (AERA) publication, *Teaching Teachers: Professional Development to Improve Student Achievement*, high quality professional development must incorporate many specific elements. One of the most important is building teachers' deep understanding of the content they teach [AERA, 2005].

Several recent publications mentioned previously should be on the radar of all geoscientists. These publications show that on a national level the importance of Earth science being taught in science education has been realized. In 2009, the *Earth Science Literacy Principles* (ESLP) [ESLI, 2009] were published. The ESLP identified the most important big ideas and fundamental concepts that a scientifically literate member of society should understand about the geosciences [Wysession et al., 2012]. In 2011, the National Research Council (NRC) released the *Framework for K-12 Science Education* which identified the science content knowledge and engineering concepts that students should know by the time they finish high school. In the NRC's *Framework*, Earth and space science became one of four major science domains along with the physical sciences, the life sciences, and engineering, technology and applications of science. The *Framework* also describes a set of important "Disciplinary Core Ideas" within each domain [NAS, 2011], with three of the thirteen "Disciplinary Core Ideas" coming from the geosciences. These two publications alone have increased awareness among geoscientists of the importance of geoscience in K-12 education, and have increased concern about teachers being prepared to teach the "Earth Science Disciplinary Core Ideas" [NAS, 2011].

This research provides information for geoscientists about which assessment methods are most effective for measuring change in teachers' knowledge of Earth science content. Geoscientists want to know that their efforts have made a difference and that they have improved teacher quality [Andrew, 2005]. It is reasonable to expect that geoscientists are more likely to make repeat attempts to reach out to the community and/or build additional K-12 partnerships when they are certain that they are contributing to the improvement of Earth science literacy.

This research introduces two new products that were created to support the measurement of the effectiveness of Earth science professional development programs. Creating new instruments is time consuming and labor intensive because the quality of the instruments needs to be demonstrated. For new test instruments to be used in research, they require tests to determine that the instruments have validity and that they will reliably test what they are supposed to test. The instruments to come out of this work have undergone the appropriate tests and they are being made available to all geoscientists.

Through the evolution of an effective assessment program, MiTEP has demonstrated that multiple methods are necessary to measure the impact of changes within the area of teachers' understanding of geoscience content. By using a mixed-methods approach, MiTEP was able to develop an accurate picture of the impact the MiTEP Program has had on the teachers' Earth science content-area knowledge. Any one method alone proved insufficient. Test instruments must have adequate resolution and be fully aligned with the content-area focus of the professional development activity to have sufficient power to measure change. The new ESCI pilot tests were able to measure changes in teachers' content knowledge because they were fully aligned with the content-area focus emphasized by MiTEP.

Currently, a bank of test questions, tied to standards, are being developed which can be used by all geoscientists. The bank of test questions being developed will be available on-line for all geoscientists needing an instrument with adequate resolution to measure the impact of a teacher professional development program. When complete, the ESCI will be an online test question bank whose questions have been reviewed by geoscientists and master Earth science teachers and have undergone equity and reliability testing. The ESCI questions will be organized both by the NSES and the NGSS.

3.8 Conclusion

A mixed-method approach was required to measure the impact of MiTEP on teachers' content-area knowledge. The ESCI indicated that teachers participating in MiTEP increased their understanding of Earth science content. The comprehensive exit survey responses demonstrated that the MiTEP teachers attributed their increase in knowledge to the program and also indicated which parts of the program the teachers found most effective.

4. Michigan Teacher Excellence Program (MiTEP): Using Lesson Study for Professional Development[2]

4.1 Abstract

During the 2010 spring semester, nine K-12 teachers from an urban Michigan school district participated in a Lesson Study course offered by Michigan Technological University as part of the National Science Foundation funded Michigan Teacher Excellence Program (MiTEP) [MiTEP 2009]. The goal of this course was to use the Lesson Study process to promote collaboration in efforts to improve instruction and student learning. The MiTEP teachers were guided through the process of examining the effectiveness of lessons in a collaborative environment through observation, reflection, and discussion. Three teams of participants first met to plan a lesson that was to be taught by one teacher while being observed by the other team members. Following the lesson's enactment, the team used their observations to reflect on the lesson, which was subsequently revised and improved. Data acquired through teacher surveys, written documents, and group interviews indicate that the Lesson Study process improved teacher quality and classroom practice in the (GRPS) science program in multiple ways. In the area of teacher learning, the MiTEP Lesson Study Program empowered the teachers and improved their self-image and self-assessment of the quality of their teaching, fostered research about the content that prompted deeper understanding, and validated the insight that visiting fellow teachers' classrooms is an important learning experience. The Lesson Study process fostered teacher self-reflection on teaching practices by encouraging them to think

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[2] The material contained in this chapter was previously published in *Exemplary Science: Best Practices in Professional Development, Revised Second Edition* [Koba and Wojonowski, 2013].

more deeply about what they wanted the students to learn. It also encouraged them to identify and study research literature related to how students think. Reflection on teaching practices was evident when teachers made revisions to their lessons based on observations and debriefings. The teachers found working in a collaborative setting to be the greatest strength of the MiTEP Lesson Study Program.

4.2 Introduction

4.2.1 Michigan Teacher Excellence Program (MiTEP)

The Michigan Teaching Excellence Program (MiTEP) is a Math-Science Partnership (MSP) program funded by the National Science Foundation (NSF). Michigan Technological University has partnered with Grand Rapids (MI) Public Schools (GRPS) to promote local Earth System Science (ESS) education reform that will contribute to nationwide improvement in this domain. MTU has chosen to partner with GRPS because it is an urban district that serves a population dominated by under-represented minority students and students from low-income families, many of whom have special needs and are not native English speakers.

The professional development goals of MiTEP are to enhance teachers' content and pedagogical knowledge, to promote the use of inquiry in the partner school district's science classrooms, to encourage growth in leadership capacity exhibited by the MiTEP teachers, and to facilitate the establishment of sustainable learning communities within the partner school district. The Lesson Study process was selected by the MiTEP leadership team as a strategy to maximize attainment of the program's professional development goals while establishing meaningful, robust, and ongoing professional collaborations among teacher participants in MiTEP and throughout the district.

Prior to the inauguration of MiTEP, GRPS had adopted the “Principles of Learning” (POL) philosophy with the goal of implementing “Disciplinary Literacy” (DL) in their classrooms, and the basic goals of Lesson Study correlate well with the POL philosophy [McConachie and Petrosky, 2010]. The MiTEP Lesson Study Program was implemented as a one-graduate credit course with the MiTEP teachers during the spring semester of 2010.

All thirteen of MiTEP’s cohort-1 teachers were encouraged to participate in Lesson Study. However, because of after-school commitments and responsibilities, four of the thirteen teachers were unable to participate. These teachers indicated an interest in pursuing the Lesson Study opportunity in subsequent years, an option that has been provided by Michigan Tech University.

4.2.2 History of Lesson Study

Lesson study began in Japan as a model of instructional improvement that involves groups of teachers engaged in a cyclic study of the planning, observation, and discussion of one research lesson, leading to the subsequent modification by the research group and the re-teaching of the lesson by one group member. Lesson Study is commonly employed by practicing teachers in Japan as an aspect of professional development within a school or program, and it is also used to train pre-service teachers and beginning teachers. There are several different versions of the lesson study process in Japan, where it is tailored to specific local circumstances and where the process continues to evolve. Teacher groups in Japan frequently present their research lessons at national education conferences and engage attendees in the observation and discussion of these lessons [Lewis et al., 2008; Stepanek et al., 2007; Stigler and Hiebert, 1999].

In the United States, lesson study has been implemented in hundreds of schools and districts. There have been several research studies conducted on its implementation and the effectiveness of modifying the Japanese model to meet the needs of teachers in this country. Based on this research, a set of "Key Elements for Lesson Study" has been developed by Catherine Lewis, a leader in researching lesson study in Japan and its adaptation for use in the United States [Lewis and Tsuchida, 1998]. The key elements for implementing this process in the United States are: 1) Teachers collaborate on the development and refinement of research lessons, 2) The results of lesson study benefit all teachers and students, 3) The focus of the selected research lesson is directly related to standards and goals of the school, 4) Critical feedback is focused on the effectiveness of the research lesson and not on the teachers' performance while teaching, 5) There is a structured process for guiding the lesson study, and 6) The administration should provide the members of the team with support and access to resources and knowledgeable others [Lewis, 2002; Stepanek et al. 2007].

Recent international studies such as the Third International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA) indicate that teachers in the United States experience a very different education culture than their teaching colleagues in Japan, where teaching professionals are acknowledged as being more deeply respected and more highly valued by society. Japanese teachers commonly plan their instruction around very few topics and conceptual understandings compared to the "miles wide and inches deep" curriculum taught in the United States. Japanese teachers typically spend little time examining standards, translating standards into curriculum, selecting and ordering materials to teach the standards, and designing formative and summative assessments to determine the extent to which their students have met the standards. They teach a national curriculum and are provided with the resources they need to teach it. Unlike their Japanese counterparts, the teachers in the United States experience a time-crunch in their efforts to fit the Lesson Study process into their already busy schedules. Despite the difficulties of using this approach, hundreds of schools in the United States have begun to implement the lesson study process and are using this approach to enhance teachers' knowledge and to improve teaching and learning in their schools [Stepanek et al., 2007].

Teacher professional development in the United States has often been described as a "one size fits all" short term experience that, while meeting district and state requirements, routinely fails to provide teachers with a sustainable, practice-based, job-embedded learning experience focused on improving learning. This is exacerbated by policy makers and politicians, who frequently employ a "quick fix" methodology to solve problems in the educational arena. Lesson study is a slow process, where changes are made in small gradual steps, through research on best practices and by the development of deep understandings [Loucks-Horsley et al., 2009]. Catherine Lewis (2008) explains, "*lesson study is a way for teachers to help one another slow down the act of teaching in order to learn more about students, subject matter, and their own teaching*." Stigler and Hiebert (1999) add, "*lesson study is the process of improvement that is expected to produce small, incremental improvements in teaching over long periods of time*."

Efforts to ameliorate these complications have resulted in some creative solutions leading to the adoption of lesson study by some U.S. schools, including some that couple the lesson study process with other professional development strategies already being implemented. In some districts, lesson study has been combined with "curriculum topic study," "examining student work and learning," or as a focus of "action research." Some districts perceive the lesson study approach to be a desirable component of their suite of professional development activities, but not all see it as a panacea. Schools that embrace a collegial "learning community" philosophy have most effectively employed lesson study. Lesson study embodies the “best practice” research findings for high quality, effective professional development for teachers; it enhances teachers’ knowledge, enhances quality teaching, develops leadership capacity, and builds learning communities [Loucks-Horsley et al., 2009].

The lesson study process has demonstrated effectiveness in promoting educators from novice to expert, an endeavor endorsed by many cognitive science researchers. For teachers to advance to expert status, the research implies that they first need to activate prior knowledge related to something they want to study about, to build new learning relative to past experiences, and to observe and evaluate how the new learning is applied in the real world. As teachers develop expertise, they must also consider when, how, and under what conditions their new skills would be most effectively deployed. Additionally, the practice of these emergent skills must be accompanied by thoughtful reflection [Bransford et al., 1999; Greeno et al., 1997].

4.2.3 Lesson Study and New Paradigms of Teacher Professional Development

The *National Science Education Standards* [NRC, 1996] defined which criteria should be met for implementation and maintenance of high quality professional development. The four “Professional Development Standards” described by NSES call for a change in the way that teachers learn science content, the way that teachers learn how to teach science, and the way that teachers learn how science is understood. The MiTEP Lesson Study Program addresses all four standards and meets the high-quality criteria.

1. **Professional development for teachers of science requires learning essential science content through the perspectives and methods of inquiry.** Because the MiTEP Lesson Study Program was implemented after an intensive two-week summer field course that embedded inquiry, “Big Ideas,” [Engelmann et al., 2010] and student misconceptions in the

daily lesson design, the teachers had previously been immersed in a model of content acquisition through inquiry. Lessons designed by teachers for the MiTEP Lesson Study Program were expected to embody adequately designed and effectively implemented inquiry methods.

2. **Professional development for teachers of science requires integrating knowledge of science, learning, pedagogy, and students; it also requires applying that knowledge to science teaching.** Banilower (2010) and others have labeled the confluence of these complementary facets, "pedagogical content knowledge." The MiTEP Lesson Study Program was implemented as an extension of a quarterly series of "Pedagogy/Content Professional Development Workshops" that provided opportunities for the MiTEP teachers to engage in the conjoining of new content knowledge with effective pedagogical skills to synthesize effective lessons. Lesson study provided them with a vehicle of presenting these lessons in a non-threatening (albeit evaluative) format.

3. **Professional development for teachers of science requires building understanding and ability for lifelong learning.** In a report addressing "Professional Learning Communities" (PLCs) as an emergent professional development strategy targeted at specifically providing continuing professional development, a group of Program Officers at the National Science Foundation identified several Math-Science Partnership cases in which initiatives such as lesson study have been adapted to provide measurable and meaningful continuing professional development leading to lifelong learning [Foster et al., 2010]. The MiTEP Lesson Study Program was seamlessly and effectively adapted to emergent GRPS district initiatives aimed at providing staff development time for the establishment of "Professional Learning Communities."

4. **Professional development for teachers of science must be coherent and integrated. The National Staff Development Council [Wei et al., 2009] singles out lesson study as a "coherent, sustained, and evidenced-based learning strategy" in its definition of professional development.** The MiTEP Lesson Study Program reveals that lesson study can be implemented effectively not only within school buildings and within common grade-level and content domains, but also district-wide and across disciplines and grade levels.

4.2.4 Lesson Study Relationship to *More Emphasis* Conditions

The MiTEP Lesson Study Program embodies the move toward the *more emphasis* conditions for providing quality professional development according to the NSES Professional Development Standards. The Lesson Study process puts more emphasis on "treating teachers as professionals whose work requires opportunities for continual learning and networking." Through the Lesson Study process, teachers make their own informed decisions about what they expect to gain from their professional development activity. Teachers decide which aspects of their craft they want to improve as well as what topic they want to focus on. The process of lesson study puts more emphasis on "promoting collegiality among teachers as a team to improve the school," and "teachers as decision makers." As a Lesson Study team, the MiTEP teachers engaged in pedagogy research and worked collaboratively to create an exemplary lesson that aligned with the Michigan state standards and focused on bringing inquiry based learning to students.

4.2.5 Major Features of the Michigan Teacher Excellence Lesson Study Program

At its outset, the MiTEP Lesson Study Program was built on the foundational tenets outlined in *Leading Lesson Study: A Practical Guide for Teachers and Facilitators* [Stepanek, et al., 2007]. Suggestions from three graduate students working with MiTEP teachers, as well as the Science Curriculum Coordinator from GRPS, helped customize the course curriculum to incorporate the features of the formal Lesson Study outlined in the book and four specific GRPS district-adopted initiatives described below:

1. Disciplinary Literacy and the Principles of Learning (DL and POL): GRPS has been affiliated with the Institute for Learning (IFL) since 2007. The district embraced the Disciplinary Literacy (DL) framework and initiated the enactment of the associated Principles of Learning (POL) by classroom teachers to provide a "culture of effort-based education" through professional development activities designed around teachers' "working together in nested learning communities" [GRPS, 2010].

2. Claim-Evidence-Reasoning (C-E-R) Protocol: This is an approach to promoting effective construction and communication of scientific explanations that serves as a cornerstone for science staff development initiatives in GRPS [McNeill and Krajcik, 2006]. An individual's "claim" is an assertion or conclusion responding to a question or problem. "Evidence" includes observations or scientific data that supports the individual's claim. "Reasoning" utilizes scientifically valid and appropriate justification to link the supporting evidence to the original claim.

3. The Learning Walk: **The Learning Walk:** employs a non-judgmental, non-threatening approach to classroom visitations by teams of teachers and administrators [McConachie and Petrosky, 2010]. The focus is on using descriptive statements rather than evaluative, summative statements when discussing an observed lesson. It dovetails completely with the lesson study framework adopted for the one-credit course.

4. ***Thinking Through a Lesson Protocol (TTLP):*** The GRPS science department employs this adaptation of a pre-lesson planning strategy developed by IFL [Hughes and Smith, 2004]. The modified strategy involves the following key questions:

- What science concept are you teaching?
- Why are you teaching this science concept?
- How are you teaching this science concept?
- Why are you teaching the science concept that way?
- What evidence will you collect concerning students' understanding of the science concept?
- How will you know if your students are building an understanding of the science concept?
- What will you do if students aren't building an understanding of the science concept?
- How does the lesson provide for student metacognition concerning their knowledge and understanding of the science concept?

The four elements outlined above provided a district-adopted pedagogical framework into which the Lesson Study approach was integrated, leading to a more collaborative and reflective culture among the teacher participants.

The Lesson Study process was implemented over a three month time period. An introductory meeting and subsequent planning and consulting meetings were held after school. At the introductory meeting, the graduate student facilitators guided the teachers through the MiTEP Lesson Study Action Plan (table 41). During the initial meeting, the nine participating teachers self-organized into three teams, ranging from two to five teachers. Each of the teams was to become a "case" to use for assessment and qualitative research purposes. Once established, the teams worked independently to determine what their "Expected Outcomes" would be from participation in the Lesson Study process. Teachers explained their reasons for engaging in the program, what they hoped to gain from participation, and ways they could share their learning with the schools and district. They identified and selected specific tasks and established a schedule for working through the steps in the Lesson Study process. Emphasis was placed on how the process would be documented and which artifacts would be collected and analyzed. Teachers were asked to identify sources of support they could tap including resources, administrators, local DL and inquiry experts, and access to video equipment to record the research lessons. They had approximately two months to plan, design, teach, improve, and re-teach the research lesson and then another month to prepare their final report. They were also provided release time during the school day to provide opportunities for observation and discussion of their group's research lesson.

Table 41: Lesson Study action plan that groups completed at the first meeting to assign responsibilities and work out logistics for the team.

Action Plan Parts	***Explanation***
Expected outcomes	Explain the reasons for engaging in lesson study and what the team members hope to get out of it. Think about how to demonstrate the value of the study to the school, and to the district.
Team Members	Identify the lesson study team members and/or describe a plan for recruiting teachers.
Time needed	Provide an overview of the time that will be needed and the strategies that will be used to create that time.
Administrator support	Describe the strategies that you will use and information that will be communicated with administrators.
Sources of external support	Identify people who are available to assist the team in their work with such issues as DL strategies, inquiry, and video recording.
Documentation	Describe the records that the team will maintain of their work and how they will share their activities with others.
Compensation	How will teachers be compensated for their time and work?

The structure for leading the teachers through this process evolved through combining and modifying "Planning the Research Lesson" [Lewis, 2002] and IFL strategies such as DL, C-E-R, and TTLP [McConachie and Petrosky, 2010]. The IFL strategies that the teachers were familiar with were combined with Lewis' steps 1-5 for "Planning the Research Lesson" to insure that their lessons met the GRPS standards (table 42).

Table 42: Steps 1-5 for "Planning the Research Lesson" to insure that all lessons met the Grand Rapids Public School standards (Lewis, 2002).

Guiding Questions	***Description***
Step 1: Identify the Topic ***(Overarching Question, Organizing for Effort)***	
What areas are challenging for our students? What are common challenges from research on student learning? What areas are difficult to teach? Are there weak or missing topics in our curriculum? What topic will contribute to our knowledge about the research theme? Will the topic we identify work within the lesson study time frame?	The lesson study team pinpoints a topic for the research lesson by looking at: Student achievement data Challenging concepts and common misconceptions Teacher learning needs Curriculum gaps
Step 2: Map the Unit ***(Arc of Lessons, Organizing for Effort)***	
Which lesson will have the most impact on the unit? Why focus on this particular lesson? How does a focus on a single research lesson affect the other lessons in the unit? What will students learn in the activities leading up to the research lesson? Where will students be going next?	The lesson study team examines the unit for the topic they identified in Step 1. The teachers will select the research lesson and consider the connections with the other lessons in the unit.
Step 3: Identify Lesson Goals ***(Organizing for Effort, Clear Expectations)***	
What are the content and process goals for this unit? What do the standards say about these goals? What makes these goals worthwhile? How can the research theme and unit goals be brought to life with the research lesson?	The lesson study team identifies the unit goals that apply to the research lesson. The lesson goals are derived from the unit goals and the research theme.
Step 4: Create the Lesson Plan ***(Academic Rigor in a Thinking Curriculum, Fair & Credible Evaluations)***	
What is our research question or hypothesis? How does our design support the goals of the research question? Have we anticipated student responses based on our experience and research? What kinds of prior knowledge of the topic should students have? How will the teacher respond to student reactions and misconceptions? What kinds of evidence would be sufficient for demonstrating student understanding? Do we have a plan for evaluating the lesson?	The team develops the research lesson. The lesson plan is extremely detailed and represents the team's research and their collective questions and ideas about how best to foster student learning.

The teachers were introduced to the expectations for their final report and presentation at the introductory meeting. Since the teachers were expected to document the entire MiTEP Lesson Study process, they were provided with instructions on how to organize this data into their final report. “MiTEP Lesson Study Expectations” (table 43) served to direct the teachers’ work in preparing their final report which documented their goal selection process, described the original research lesson plan, shared the observations and discussion of the lesson’s first iteration, described subsequent modifications to the research lesson, and summarized the team conclusions and key learnings related to the MiTEP Lesson Study process.

Table 43: Expectations for the final lesson study report and presentations.

Report Components	Lesson Study Expectations
Goal Selection	Introduced the theme and explained how the goals related to the theme, summarized the research that informed the planning, and provided a detailed explanation of the planning process.
Lesson I	Described the lesson in detail including learning activities and teacher questions, expected student reactions, teacher supports, and evaluation and provided a detailed description of the implementation of the lesson.
Results	Documented the evidence discussed during the debriefing and summarized suggestions for revising based on observations. Provided examples of student work, with interpretation, showing successful learning and where re-learning may be necessary.
Lesson II	Described the revised lesson and explained in specific detail why each revision was made.
Conclusion	Described the challenges that the team faced as part of the lesson study cycle and describes the professional knowledge acquired by the team and the implications of this knowledge for practice. Discussed how reflection and collaboration impacted the learning process. Included plans for sharing lesson study with other teachers.
Appendices	Includes: meeting notes, team worksheets, notes from research, examples of student work, video tape of lesson, and other artifacts

4.3 Research Questions

1. The Lesson Study process focused on a set of five interrelated questions:
2. In what ways, if any, did the MiTEP Lesson Study Program promote teacher learning?
3. In what ways, if any, did the MiTEP Lesson Study Program promote teacher self-reflection on teaching practices?
4. How well did the MiTEP Lesson Study Program context of a collaborative setting promote the desire for improving teaching practices?

5. In what ways, if any, did the MiTEP Lesson Study Program promote teacher leaders?
6. In what ways can the MiTEP Lesson Study Program be refined and improved?

4.4 Methods

A qualitative approach was used to evaluate the Lesson Study protocol as part of the seven components of the MiTEP professional development model. The case study design was chosen because it is the best method to use when an in-depth detailed program analysis is needed. The purpose of this collective case study was to describe how the MiTEP Lesson Study Program enhanced teachers' knowledge promoted use of inquiry in GRPS science classrooms, developed leadership capacity within the MiTEP teachers, and facilitated learning community development within GRPS. The case study method best fit the scope of this study because we examined a program that was bounded by location, time, and unit. The program was implemented in GRPS (location) with specific modifications allowing us to align with the GRPS district's POL goals and was implemented during spring semester, 2010 (time). Our sample was limited to the group of MiTEP teachers that participated in the MiTEP Lesson Study Program (N=9).

Three sources of data were used to determine ways in which the MiTEP Lesson Study Program impacted teacher quality and classroom practice in the GRPS science program: 1) A survey of MiTEP Lesson Study participants, 2) An analysis of written artifacts (the formal written reports from the three MiTEP Lesson Study teams), and 3) Focus group interviews.

4.4.1 Teacher Survey

The survey administered to the MiTEP Lesson Study participants came from *Leading Lesson Study: A Practical Guide for Teachers and Facilitators* [Stepanek et al., 2007, pp. 147 –

148]. The survey was designed to provide data on the efficacy of the Lesson Study process, and it evaluates the process in three dimensions. Statements 1-7 evaluate the efficacy and organization of the Lesson Study workshops, statements 8-20 evaluate the impact and quality of the Lesson Study cycle and statements 21-26 evaluate participant insights related to their own personal gains and improvements related to impact on classroom practice. The 5-point Likert scale survey ranged from 1 (disagree) through 5 (agree). Also included in the survey were twenty-four free-response questions broken into three categories: 1) Strengths of Lesson Study, 2) Weaknesses of Lesson Study, and 3) Suggestions for Improvement. Some of the nine participants in the survey chose to answer only some of these questions.

4.4.2 Written Reports

One of the university credit requirements for successful completion of the MiTEP Lesson Study course was submission of a written report. The process of writing this report was also intended to be collaborative and to encourage reflection. The following narratives provide insight into each of the three MiTEP Lesson Study teams. Since the written report was a team effort, each team was able to document their journey and address the effectiveness of the Lesson Study process in promoting teacher learning, self-reflection, collaboration, teacher leadership practices as well as changes in classroom practices.

4.4.3 Focus Group Interviews

Six months after the teachers were involved in the MiTEP Lesson Study Program, they were assembled into two groups to discuss the impact of participating in the program. Both groups were recorded, their comments transcribed, and these focus group discussions were coded for remarks pertinent to the four research questions.

4.5 Results

4.5.1 Lesson Study Participant Survey

Results from this survey are found in tables 44-46. In evaluation of the efficacy and organization of the Lesson Study workshops, the mean was 4. 000. The teachers ranked the impact and quality of the Lesson Study cycle significantly higher with a mean of 4.356. The impact on classroom practice was ranked lowest of the three dimensions with a mean of 3.812, which still shows that the majority agreed that there was a positive impact and may reflect the expected time lag between the participants' involvement in the process and the subsequent application of emergent insights directly to their own classroom practices.

Table 44: Teacher responses on post-lesson study survey The Efficacy and the Organization of the Lesson Study Workshops" theme, showing the mean and standard deviation for each question.

Theme-The Efficacy and the Organization of the Lesson Study Workshops	***N***	***Mean***	***SD***
1. I understood the goals and process of LS prior to starting a LS cycle.	9	3.625	0.279
2. The materials provided were helpful to develop my understanding of LS	9	4.125	0.229
3. The introductory activities were helpful to develop my understanding of LS.	9	3.875	0.247
4. I found the time to collaborate with my LS group members helpful to develop my understanding of LS	9	4.5	0.254
5. The facilitation helped me to develop my understanding of LS.	9	4.25	0.177
6. The workshops provided me with enough time to develop my understanding of LS.	9	3.75	0.122
7. The workshops were held at convenient times for me.	9	4	0.009
Mean		**4.0**	**0.188**

Table 45: Teacher responses on post-lesson study survey "The Efficacy and Quality of the Lesson Study Cycle" theme, showing the mean and standard deviation for each question.

Theme-The Efficacy and Quality of the Lesson Study Cycle	***N***	***Mean***	***SD***
8. The workshops were valuable..	9	4.125	0.272
9. Meetings during the LS cycle were held at convenient times.	9	4.375	0.264
10. I was able to attend all of the meetings during the LS cycle.	9	4.375	0.275
11. My LS team collaborated effectively to plan a research lesson.	9	4.625	0.287
12. The research lesson matched our overarching goal.	9	4.625	0.289
13. My LS group used textbooks, research, or other outside information to help plan the research lesson.	9	4.625	0.289
14. We had an opportunity during the LS cycle to do the problem of the research lesson.	9	3.75	0.284
15. Dev. the research lesson allowed me to think deeply about issues in my content or teaching.	9	4.375	0.216
16. Dev. the research lesson allowed me to increase my content knowledge.	9	3.875	0.23
17. Dev. the research lesson allowed me to better understand student thinking and/or challenges in my content.	9	4.375	0.103
18. Observing student learning and thinking during the teaching of the research lesson was an important learning opportunity.	9	4.5	0.108
19. I feel our research lesson was successful.	9	4.375	0.123
20. Participating in a LS cycle was a valuable professional development activity.	9	4.625	0.135
Mean		**4.356**	**0.221**

Table 46: Teacher responses on post-lesson study survey "Lesson Study Cycle's Impact on Classroom Practice" theme, showing the mean and standard deviation for each question.

Theme- Lesson Study Cycle's Impact on Classroom Practice	***N***	***Mean***	***SD***
21. I gained specific new understandings about my content and teaching from LS.	9	4.125	0.373
22. I have been able to apply these new understandings to my teaching.	9	4.25	0.379
23. I think about lesson planning and my teaching differently as a result of participating in LS.	9	3.5	0.319
24. I more carefully select instructional materials and questions as a result of LS.	9	3.25	0.358
25. I anticipate and plan for student understanding in my lessons as a result of LS.	9	3.625	0.25
26. Lesson Study has helped me to be a better teacher.	9	4.125	0.373
Mean		**3.812**	**0.282**

The graph of the mean responses to each of the questions in the survey provides a clearer picture of areas for further investigation and improvement in the MiTEP Lesson Study process, most of which fell into the category of impact on classroom practice (figure 5). Due to the longitudinal nature of the Lesson Study impact in this category, analysis of this portion of the study might best be accomplished through the distribution of one or more follow-up surveys at yearly time intervals.

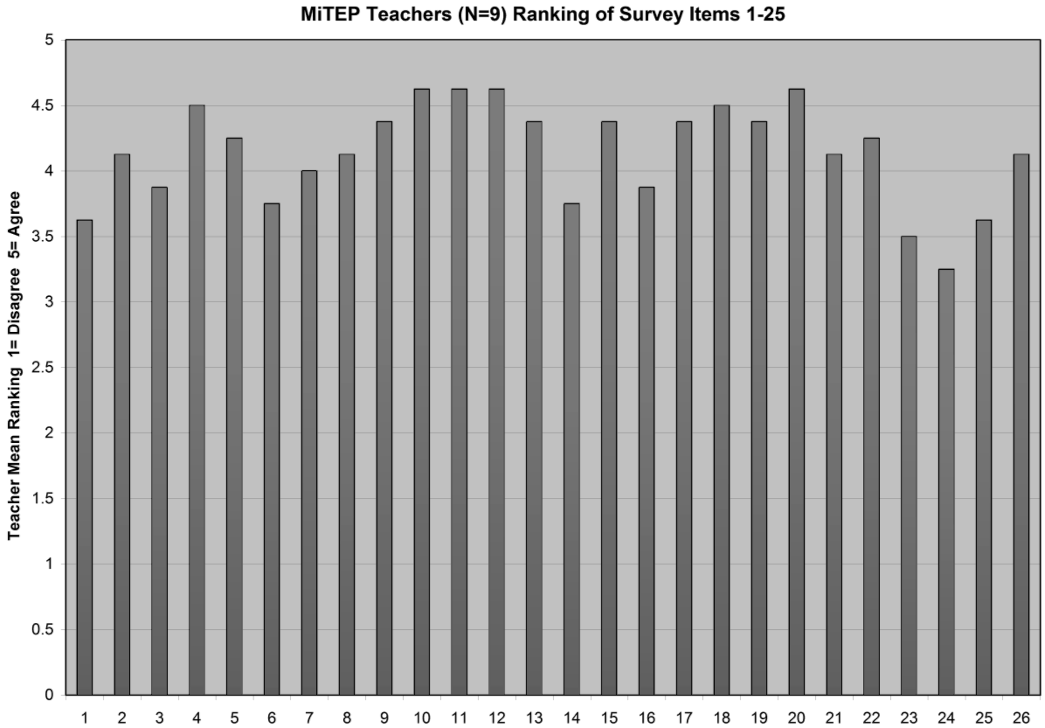

Figure 5: Graph of MiTEP teachers ranking of survey items based on Likert scale of 1-5.

The teachers were least in agreement with the survey statement, “I more carefully select instructional materials and questions as a result of LS.” Also coding low on the survey analyses were the statements, “I think about lesson planning and my teaching differently as a result of participating in LS,” and, “I anticipate and plan for student understanding in my lessons as a result of LS.” Analysis of data collected from the written reports and the focus groups reveals that the teachers focused their lessons on improving student understanding, engagement with the lesson, and applying the inquiry approach. The next implementation of the MiTEP Lesson Study Program (MiTEP Cohort-2) will focus more on extending the teacher learning beyond this experience to more consistently have an impact on classroom practices.

When responding to those questions asking about the strength of the Lesson Study process, seven of the nine teachers responded that the greatest strength was the opportunity to collaborate with their colleagues and the time provided during the school day to engage in this collaboration. The teachers generally indicated that the safe, collaborative environment created through the Lesson Study process was valuable to them and essential to their endeavor to improve their own classroom practices. While the majority of respondents named “time” as strength of the process, seven out of nine also opined that “time” was a major weakness. Two of seven respondents said the process of working with their teams required that time be taken away from other teacher responsibilities, and while they felt the time spent on the Lesson Study process was valuable, it was also difficult to justify investing a large quantity of time for just one lesson. When asked for advice for improvement, some MiTEP teachers recommended that an online communication collaborative tool become part of the course so that it could help pace the process and allow for asynchronous communication within the team. Five of seven teachers said that while they benefited from the diversity within a multilevel team, they indicated that homogenous grade level teams might have been more beneficial, adding that there would be a stronger commitment and interest in perfecting a lesson that will be ultimately taught by all members of the Lesson Study team.

4.5.2 Evidence from Written Reports

The following three cases describe the journeys taken by three very different teams of teachers.

4.5.2.1 Case Study 1

The goal of this team’s research lesson was to guide students to an understanding that water is an indispensable natural resource whose use and quality needs to be monitored carefully. Teachers wanted the lesson to increase student engagement through the use of kinesthetic learning in order to develop the skills of making predictions and designing experiments. It was agreed by the team members that once they had selected a content topic and designed the lesson, one of them would participate in the teaching of the lesson and another would re-teach a modified version of the lesson. The team first chose an activity listed in the 8th Grade Curriculum Guide within the *EarthComm* [AGI, 2006] textbook. Students were to create a ground water system, introduce a contaminant and observe the flow of contamination. The team piloted the activity and found that the activity did not work as written. One veteran teacher on the team had previously taught a similar activity from another textbook – *Issues, Evidence and You* [SEPUP, 1992] – and shared her knowledge with her team. In the revised lesson, students essentially followed a similar procedure, observing pollution that, in this case, spread through a small quantity of sand in a Petri dish. They saw how this single, well-designed lesson could be taught in two different school settings, one whose student body was from predominantly low socio-economic families and the other whose families would be considered predominantly middle class. The first time it was taught, they observed engaged students working together effectively, but the students had a lot of clarifying questions. The participants in this teaching group modified the lesson by designing an improved student lab sheet prior to the lesson's repeat performance in the second classroom. They also modified the lesson to make it more inquiry based, requiring students to design an experiment that compared different sizes of particles within an aquifer. This team was able to observe whether the revisions were successful or not since they taught the lesson twice. They concluded that the modifications improved the lesson and were able to witness the improvements through their own classroom observation and by examining student work.

4.5.2.2 Case Study 2

This team's objectives were for students to distinguish between the ways organisms obtain energy, describe common patterns of relationships among populations (predator/prey), and predict how changes in one population might affect other populations based on relationships in ecosystems. The team was comprised of teachers from various grade levels responsible for different content. This group came to a general consensus was that it would have been more effective for them to have chosen a research lesson that each member of the team could teach in their classroom. They used the study of owl pellets to engage the students in analyses of an ecosystem and as an example of the predator/prey relationship. To begin their research lesson, the teacher simulated the owl regurgitating an owl pellet as he pretended to cough up a wad of candy wrappers. The wad was placed on display and the class used their analysis of the wad to make a claim about what the teacher had eaten that morning. These introductions lead the students to learn about owls and owl pellets. The students were provided owl pellets to tear apart and collect the bones of the animals that the owl had preyed upon. The students eventually identified the bones and mounted them on cardboard to help them identify the organism the bones came from. In the end, the students chose to answer one of three questions: What would happen if the owl's energy source disappeared? How do owls affect other organisms within a habitat? What information is provided by owl pellets? This lesson incorporated the C-E.R. strategy; first, the students stated an answer to their question (claim), then they accumulated evidence related to their claim, and finally they supported or revised their claim based upon the consideration of how adequately the evidence supported it. The students collected evidence from the owl exercise, researched information, and from an owl video they watched as a class.

This team only taught their research lesson once, but as a result of the observation and reflection of the lesson, they produced a set of improvements for future enactments of the lesson. Their suggestions focused on modifying the learning environment to encourage students to engage in independent learning strategies. The revision provides more opportunities for students to write their own questions and independently gather their own information to use as evidence in their final reports. The revision also modifies the activity so that the lesson would be more inquiry based and the learners would play a greater role in designing their own research.

4.5.2.3 Case Study 3

This team's goal was for students to actively participate in a math lesson and for the students to interact with each other in groups. The two members of the team both taught math, one at a middle school and the other at a high school. The typical mode of teaching in this middle school math class was for the teacher to direct instruction and then for the students to work independently on practice problems out of the textbook. The high school math teacher often structured her lessons so that students engaged in team-oriented inquiry activities; therefore, her goal was for the students to exhibit self-starting and collaborative behavior. Both teachers featured the use of Jell-O as part of their research lesson, which focused generally on the same general content standards; geometry and measurement. The two teachers modified how they taught their lessons to accommodate the different levels of learning. In both classrooms, students were given cubes of Jell-O which they measured in three dimensions, then used the measurements to calculate surface area and volume. The middle school team member was a co-teacher and this was her first time to teach the entire class. The math teacher assigned to the class, her principal, and the high school math teacher on her Lesson Study team observed her as she taught her first lesson. Following the first teaching of the lesson, the observers and teacher reflected on the lesson and reached consensus on modifications for the next class, most notably the addition of strategies that would focus the students and create more time on task. Her second teaching of the lesson served to improve student engagement, which not only sharpened the students' focus but also resulted in improved productivity. The high school member of the team taught a similar lesson after the re-teaching of the lesson by the middle school team member, providing three iterations of the same lesson. This Lesson Study team found that their impact went beyond the members of their team, as the regular middle school math teacher chose to teach this inquiry based Jell-O lesson to the rest of his classes that day. Improving classroom practices by using an inquiry approach coupled with the Lesson Study prescribed observation of classroom performance impacted teachers beyond the MiTEP Lesson Study Program.

4.5.2.4 Effectiveness of Michigan Teacher Excellence Lesson Study Process

The written reports from the three case studies provided evidence about the effectiveness of the MiTEP Lesson Study process. The experience of Case 1 indicates that the teachers were able to learn from each other. This was critical when they found that the model lesson given in the textbook did not work as anticipated. Second, by being present in the classroom at the time the lesson was first taught, each teacher on the team was able to observe the students more carefully and note potential barriers to learning. During the analysis of the first lesson, members of the team clarified their expectations and the directions. Third, the teachers were able to pilot test the lesson with a more diverse group of students than they might normally be able to do. This is a critical step because of the challenges that teachers face to adapt lessons to learners with diverse knowledge, backgrounds, and aptitudes.

The Case 2 experience demonstrates the importance of teacher observation and reflection when moving a lesson from a more traditional teacher-led activity to an inquiry based, student-focused activity. In addressing the “more emphasis” on inquiry based teaching, this team planned a research lesson that they believed to be inquiry based. The teachers were excited about the unique introduction they developed for the activity and expected their lesson to meet their goals. Only through observation and reflection as a team did they acknowledge that their goals had been only moderately reached, and that with the immediate implementation of planned modifications in a different classroom, they could acquire feedback on the impact of their attempts to improve the quality of their lesson. This case demonstrates the importance of collaboration and it also reveals another unique benefit of the Lesson Study process; group observation and analysis of a lesson, coupled with the lesson’s redesign and re-teaching within a short time frame, provides an important feedback loop which allows members of the team to witness the effectiveness of their lesson modification strategies. .

The experience of Case 3 involved coordinating high school and middle school math standards into an inquiry based lesson. Case 3 demonstrated how collaboration between one middle and one high school teacher, along with their direct observation of each other’s lesson performance, allowed teachers to improve student learning at different grade levels. By reflecting on the lesson, the teachers shared their areas of expertise and looked for strategies where both teachers improved their teaching. By examining student work, they confirmed that the modifications made to the second teaching of the lesson increased higher-level thinking and inquiry skills for their students. While a group of only two teachers engaged in Lesson Study is considered small by traditional standards [Stepanek et al. 2007], these two teachers’ revealed personal satisfaction and professional gain from their involvement in the MiTEP Lesson Study Program.

4.5.3 Evidence from Focus Group Discussions

The transcripts validated the descriptions teachers had previously given in both the surveys and written documents. Table 47 lists relevant quotes selected from the focus group transcripts that provide evidence useful in the evaluation of the lesson study process.

Table 47: Quotes from teachers that were taken from the transcript of the focus groups that provides relevant information about the MiTEP lesson study process.

Focus Group Quotes from Transcript
"We found that observing the lesson in person is better than watching a videotaped lesson because with a videotaped lesson you are limited by the camera as to what you hear and see. A problem with trying to use video tapes is that you can't see everything going on in the classroom and it is hard to hear what all the students are saying. Besides, this was the first time I was able to visit other classrooms in the district where they are teaching what I am teaching and just that experience helps make me a better teacher."
"Something that I learned in lesson study and continue to do is to reflect more on how my lessons are working. I learned that I need to modify the lessons to make them more beneficial for my students. The reflection and revision process is something I do more now; I keep looking for ways to make the lessons better."
"We found that working in a group gave us an advantage. By working together we were able to share what each of us had done to teach a concept before and put it all together. We began with 4 OK lessons and ended up with 1 awesome lesson. One teacher kept helping us think from the student learners' perception and that helped us identify what our students might be thinking and focus on their learning."
"Insights about myself: Going through this process, I realized that I wasn't the only one dissatisfied with our curriculum and labs, there are many people attempting to modify different labs. Through this process, I found validation. Having other teachers to talk to allowed me to find, that as a team we can work to make things better. I no longer feel like I am stranded out on a boat by myself. Now I feel like we can all put our boats together and make a raft. For me, it built confidence that collectively we can really make it better."
"My experience working with a team was great. I liked it so much that it has made me work harder to get my students working in teams."
"We taught our research lesson in two different schools. One school had some of our high achievers and that school was on a block schedule. The other school has more low achieving students and it is on a more traditional 45 minute class schedule. The same lesson was appropriate for both schools and both sets of students, we just modified what we stressed in the lesson so we could maximize student learning. One classroom worked more on predicting and testing how different types of substrate influenced the area that would be contaminated by a pollutant where the other class worked on properties that would make a substrate a more effective aquifer."

The focus group discussions confirmed that teachers valued working with other team members in reflecting on student learning to determine the effectiveness of a lesson, and that a good lesson can be taught effectively in very different school settings. One teacher found working with others to be empowering for him and is implementing more group work in his classroom. Another insight revealed that personal observation of a lesson was more powerful than watching a lesson taught in a video.

Each of the tables is focused on one of research questions and displays the evidence collected through the three quantitative methods, survey, written documents, and focus groups (tables 48-51). Together, this data indicates that Lesson Study was a valuable professional development experience for the MiTEP teacher participants.

Table 48: The evidence collected through the teacher survey, written documents, and the focus group are displayed. These responses relate to the research question, "In what ways, if any, did the Michigan Teacher Excellence Lesson Study Program promote teacher learning?"

Method	***Responses Related to Teacher Learning***
Survey	• 100% reported that the LS program helped them be a better teacher. • 88% reported that their LS group used textbooks, research, or other outside information to help plan the research lesson. • 81% reported that they gained specific new understandings about their content and teaching from LS.
Written Documents	• Teachers learned to critically look for inquiry in a lesson and rewrite a lesson to be more inquiry based.
Focus Group	• Teachers learned how important it is to visit classrooms of fellow teachers and found benefits in this type of collaboration and reflection.

Table 49: The evidence collected through the teacher survey, written documents, and the focus group are displayed. These responses relate to the research question, "In what ways, if any, did the Michigan Teacher Excellence Program promote reflection on teaching practices?"

Method	***Responses Related to Reflection on Practice***
Survey	• 82% reported that developing the research lesson allowed me to think deeply about issues in my content or teaching. • 88% reported that the research lesson allowed them to better understand student thinking and/or challenges in my content.
Written Documents	• Based on the observations and debriefing, revisions were made and then taught again by another 8^{th} grade EarthComm teacher.
Focus Group	• Teachers described how they learned about and continue to practice reflection and improving teaching skills.

Table 50: The evidence collected through the teacher survey, written documents, and the focus group are displayed. These responses relate to the research question, "In what ways, if any, did the Michigan Teacher Excellence Lesson Study Program context of a collaborative setting promote the desire for improving teacher practices?"

Method	***Responses Related to Collaboration***
Survey	• 75% reported that the greatest strength of LS was collaboration with their peers and having the time for interaction with their peers. • 92% reported that their LS team collaborated effectively to plan a research lesson.
Written Documents	• Teachers reported that this collaboration and being able to visit each other's schools was extremely empowering and a valuable way to assess a lesson that they developed.
Focus Group	• Teachers described why collaboration with other teachers promotes security and confidence for a teacher to present a better way to reach a specific learning goal.

Table 51: The evidence collected through the teacher survey, written documents, and the focus group are displayed. These responses relate to the research question, "In what ways, if any, did the Michigan Teacher Excellence Lesson Study Program Lesson Study Program promote teacher leaders?"

Method	***Responses Related to Teacher Leaders***
Survey	• 90% reported that observing student learning and thinking during the teaching of the research lesson was an important learning opportunity. • Strength of LS was collaboration: talking thru a lesson; honing in on my teacher-as-facilitator skills. • Because of LS, I select instructional materials and questions more carefully.
Written Documents	• Her second demonstration of the lesson was so successful that the General Math teacher chose to continue to teach her lesson for the rest of his classes and has continued to increase his use of manipulatives in his classroom. • They recommend that the Lesson Study Process be implemented as part of the Professional Learning Communities (PLC) that GRPS has begun to form in all departments in their schools.
Focus Group	• Teacher leadership is seen here by purposeful sharing of the research lesson and how reflecting on the first time the lesson was taught, enabled them to improve the lesson, and benefits of collaborating with teachers that teach the same content.

4.6 Discussion

Analysis of the data collected from the teacher participants in the MiTEP Lesson Study Program indicates that Lesson Study is a successful professional development process, and with data-driven modifications, the Lesson Study process will be repeated with the remaining three teacher cohorts. The Lesson Study process improved teacher quality and classroom practice in the GRPS science program in multiple ways. In the area of teacher learning, Lesson Study empowered the teachers and improved their willingness to evaluate the quality of their own teaching, it stimulated research about the content that prompted deeper understanding, and it revealed that planned and purposeful collegial observations coupled with critical analysis can improve classroom learning experiences. The teachers learned to analyze student work for ways to improve student learning and look at the effectiveness of lesson modifications.

The MiTEP Lesson Study Program fostered teacher self-reflection on teaching practices by encouraging teachers to think more deeply about what they want students to learn. That process encouraged the teachers to dig even deeper by inquiring into literature about how students think. Reflection on teaching practices was also evident when teachers made revisions to their lessons based on observations and debriefings. Student learning became the focus of self-reflection and group-reflection. While one of the groups began their lesson with an activity to get the students excited, upon reflection, they realized they needed to focus the lesson more on student learning. Examining student work led them to re-design the lesson so that it placed more emphasis on student choice and less emphasis on teacher directed learning.

The teachers found working in a collaborative setting to be the greatest strength of the lesson study process. Working in a team promoted confidence to make changes since teachers found they were not the only ones with concerns about perceived lesson weaknesses. Each of the teams was made up of both regular content teachers and special education co-teachers. This configuration enriched the team both as they designed the lesson and as they reflected upon the teaching of the lesson. This confluence of collaboration and shared perspectives increased awareness and understanding for how lessons could be modified to better meet the needs of all students.

The MiTEP Lesson Study Program prompted the teacher participants to demonstrate leadership skills as a result of the confidence building that occurred from working with their peers. There are three specific examples. The first was the transfer that occurred when a MiTEP participating teacher demonstrated a way to use inquiry and hands-on teaching to a traditional 7th grade math teacher. The teacher later taught the inquiry-based, hands-on lesson to his own classes. The second example is where the team posted the lesson on the curriculum drive to share it with teachers throughout the district. The third example is that several of the teachers chose to present their research lesson at the Michigan Science Teacher Association conference the following year.

Of the MiTEP Lesson Study teams, only one group was homogeneous as to grade level and specific curriculum expectations, the other two teams were heterogeneous in composition. The greatest advantage to the homogenous team was being able to teach the lesson multiple times because they all taught the same curriculum and all were committed to creating an excellent lesson for personal use. The disadvantage to the heterogeneous groups was that they did not have that same level of commitment, however, an advantage they had was that their knowledge and perspectives strengthened the richness of the design and reflection upon the teaching of the research lesson. Our study does not suggest that either homogeneous or heterogeneous teams are most effective, but both demonstrated strengths.

Much of the initial teacher discussion stimulated by the implementation of Lesson Study in the Grand Rapids Public Schools focused on *time*; *time* spent organizing and planning the lesson; *time* spent identifying key concepts and standards; *time* spent observing the lesson; *time* spent analyzing and refining the lesson; *time* spent observing the re-teaching of the lesson; and *time* spent evaluating the lesson and the process. At the completion of the project, however, most participants acknowledged that the *process* of Lesson Study was transferable to other lessons and classroom strategies, that collaboration can be a crucial element of improvement, not only in a single classroom but throughout buildings and districts, and that this initial investment in time can catalyze and inspire sweeping, sustainable improvements in teaching and learning.

4.7 Conclusion

A list of conditions conducive to the implementation of the lesson study process is provided here, including both “Optimal Conditions” and “Less than Ideal Conditions”. A school climate where the entire school functions as a learning community is ideal for a Lesson Study program. It may be less effective where the school climate is one of insecurity, where teachers fear admitting weaknesses could be used against them and in a school that does not value or support a community, learning environment. Administrative support to provide release time for observations during the school day is important. Lesson Study programs have been implemented in this country where the lessons are taped and then shared and reflected upon as a group. Our teachers valued the time awarded them to visit other classrooms in the district and conduct direct observations of the students during the lesson. Administrators need to value teachers as professionals and believe that teachers are capable of planning and orchestrating their own learning for Lesson Study to work. If the administration is demanding immediate and wide spread changes to improve test scores, this may not be the best approach. Lesson Study is most effective in schools that are seeking a professional development program that produces gradual but sustainable reform in teaching and learning. Providing teacher incentives such as stipends or credits offered through a local university can enhance the implementation of the Lesson Study professional development program. This article has been designed to support a committee of learners about teacher professional development, therefore a set of discussion or assignment questions have been included (table 52).

Table 52: Reflective questions: assignment or discussion group questions for groups and committees.

	Reflective Questions
1.	What are the benefits for teachers, students, and the district when lesson study is implemented in a school?
2.	What advantage, if any, is there to being part of a team while designing a lesson?
3.	What advantage, if any, is there to being in someone's classroom to make observations compared to making observations of a teacher in a video?
4.	In what ways might it be helpful to have time set aside to discuss a lesson with other teachers?
5.	What conditions would need to be established for teachers to feel confident about sharing their alternate perspectives when a group plans a lesson?
6.	What conditions would you need to have in place in order for you to feel confident to participate in lesson study?
7.	If given the opportunity through your school district and the district met your specific conditions, would you want to participate in lesson study? Why or why not?
8.	What pitfalls might there be to continuing the lesson study program in your school district?

5. Conclusion

This dissertation supports the development of partnerships that provide teachers professional development experiences where Earth scientists share their time and expertise with the teachers to improve the teachers' Earth science literacy. There are challenges to creating partnerships. This research investigated possible strategies that Earth scientists can implement to mitigate some of the challenges that can arise when developing such partnerships. The Michigan Teacher Excellence Program (MiTEP) served as an excellent test bed for developing and testing strategies and tools that to facilitate and guide Earth scientists as they create partnerships with teachers. These partnerships can support the development of exemplary lessons that can then be used to support the national call for science education reform identified in the National Research Council's (NRC) *Framework* [NRC, 2011] and the *Next Generation Science Standards* (NGSS) [Achieve, 2013].

Over the course of the MiTEP program (from 2009 through 2013), three of multiple strategies employed with four cohorts of teacher participants were investigated for this research: 1) a strategy employed to promote communication among scientists and teachers for the purpose of planning effective professional development programs; 2) the development and testing of tools for measuring change in teachers' Earth science content knowledge; and 3) a process used to promote sustainable collaborative efforts among the teacher participants for ongoing improvement of teaching practices.

The *Earth Science Literacy Principles* (ESLP) are an effective tool for planning an Earth science teacher professional development program. The ESLP facilitate communication between geoscientists and K-12 teachers and serve to focus the teachers' learning of Earth science content. This research established that the MiTEP teacher participants found that the ESLP big ideas helped them learn Earth science content and helped them to develop a deeper understanding of what it means to be Earth science literate. The MiTEP teachers stated that the ESLP big ideas fostered their thinking about the Earth as a system with interrelated sub-systems. The geoscientists, who served as MiTEP instructors, found that the ESLP big ideas helped them organize and later teach a comprehensive perspective of ESS to the participating teachers.

The development and testing of tools for measuring changes in teacher content was an important part of this research. MiTEP has demonstrated that multiple methods are necessary to measure the changes in teachers' geoscience knowledge. By using both quantitative and qualitative methods, MiTEP was able to measure the impact MiTEP has had on the teachers' Earth science knowledge. Content-area test instruments must have adequate resolution to assess changes in knowledge among teachers. An important product to come from the MiTEP program is The Earth System Concept Inventory (ESCI). This will be a bank of test questions that have undergone extensive validity and reliability testing. They are currently organized and searchable according to the *National Science Education Standards* (NSES) and Michigan High School Earth Science Content Expectations (HSCE), and eventually will also be organized and searchable according to the NGSS. Eventually geoscientists conducting teacher professional development program, will be able to select questions from the ESCI test bank that will provide the resolution they require to measure the impact of their efforts. These questions will align directly with the standards that Earth science teachers are responsible for teaching to their students.

The MiTEP program learned that the inherent weaknesses within any one assessment method can be overcome through a system of checks and comparisons. The MiTEP program found that observations, surveys, and interviews were effective methods for checking the accuracy quantitative data. These qualitative methods confirmed the ESCI pilot test results and eventually lead to the construction of the exit survey.

The MiTEP exit survey reliably obtained information from the teachers in order to evaluate their MiTEP professional development experience. The responses provided by the teachers on the exit survey not only provided MiTEP with specific information about which parts of the program the teachers found most effective, but also served as a comparison to findings from the ESCI and other qualitative instruments.

A process used to promote sustainable collaborative efforts among the teacher participants for ongoing improvement of teaching practices was described in Chapter 4. This process is MiTEP's Lesson Study in which a group of teachers led their own professional development. Lesson study involves at least two teachers that work collaboratively to design a lesson and then perfect the lesson through a sequence of activities. The lesson is taught by one teacher while the rest of the teachers make observations. The entire group of teachers reflect on the observations and then revise the lesson based on those observations. The revised lesson is taught a second time by another teacher and is observed by the other teachers. The lesson is revised again based on the second set of observations and then shared.

A list of conditions conducive to MiTEP's implementation of the lesson study process was clearly identified as part of the research conducted and described in this dissertation. A required condition is a school climate where the entire school functions as a learning community. . If a school district does not value or support learning communities or does not advocate a life-long learning environment for all members of the district, lesson study may not be an appropriate process to implement. Administrative support is required to provide the teachers' release time to engage in classroom observations, as a group, during the school day. MiTEP found that the teachers highly valued their visit to other schools and classrooms within in the district. MiTEP teachers specifically identified the opportunity to conduct direct observations of the students during the lesson to be extremely valuable when reflecting on the quality of a lesson. For lesson study to continue and sustain the changes begun through a professional development program, school administrators need to value teachers as professionals and believe that teachers are capable of planning and orchestrating their own learning for lesson study to work. MiTEP found that lesson study is most effective in schools and school districts that are seeking a professional development process that produces gradual but sustainable reform in teaching and learning.

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Appendix B. - Permission to Reprint Figures 1 and 2

I, Joshua Ernstes, give Carol Engemann permission to display the front page of my lesson, "Investigating Stream Flow in your Local Watershed" with proper citation.

Joshua Ernstes

[redacted]

I, Angela Ernstes, give Carol Engemann permission to display the front page of my lesson, "Using Topographic Maps to Understand Watersheds and Stream Flow" with proper citation.

Angela Ernstes

[redacted]

Appendix C. – Michigan Teacher Excellence Program (MiTEP) Participant Exit Survey

XX Public Schools

In association with Michigan Technological University

Teacher Exit Survey

Information about this Request for Information: You are being asked to supply some information that will ultimately be used to determine the effectiveness of the Michigan Teacher Excellence Program (MiTEP). MiTEP is a research project conducted by researchers and teachers from Michigan Technological University, Colorado School of Mines, Grand Rapids Public Schools, Kalamazoo Public Schools, Jackson Public Schools, Grand Rapids Pre-College Engineering Program, Grand Valley State University, Western Michigan University, the American Geosciences Institute, the National Park Service, and Cass Technical High School. MiTEP's activities are funded by the National Science Foundation. MiTEP is an exciting project because, if successful, it may become a model for nationwide teacher-led reform of science education.

Confidentiality: The information you provide will be compiled by the MiTEP project evaluation teams at Michigan Technological University and the Colorado School of Mines for use in project improvement and evaluation. Your response to this request will be coded to ensure that your identity is kept confidential.

Duration: It should take approximately 30 minutes for you to respond to this survey.

The Michigan Tech Institutional Review Board (Michigan Tech-IRB) has reviewed this project. If you have any concerns about your rights in this study, please contact Ms. Joanne Polzien of the Michigan Tech-IRB at 906-487-2902 or email jpolzien@mtu.edu**.**

Everyone associated with MiTEP thanks you very much for taking the time to contribute to the success of the MiTEP project.

MiTEP Participant Exit Survey

Gender:

☐ Male
☐ Female

Please indicate the highest degree you have completed to date.

Bachelors ______ Masters ______ Doctorate ______

Mark the table below to indicate the degrees you hold.

Degree Type	Bachelors	Masters	Doctorate
Biology/Life Sciences			
Chemistry			
Earth/Space Science			
Environmental Science			
Physics			
Mathematics			
Mathematics Education			
Elementary Education			
Secondary Education			
Special Education			
Other?			
Other?			

Are you interested in pursuing or currently pursuing a graduate degree?

______Yes ______ No

Has the MiTEP program increased your interest in pursuing a graduate degree?

______Yes ______ No

Please list your professional certifications, including subjects and grade levels.

Certification	Content Area	Specific Grade Levels

Please indicate the extent of your influence on the following conditions.

Condition	0=No Influence									Significant Influence =10	
Your teaching assignment	0	1	2	3	4	5	6	7	8	9	10
Building or room in which you teach	0	1	2	3	4	5	6	7	8	9	10
Determining course goals and objectives	0	1	2	3	4	5	6	7	8	9	10
Selecting textbooks and instructional materials	0	1	2	3	4	5	6	7	8	9	10
Selecting content, topics and skills to be taught	0	1	2	3	4	5	6	7	8	9	10
Selecting sequence in which topics are covered	0	1	2	3	4	5	6	7	8	9	10
Setting the pace for covering topics	0	1	2	3	4	5	6	7	8	9	10
Selecting teaching techniques	0	1	2	3	4	5	6	7	8	9	10
Determining homework to be assigned	0	1	2	3	4	5	6	7	8	9	10
Choosing criteria for grading students	0	1	2	3	4	5	6	7	8	9	10
Choosing tests for classroom assessment	0	1	2	3	4	5	6	7	8	9	10

Have you experienced involuntary transfer(s) (change in your assignment initiated by school or district administration) since becoming a MiTEP partner teacher?

______Yes   _____ No

If “yes,” please provide details surrounding the transfer(s):

Please indicate all of the work assignments you have had since you entered the MiTEP program.

Assignment	***2009-2010***	***2010-2011***	***2011-2012***	***2012-2013***	***2013-2014***
Elementary					
• Regular Elementary					
• Special Education					
• Other (Specify)					
Middle School					
• Earth/Space Science					
• Environmental Science					
• Biology/Life Science					
• Physical Science					
• Mathematics					
• Special Education					
• Other (Specify)					
High School					
• Earth/Space Science					
• Environmental Science					
• Biology/Life Science					
• Chemistry					
• Physics					
• Physical Science					
• Mathematics					
• Special Education					
• Other (Specify)					
Administration					
• Principal					
• Assistant Principal					
• Content Specialist					
• Student Liaison					
• Other (Specify)					

Please RATE the usefulness of the components of the MiTEP program listed below in improving <u>your own understanding of Earth science</u>.

Please <u>ALSO</u> place checkmarks to the left of the 5 items that were MOST HELPUFL in improving your own understanding of Earth science content knowledge.

Top 5	***Component***	***0=Not Useful***										***10=Very Useful***	***NA= Not Applicable***
	Fieldwork in the Upper Peninsula	0	1	2	3	4	5	6	7	8	9	10	N/A
	Fieldwork in the Lower Peninsula	0	1	2	3	4	5	6	7	8	9	10	N/A
	Michigan Geography and Geology Text	0	1	2	3	4	5	6	7	8	9	10	N/A
	Pedagogy days	0	1	2	3	4	5	6	7	8	9	10	N/A
	Lesson Study Course	0	1	2	3	4	5	6	7	8	9	10	N/A
	Earth System Science Content On-line Course	0	1	2	3	4	5	6	7	8	9	10	N/A
	Science Learning Materials, Inquiry, and Assessment On-line Course	0	1	2	3	4	5	6	7	8	9	10	N/A
	Scientists on Call	0	1	2	3	4	5	6	7	8	9	10	N/A
	National Park Internship	0	1	2	3	4	5	6	7	8	9	10	N/A
	Vernier LabQuest Pro probe devices	0	1	2	3	4	5	6	7	8	9	10	N/A
	Commercial posters, booklets, pamphlets	0	1	2	3	4	5	6	7	8	9	10	N/A
	MiTEP grants for classroom supplies	0	1	2	3	4	5	6	7	8	9	10	N/A
	Membership in MSTA	0	1	2	3	4	5	6	7	8	9	10	N/A
	Attendance at the MSTA Conference	0	1	2	3	4	5	6	7	8	9	10	N/A
	Participation in MSTA Conference	0	1	2	3	4	5	6	7	8	9	10	N/A
	Membership in NSTA	0	1	2	3	4	5	6	7	8	9	10	N/A
	Participation in GSA National Conference	0	1	2	3	4	5	6	7	8	9	10	N/A
	MiTEP Field Course Website	0	1	2	3	4	5	6	7	8	9	10	N/A
	Classroom visits by colleagues	0	1	2	3	4	5	6	7	8	9	10	N/A
	Classroom visits by MiTEP personnel	0	1	2	3	4	5	6	7	8	9	10	N/A

Please RATE the usefulness of the components of the MiTEP program listed below in improving <u>your students' learning</u>.

Please <u>ALSO</u> place checkmarks to the left of the 5 items that were MOST HELPFUL in improving your students' learning.

Top 5	***Component***	***0=Not Useful***					***NA= Not Applicable***					***10=Very Useful***	
	Fieldwork in the Upper Peninsula	0	1	2	3	4	5	6	7	8	9	10	N/A
	Fieldwork in the Lower Peninsula	0	1	2	3	4	5	6	7	8	9	10	N/A
	Michigan Geography and Geology Text	0	1	2	3	4	5	6	7	8	9	10	N/A
	Pedagogy days	0	1	2	3	4	5	6	7	8	9	10	N/A
	Lesson Study Course	0	1	2	3	4	5	6	7	8	9	10	N/A
	Earth System Science Content On-line Course	0	1	2	3	4	5	6	7	8	9	10	N/A
	Science Learning Materials, Inquiry, and Assessment On-line Course	0	1	2	3	4	5	6	7	8	9	10	N/A
	Scientists on Call	0	1	2	3	4	5	6	7	8	9	10	N/A
	National Park Internship	0	1	2	3	4	5	6	7	8	9	10	N/A
	Vernier LabQuest Pro probe devices	0	1	2	3	4	5	6	7	8	9	10	N/A
	Commercial posters, booklets, pamphlets	0	1	2	3	4	5	6	7	8	9	10	N/A
	MiTEP grants for classroom supplies	0	1	2	3	4	5	6	7	8	9	10	N/A
	Membership in MSTA	0	1	2	3	4	5	6	7	8	9	10	N/A
	Attendance at the MSTA Conference	0	1	2	3	4	5	6	7	8	9	10	N/A
	Participation in MSTA Conference	0	1	2	3	4	5	6	7	8	9	10	N/A
	Membership in NSTA	0	1	2	3	4	5	6	7	8	9	10	N/A
	Participation in GSA National Conference	0	1	2	3	4	5	6	7	8	9	10	N/A
	MiTEP Field Course Website	0	1	2	3	4	5	6	7	8	9	10	N/A
	Classroom visits by colleagues	0	1	2	3	4	5	6	7	8	9	10	N/A
	Classroom visits by MiTEP personnel	0	1	2	3	4	5	6	7	8	9	10	N/A

Please INDICATE the strength of MiTEP's negative or positive impact on your <u>attitudes about teaching</u>.

Please <u>ALSO</u> place checkmarks to the left of the 5 items above that MOST INFLUENCED your attitudes about teaching.

Top 5	***Attitude***	***Negative***					***0=No Impact***			***Positive***		
	Your enjoyment of teaching	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Your desire to engage students in activity-based learning	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Your confidence in leading inquiry-based student activities	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Your confidence in identifying and addressing student misconceptions	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Your interest in working with colleagues to improve teaching practices	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Your interest in working with colleagues to improve curriculum	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Your interest in sharing ideas and materials related to teaching with colleagues	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Your interest in observing others' teaching	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Your interest in having your teaching observed by others	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Your confidence in explaining earth science concepts to students	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Your confidence in talking about earth science concepts with other teachers	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Your desire to be involved in making decisions about curriculum	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Your interest in helping to develop science assessments	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Your interest in being involved in state or national organizations related to teaching or earth science	-5	-4	-3	-2	-1	0	1	2	3	4	5

Please INDICATE the strength of MiTEP's negative or positive impact on <u>your ability to make EFFECTIVE USE of the following teaching strategies</u>.

Please <u>ALSO</u> place checkmarks to the left of the 5 items above that had the GREATEST impact on your teaching strategies.

Top 5	***Teaching Strategy***	***Negative***					***0=No Impact***					***Positive***
	Asking students questions in order to gauge their understanding	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Taking students' prior knowledge into account when planning instruction	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Demonstrating discrepant events to challenge student thinking	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Discussing common misconceptions related to science concepts	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Looking for deeper understanding by asking students to explain their answers	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Having students build models or use models of processes or events	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Engaging students in hands-on work in science	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Purposely grouping students for learning activities based on student strengths and weaknesses	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Differentiating instruction based on ability	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Differentiating instruction based on student interests in science	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Using think-pair-share to promote small group discussions	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Soliciting student perspectives on science topics or issues using a gallery walk	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Requiring students to examine alternative perspectives, such as in a debate	-5	-4	-3	-2	-1	0	1	2	3	4	5

Top 5	*Teaching Strategy*	*Negative*					*0=No Impact*					*Positive*
	Providing students opportunities to use interactive web sites	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Integrating the use of GPS receivers and their technology	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Integrating the use of satellite images or maps (such as GoogleEarth)	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Relating science content to local or current events in the news	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Identifying places near where students live as examples of science content/concepts	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Relating science content/concepts to the "Big Ideas" of Earth Science Literacy	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Changing student activities to make them more inquiry based	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Relating science content to real-world examples	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Requiring students to use scientific thinking: making claims, providing evidence and explaining their reasoning	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Creating opportunities to learn about earth science in the field (outside of the classroom)	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Using real examples from your local area	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Using real examples from Michigan	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Using real examples from the National Parks	-5	-4	-3	-2	-1	0	1	2	3	4	5

Please INDICATE the strength of MiTEP's negative or positive impact on your <u>interest in being a teacher-leader</u>.

Please <u>ALSO</u> place checkmarks to the left of the 5 items that are of the GREATEST interest to you.

Top 5	***Teacher-leader Interest***	***Negative***					***0=No Impact***					***Positive***
	Interest in teaching an in-service workshop	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Interest in applying for a local, state, or national grant	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Interest in applying for a local, state, or national award	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Interest in serving on a school or district committee	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Interest in enrolling in a formal college/university course	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Interest in formally observing colleagues teaching	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Interest in having others formally observe my teaching	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Interest in meeting with other teachers to study/discuss teaching activities, pedagogy, etc.	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Interest in serving as a mentor and/or peer coach to another teacher	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Interest in attending a workshop on teaching practices	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Interest in attending a national or state professional association meeting (MSTA, NSTA, etc.)	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Interesting in pursuing an additional internships with the national parks	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Interest in presenting at a national or state professional association meeting (MSTA, NSTA, etc.)	-5	-4	-3	-2	-1	0	1	2	3	4	5

Top 5	*Teacher-leader Interest*	***Negative***					***0=No Impact***					***Positive***
	Interest in working toward becoming certified as a National Board for Professional Standards (NBPTS) teacher	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Received National Board for Professional Standards (NBPTS) Certification	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Interest in networking with college or university faculty	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Interest in networking with peers at other schools	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Interest in working on district or school wide assessments	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Interest in working on development of school or district curriculum	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Interest in networking with others to influence school or district decisions that impact learning	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Interest in offering after school science activities for students	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Interest in sponsoring extracurricular activities related to science	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Interest in creating or participating in a Professional Learning Community (PLC)	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Interest in creating or participating in a MiTEP-based Professional Learning Community (PLC)	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Interest in leading earth science field trips to national parks with students	-5	-4	-3	-2	-1	0	1	2	3	4	5
	Interest in leading earth science field trips to national parks with colleagues	-5	-4	-3	-2	-1	0	1	2	3	4	5

<u>Additional Questions:</u>

Did MiTEP change your understanding of the nature of science and/or how scientists do science?
If so, please provide one or more examples of what happened within MiTEP that led to a particular change in your understanding.

Did MiTEP change your understanding of how the Earth works?
If so, please provide one or more examples of what happened within MiTEP that led to a particular change in your understanding.

Has MiTEP influenced your attitude about the societal importance of earth science literacy?
Please provide one or more examples of what happened within MiTEP that led to a particular change in your attitude.

Did MiTEP change your attitude about improving your teaching skills?
If so, please provide one or more examples of what happened within MiTEP that led to a particular change in your attitude.

Have you encountered obstacles that have prevented you from improving earth science education in your school or district?
If so, please provide one or more examples of the obstacles you have encountered.

Did MiTEP change your attitude and/or involvement in teacher leadership activities?
If so, please provide one or more examples of what happened within MiTEP that led to a particular change.

Did your participation in the MiTEP program influence how you see yourself as a professional?
If so, please provide a brief narrative of this influence.

Did your participation in the MiTEP program change your personal views?
If so, briefly describe the change(s) and why you think they occurred.

Thank you for completing this survey!

We may want to contact some of you at a later time to discuss some of the responses we receive on this survey.

Please provide the following information if you would be willing to participate in a follow-up interview.

You will be contacted to set up a convenient time that will fit your schedule.

Thank you.

Name: ____

E-mail address ____

Phone # (day) ____

(evening): ____

Best time to call? ____

Appendix D. – Alignment of MiTEP Exit Survey Items with MiTEP Project Goals

MiTEP Goal 1: Teachers will demonstrate increases in science content knowledge.

Objective: More teachers will become "highly qualified" in earth science.

Related Survey

Statements

- Fieldwork in the Upper Peninsula
- Fieldwork in the Lower Peninsula
- Michigan Geography and Geology Text
- Pedagogy days
- Lesson Study Course
- Earth System Science Content On-line Course
- Science Learning Materials, Inquiry, and Assessment On-line Course
- National Park Internship
- Attendance at the MSTA Conference
- Participation in MSTA Conference

Free Response Questions

- Did MiTEP change your attitude about improving your teaching skills?
- If so, please provide one or more examples

Objective: Faculty will show improvement on faculty-designed content tests.

Free Response Questions

- Did MiTEP change your understanding of the nature of science and/or how scientists do science?
- If so, please provide one or more examples of what happened within MiTEP that led to a particular change in your understanding.

- Did MiTEP change your understanding of how the Earth works?
- If so, please provide one or more examples of what happened within MiTEP that led to a particular change in your understanding.

- Has MiTEP influenced your attitude about the societal importance of earth science literacy?
- Please provide one or more examples of what happened within MiTEP that led to a particular change in your attitude.

MiTEP Goal 2: Teachers will demonstrate commitment to inquiry-based teaching and learning.

Objective: Teachers will exhibit more frequent use of inquiry techniques.

Related Survey Statements

- Taking students' prior knowledge into account when planning instruction
- Discussing common misconceptions related to science concepts
- for learning activities based on student strengths and weaknesses
- Differentiating instruction based on student interests in science
- Soliciting student perspectives on science topics or issues using a gallery walk
- Requiring students to examine alternative perspectives, such as in a debate
- Changing student activities to make them more inquiry based
- Requiring students to use scientific thinking: making claims, providing evidence and explaining their reasoning

Objective: Teachers' attitudes about science, teaching, and inquiry will improve.

Related Survey Statements

- Your enjoyment of teaching
- Your desire to engage students in activity-based learning
- Your confidence in leading inquiry-based student activities
- Your confidence in identifying and addressing student misconceptions
- Your interest in working with colleagues to improve teaching practices
- Your interest in working with colleagues to improve curriculum
- Your interest in sharing ideas and materials related to teaching with colleagues
- Your interest in observing others' teaching
- Your interest in having your teaching observed by others
- Your confidence in explaining earth science concepts to students

Objective: Teachers will employ strategies that engage students.

Related Survey Statements

- Asking students questions in order to gauge their understanding
- Demonstrating discrepant events to challenge student thinking
- Looking for deeper understanding by asking students to explain their answers
- Having students build models or use models of processes or events
- Engaging students in hands-on work in science
- Purposely grouping students
- Differentiating instruction based on ability
- Using think-pair-share to promote small group discussions
- Providing students opportunities to use interactive web sites
- Relating science content to local or current events in the news

MiTEP Goal 3: Teachers' leadership skills will improve.

Objective: Teachers will report increased leadership in STEM education.

Related Survey Statements

- Interest in serving as a mentor and/or peer coach to another teacher
- Interest in meeting with other teachers to study/discuss teaching activities, pedagogy, etc.
- Interest in having others formally observe my teaching
- Interest in formally observing colleagues teaching
- Interest in working on district or school wide assessments
- Interest in working on development of school or district curriculum
- Interest in creating or participating in a Professional Learning Community (PLC)
- Interest in leading earth science field trips to national parks with students
- Interest in leading earth science field trips to national parks with colleagues

Objective: Teachers will report empowerment to identify, implement, and analyze the effect of change.

Related Survey

Statements

- Interest in applying for a local, state, or national grant
- Interest in applying for a local, state, or national award
- Interest in attending a workshop on teaching practices
- Interesting in pursuing an additional internships with the national parks
- Interest in working toward becoming certified as a National Board for Professional Standards (NBPTS) teacher
- Interest in networking with college or university faculty
- Interest in networking with others to influence school or district decisions that impact learning

Objective: Teachers' participation in professional activities will improve.

Related Survey Statements

- Interest in teaching an in-service workshop
- Interest in serving on a school or district committee
- Interest in enrolling in a formal college/university course
- Interest in attending a national or state professional association meeting (MSTA, NSTA, etc.)
- Interest in presenting at a national or state professional association meeting (MSTA, NSTA, etc.)
- Interest in networking with peers at other schools
- Interest in offering after school science activities for students
- Interest in sponsoring extracurricular activities related to science
- Interest in creating or participating in a MiTEP-based Professional Learning Community (PLC)

Appendix E. – Correlation of Michigan Earth Science High School Science Expectations to Earth Science Literacy Principles

Table C.1: Supporting concepts for Big Idea 1 with the correlated codes for the Michigan High School Content Expectations [MDE, 2006].

Big Idea 1: Earth scientists use repeatable observations and testable ideas to understand and explain our planet.				
Supporting Concepts	***Earth Systems HSCE***	***Solid Earth HSCE***	***Fluid Earth HSCE***	***Space and Time HSCE***
1.1 Earth scientists find solutions to society's needs.	E2.2B, E3.3A, E2.3b, E2.3d, E2.4A, E2.4B, E2.4c, E2.4d	E3.4C	E4.1B, E4.1C, E4.2g, E4.3A, E4.3B, E4.3C	E5.2B
1.2 Earth scientists use a large variety of scientific principles to understand how our planet works				
1.3 Earth science investigations take many different forms.	E2.1B, E2.1C, E2.2B, E2.2e, E2.2f, E2.3A, E2.3b, E2.3c, E2.4B, E3.4c	E3.p1A, E3.p1B, E3.p1C, E3.4C, E3.4e	E4.p1A, E4.p1B, E4.p1C, E4.p1D, E4.p2A, E4.p2G, E4.p2H, E4.p2I, E4.p3C, E4.1A, E4.1B, E4.1C, E4.2B E4.2c, E4.2g, E4.3A, E4.3B, E4.3C	E5.p1A, E5.p1B, E5.1A, E5.2B, E5.3B, E5.3C, E5.3D, E5.3e, E5.4A, E5.4B, E5.4C, E5.4D, E5.4e, E5.4f, E5.4g, E5.4h, E54i, E5.4j
1.4 Earth scientists must use indirect methods to examine and understand the structure, composition, and dynamics of Earth's interior.		E3.2A, E3.2B, E3.2d		

1.5 Earth scientists use their understanding of the past to forecast Earth's future.	E2.1A, E2.1B, E2.1C, E2.2A, E2.2B, E2.2e, E2.2f, E2.3A, E2.3b, E2.3c, E2.3d, E2.4A, E2.4B, E2.4c	E3.p1A, E3.p1B, E3.p1C E3.p3A,	E4.p1B, E4.p1C, E4.p1D, E4.p2A, E4.p2E, E4.p2F, E4.p2G, E4.p2H, E4.p3A, E4.p3B, E4.p3C, E4.1A, E4.1B, E4.1C, E4.2A, E4.2B, E4.2c, E4.2e, E4.2f, E4.2g, E4.3A, E4.3B, E4.3C, E4.3D, E4.3E, E4.3F	E5.p1A, E5.p1B, E5.1A, E5.1c, E5.1d, E5.2A, E5.2B, E5.2g, E5.2h, E5.3A, E5.3B, E5.3C, E5.3D, E5.3e, E5.3f, E5.3g, E5.4A, E5.4B, E5.4C, E5.4D, E5.4e, E5.4f, E5.4g, E5.4h, E54i, E5.4j
1.6 Earth scientists construct models of Earth and its processes that best explain the available geological evidence.	E2.1B, E2.1B, E2.2B, E2.2C, E2.2D, E2.2e, E2.2f, E2.3A, E2.3b, E2.3c, E2.3d, E2.4A, E2.4B, E2.4d	E3.p1A, E3.p1B, E3.p1C, E3.1B, E3.1c, E3.1d, E3.1e, E3.2d, E3.4A, E3.4B, E3.2A, E3.4C, E3.4d, E3.4e, E3.4f	E4.p1A, E4.p1B, E4.p1C, E4.p1D, E4.p2A, E4.p2C, E4.p2D, E4.p2E, E4.p2F, E4.p2G, E4.p2H, E4.p3A, E4.p3B, E4.p3C, E4.1A, E4.1B, E4.1C, E4.2A, E4.2B, E4.2c, E4.2d, E4.2e, E4.2f, E4.2g, E4.3A, E4.3C, E4.3D, E4.3E, E4.3F, E4.3g	
1.7 Technological advances, breakthroughs in interpretation, and new observations continuously refine our understanding of Earth.	E2.2A, E2.2B, E2.2D, E2.2e	E3.p1A, E3.p1B, E3.p1C E3.p3A, E3.1A, E3.1B, E3.1c, E3.1d, E3.1e, E3.2A, E3.2B, E3.2C, E3.2d, E3.4A, E3.4B, E3.4d, E3.4e, E3.4f		

Table C.2: Supporting concepts for Big Idea 2 with the correlated codes for the Michigan High School Content Expectations [MDE, 2006].

Big Idea 2: Earth is 4.6 billion years old.				
Supporting Concepts	***Earth Systems HSCE***	***Solid Earth HSCE***	***Fluid Earth HSCE***	***Space and Time HSCE***
2.1 Earth's rocks and other materials provide a record of its history.	E2.1B	E3.p1A, E3.p1B, E3.p3A E3.p3B, E3.p3C, E3.1A, E3.1B, E3.1c, E3.1d, E3.1e, E3.2A, E3.2C, E3.4d, E3.4e	E4.p3A, E4.p3B, E4.p3C,	E5.3A, E5.3B, E5.3C, E5.3D, E5.3e, E5.3f, E5.3g
2.2 Our Solar System formed from a vast cloud of gas and dust 4.6 billion years ago.	E2.1A			E5.1A, E5.1b, E5.1c, E5.1d, E5.2e, E5.2g, E5.2h, E5.3A, E5.3B, E5.3C
2.3 Earth formed from the accumulation of dust and gas, and multiple collisions of smaller planetary bodies.	E2.1A	E3.p2A, E3.p2B		E5.p1A, E5.3A, E5.3C
2.4 Earth's crust has two distinct types: continental and oceanic.		E3.p1A, E3.1B, E3.2C, E3.4d	E4.p3C	E5.3C
2.5 Studying other objects in the solar system helps us learn Earth's history.				E5.1A, E5.1c, , E5.2B, E5.2C, E5.2D, E5.3A, E5.3B, E5.3C, E5.3e
2.6 Life on Earth began more than 3.5 billion years ago.	E2.1B, E2.1C, E2.2f, E2.3A, E2.3b, E2.3c, E2.3d			E5.3C, E5.3D, E5.3e, E5.3f, E5.3g
2.7 Over Earth's vast history, both gradual and catastrophic processes have produced enormous changes.	E2.1A, E2.1B, E2.1C, E2.2A, E2.2C, E2.2D, E2.3A, E2.3c, E2.3d	E3.p1A, E3.p1B, E3.p1C E3.p2B, E3.1B, E3.1c, E3.1d, E3.1e, E3.2d, E3.2A, E3.2d, E3.4A, E3.4B, E3.4C, E3.4d		

Table C.3: Supporting concepts for Big Idea 3 with the correlated codes for the Michigan High School Content Expectations [MDE, 2006].

Big Idea 3: Earth is a complex system of interacting rock, water, air, and life.				
Supporting Concepts	***Earth Systems HSCE***	***Solid Earth HSCE***	***Fluid Earth HSCE***	***Space and Time HSCE***
3.1 The four major systems of Earth are the geosphere, hydrosphere, atmosphere, and biosphere.	E2.1A, E2.1B, E2.1C,			
3.2 All Earth processes are the result of energy flowing and mass cycling within and between Earth's systems.	E2.1A, E2.1B, E2.1C, E2.2A, E2.2B, E2.2C, E2.2D, E2.2e, E2.2f, E2.3A, E2.3c, E2.3d, E2.4A, E2.4B, E2.4c, E2.4d		E4.1A, E4.1B, E4.2A, E4.2B, E4.2c, E4.2e, E4.2f	E5.4A, E5.4B, E5.4C, E5.4D, E5.4e, E5.4f, E5.4g, E5.4h, E54i, E5.4j
3.3 Earth exchanges mass and energy with the rest of the Solar System.			E4.p1A, E4.p3A, E4.p3C, E4.2A, E4.2B, E4.3A	E5.p1A, E5.p1B, E5.2A , E5.2B, E5.4A, E5.4B, E5.4C, E5.4D, E54i, E5.4j
3.4 Earth's systems interact over a wide range of temporal and spatial scales		E3.p1A, E3.p1B, E3.p1C E3.p3A, E3.p3B, E3.p3C, E3.1A, E3.1B, E3.1c, E3.1d, E3.1e, E3.2A, E3.4A, E3.4B, E3.4d, E3.4e	E4.p1A, E4.p1B, E4.p1C, E4.p1D, E4.p2A, E4.p2H, E4.p2I, E4.p3A, E4.p3B, E4.p3C, E4.1A, E4.1B, E4.1C, E4.2A, E4.2B, E4.2c, E4.2d, E4.2g, E4.3C, E4.3D	E5.p1A, E5.p1B, E5.p1D, E5.2B , E5.3C, E5.3f, E5.4B, E5.4C, E5.4D, E5.4e, E5.4f, E5.4g, E5.4h, E54i, E5.4j
3.5 Regions where organisms actively interact with each other and their environment are called ecosystems.				

3.6 Earth's systems are dynamic; they continually react to changing influences.				
3.7 Changes in part of one system can cause new changes to that system or to other systems, often in surprising and complex ways.				
3.8 Earth's climate is an example of how complex interactions among systems can result in relatively sudden and significant changes.				

Table C.4: Supporting concepts for Big Idea 4 with the correlated codes for the Michigan High School Content Expectations [MDE, 2006].

Big Idea 4: Earth is continuously changing.				
Supporting Concepts	***Earth Systems HSCE***	***Solid Earth HSCE***	***Fluid Earth HSCE***	***Space and Time HSCE***
4.1 Earth's geosphere changes through geological, hydrological, physical, chemical, and biological processes that are explained by universal laws.	E2.1A, E2.1B, E2.1C, E2.2A, E2.2C, E2.2D, E2.2f	E3.p1A, E3.p1B, E3.p1C E3.p2A, E3.p2B, E3.p3A, E3.p3B, E3.p3C, E3.1A, E3.1B, E3.1c, E3.1d, E3.1e, E3.2A, E3.2B, E3.2C, E3.2d, E3.4A, E3.4B, E3.4C, E3.4d, E3.4e, E3.4f	E4.p3A, E4.p3B, E4.p3C,	E5.3B, E5.3C,E5.3D, E5.3e, E5.3f, E5.3g, E5.4B, E5.4f, E5.4h
4.2 Earth, like other planets, is still cooling, though radioactive decay continuously generates internal heat.	E2.2A, E2.2C, E2.2e	E3.2A, E3.2d		E5.3C

4.3 Earth's interior is in constant motion through the process of convection, with important consequences for the surface.	E2.2A, E2.2C, E2.2e	E3.2A, E3.2d		
4.4 Earth's tectonic plates consist of the rocky crust and uppermost mantle, and move slowly with respect to one another.	E2.1B, E2.1C	E3.4A, E3.4C, E3.4d		
4.5 Many active geologic processes occur at plate boundaries.	E2.1B, E2.1C	E3.4A, E3.4C, E3.4d		
4.6 Earth materials take many different forms as they cycle through the geosphere.	E2.3A, E2.3c, E2.3d, E2.4A, E2.4d	E3.p1A, E3.p1B, E3.p1C E3.p2A, E3.p2B, E3.p3A, E3.p3B, E3.p3C, E3.1A, E3.1B, E3.1c, E3.1d, E3.1e, E3.2B, E3.2C, E3.4A, E3.4C, E3.4d		E5.3B, E5.3C
4.7 Landscapes result from the dynamic interplay between processes that form and uplift new crust and processes that destroy and depress the crust.		E3.p1A, E3.p1B, E3.p3A, E3.1c, E3.4A, E3.4d		E5.3C, E5.4D
4.8 Weathered and unstable rock materials erode from some parts of Earth's surface and are deposited in others		E3.p1A, E3.p1B, E3.p1C E3.p3A, E3.1c	E4.p1B, E4.p1C,	E5.3C, E5.4D, E5.3f

Table C.5: Supporting concepts for Big Idea 5 with the correlated codes for the Michigan High School Content Expectations [MDE, 2006].

Big Idea 5: Earth is the water Planet				
Supporting Concepts	***Earth System HSCE***	***Solid Earth HSCE***	***Fluid Earth HSCE***	***Space and Time HSCE***
5.1 Water is found everywhere on Earth, from the heights of the atmosphere to the depths of the mantle.	E2.1A, E2.1B, E2.1C, E2.2B, E2.2C, E2.23, E2.2f, E2.3A, E2.4B	E3.p1A, E3.p2A, E3.p2B, E3.1A, E3.1c, E3.4e	E4.p1A,E4.1A, E4.1B, E4.2A, E4.2B, E4.2f, E4.3A	E5.3C
5.2 Water is essential for life on Earth.	E2.1A, E2.1B, E2.1C, E2.2f, E2.3A, E2.3b, E2.3c, E2.3d, E2.4B		E4.p1A, E4.p1D,E4.1A, E4.1B, E4.1C	E5.3C
5.3 Water's unique combination of physical and chemical properties are essential to the dynamics of all of Earth's systems.	E2.1A, E2.1B, E2.1C, E2.2B, E2.2C, E2.2e, E2.2f, E2.3A, E2.3b, E2.3c, E2.3d, E2.4B	E3.p1A, E3.p1B, E3.p1C E3.p2A, E3.p2B, , E3.1A, E3.1c, E3.4e	E4.p1A, E4.p1B, E4.p1C, E4.p1D, E4.p3A, E4.p3C, E4.1A, E4.1B, E4.1C, E4.2A, E4.2B, E4.2c, E4.2d, E4.2f, E4.3A	E5.3C, E5.4D, E5.3e, E5.3f

5.4 Water plays an important role in many of Earth's deep internal processes	E2.1B, E2.2C, E2.2D, E2.2e, E2.2f	E3.p1A, E3.p1B, E3.p2A, E3.p2B, , E3.1A, E3.2A, E3.4d, E3.4e	E4.p1A	
5.5 Earth's water cycles among the reservoirs of the atmosphere, streams, lakes, ocean, glaciers, groundwater, and deep interior of the planet.	E2.1B, E2.1C, E2.2B, E2.2C, E2.2D, E2.2e, E2.2f,, E2.3A, E2.3b, E2.3c, E2.3d, E2.4A, E2.4B, E2.4d	E3.p1A, E3.p1B, E3.p1C,E3.p2B, , E3.1A, E3.1c, E3.4e	E4.p1A, E4.p1B, E4.p1C, E4.p1D, E4.p2C, E4.p2I, E4.p3A, E4.p3B, E4.p3C, E4.1A, E4.1B, E4.1C, E4.2A, E4.2B, E4.2c, E4.2d, E4.2e, E4.3A, E4.3C, E4.2g	E5.3C, E5.3g, E5.4D, E5.3e, E5.3f
5.6 Water shapes landscapes.		E3.p1A, E3.p1B, E3.p1C, E3.1A, E3.1c	E4.p1A, E4.p1C, E4.p3C	E5.3C
5.7 Ice is an especially powerful agent of weathering and erosion.		E3.p1A, E3.p1B, E3.p1C, E3.1A, E3.1c	E4.p1A, E4.p3A, E4.p3C	E5.3C
5.8 Fresh water is less than 3% of the water at Earth's surface.			E4.1A	

Table C.6: Supporting concepts for Big Idea 6 with the correlated codes for the Michigan High School Content Expectations [MDE, 2006].

Big Idea 6: Life evolves on a dynamic Earth and continuously modifies Earth.				
Supporting Concepts	***Earth Systems HSCE***	***Solid Earth HSCE***	***Fluid Earth HSCE***	***Space and Time HSCE***
6.1 Fossils are the preserved evidence of ancient life.				E5.3C, E5.3D
6.2 Evolution, including the origination and extinction of species, is a natural and ongoing process.	E2.1B, E2.1C			E5.3C
6.3 Biological diversity, both past and present, is vast and largely undiscovered.				E5.3C

6.4 More complex life forms and ecosystems have arisen over the course of Earth's history.				E5.3C
6.5 Microorganisms dominated Earth's early biosphere and continue today to be the most widespread, abundant, and diverse group of organisms on the planet.				E5.3C
6.6 Mass extinctions occur when global conditions change faster than species in large numbers can adapt.	E2.1B, E2.1C			E5.3C, E5.3D, E5.3g
6.7 The particular life forms that exist today, including humans, are a unique result of the history of Earth's systems.				E5.3C
6.8 Life changes the physical and chemical properties of Earth's geosphere, hydrosphere, and atmosphere.	E2.1B, E2.1C, E2.3c, E2.3d, E2.4A, E2.4B, E2.4c	E3.p1A, E3.p1B, E3.p1C, E3.4e,	E4.p1A, E4.p1C, E4.2B	E5.3C, E5.4A, E5.4D, E5.4e, E5.4f
6.9 Life occupies a wide range of Earth's environments, including extreme environments.				E5.4D, E5.4e, E5.4f

Table C.7: Supporting concepts for Big Idea 7 with the correlated codes for the Michigan High School Content Expectations [MDE, 2006].

Big Idea 7: Humans depend on Earth for resources				
Supporting Concepts	***Earth Systems HSCE***	***Solid Earth HSCE***	***Fluid Earth HSCE***	***Space and Time HSCE***
7.1 Earth is our home; its resources mold civilizations, drive human exploration, and inspire human endeavors that include art, literature, and science.	E2.1C, E2.2B, E2.4A, E2.4d	E3.p2A, E3.1B, E3.4C	E4.1A, E4.1B, E4.1C, E4.3C	
7.2 Geology affects the distribution and development of human populations.	E2.2B, E2.4A, E2.4d	E3.p2A	E4.1A, E4.1B	E5.4j

7.3 Natural resources are limited.	E2.2B, E2.4A, E2.4d	E3.p2A	E4.1A, E4.1B	
7.4 Resources are distributed unevenly around the planet.	E2.2B, E2.2e, E2.2f, E2.4A, E2.4c		E4.1A, E4.1B, E4.1C	
7.5 Water resources are essential for agriculture, manufacturing, energy production, and life.	E2.4A, E2.4d	E3.p2A	E4.1C	
7.6 Soil, rocks, and minerals provide essential metals and other materials for agriculture, manufacturing, and building.	E2.4A, E2.4c, E2.4d	E3.p2A	E4.1C	E5.4C, E5.4j
7.7 Earth scientists and engineers develop new technologies to extract resources while reducing the pollution, waste, and ecosystem degradation caused by extraction.	E2.2B, E2.2e, E2.3A, E2.3d, E2.4A, E2.4c, E2.4d		E4.1C	E5.4C, E5.4j
7.8 Oil and natural gas are unique resources that are central to modern life in many different ways.				E5.4C, E5.4j
7.9 Fossil fuels and uranium currently provide most of our energy resources		E3.p2A	E4.1A, E4.1B, E4.1C	E5.4C, E5.4j
7.10 Earth scientists help society move toward greater sustainability.				

Table C.8: Supporting concepts for Big Idea 8 with the correlated codes for the Michigan High School Content Expectations [MDE, 2006].

Big Idea 8: Natural hazards pose risks to humans.				
Supporting Concepts	***Earth Systems HSCE***	***Solid Earth HSCE***	***Fluid Earth HSCE***	***Space and Time HSCE***
8.1 Natural hazards result from natural Earth processes.	E2.1B, E2.1C	E3.p3B, E3.p3C, E3.4C, E3.4d, E3.4e	E4.p1C, E4.2B, E4.3A, E4.3B, E4.3C	E5.4A, E5.4B,E5.4D, E5.4i
8.2 Natural hazards shape the history of human societies.				
8.3 Human activities can contribute to the frequency and intensity of some natural hazards.				
8.4 Hazardous events can be sudden or gradual.	E2.1B, E2.1C	E3.p1C, E3.p3B, E3.p3C, E3.4B, E3.4C, E3.4d, E3.4e	E4.p1C, E4.2B, E4.3A, E4.3B, E4.3C	E5.2B, E5.4A, E5.4B , E5.4i
8.5 Natural hazards can be local or global in origin.	E2.1B, E2.1C	E3.p1C, E3.p3B, E3.p3C, E3.4C	E4.p1C, E4.2B, E4.3A, E4.3B, E4.3C	E5.2B, E5.4A, E5.4B,E5.4D, E5.4i
8.6 Earth scientists are continually improving estimates of when and where natural hazards occur.		E3.p3C, E3.4B, E3.4C, E3.4d	E4.p1C, E4.2B, E4.3A, E4.3B, E4.3C	E5.2B, E5.4B,E5.4D, E5.4i
8.7 Humans cannot eliminate natural hazards, but can engage in activities that reduce their impacts.		E3.p3C, E3.4B, E3.4C, E3.4d	E4.p1C, E4.2B, E4.3A, E4.3B, E4.3C	E5.2B, E5.4A, E5.4B,E5.4D, E5.4i
8.8 An Earth-science-literate public is essential for reducing risks from natural hazards.				

Table C.9: Supporting concepts for Big Idea 9 with the correlated codes for the Michigan High School Content Expectations [MDE, 2006].

Big Idea: Humans Significantly Alter the Earth				
Supporting Concepts	***Earth Systems HSCE***	***Solid Earth HSCE***	***Fluid Earth HSCE***	***Space and Time HSCE***
9.1 Human activities significantly change the rates of many of Earth's surface processes.	E2.3A, E2.3c, E2.3d, E2.4B, E2.4d	E3.p1A, E3.p1B, E3.p1C, E3.1B, E3.4C	E4.p1B, E4.p1C, E4.1B, E4.1C, E4.3C	E5.4C, E5.4D
9.2 Earth scientists use the geologic record to distinguish between natural and human influences on Earth's systems.	E2.3d, E2.4B, E2.4c	E3.1B, E3.4C		E5.4A, E5.4C, E5.4D, E5.4j
9.3 Humans cause global climate change through fossil fuel combustion, land-use changes, agricultural practices, and industrial processes.	E2.2B, E2.2e, E2.3A, E2.3b, E2.3c, E2.3d, E2.4B, E2.4c, E2.4d		E4.p1B	E5.4A, E5.4C, E5.4D, E5.4j
9.4 Humans affect the quality, availability, and distribution of Earth's water through the modification of streams, lakes, and groundwater.	E2.4B, E2.4d		E4.p1B, E4.p1C, E4.1A, E4.1B, E4.1C, E4.3C	E5.4D
9.5 Human activities alter the natural land surface.	E2.4B, E2.4d	E3.p1A, E3.p1B, E3.p1C, E3.1B, E3.4C	E4.p1C	
9.6 Human activities accelerate land erosion.	E2.4B, E2.4d	E3.p1A, E3.p1B, E3.p1C, E3.1B, E3.4C	E4.p1C	

9.7 Human activities significantly alter the biosphere.	E2.4B, E2.4d		E4.p1C	E5.4D
9.8 Earth scientists document and seek to understand the impacts of humans on global change over short and long time spans.	E2.4B, E2.4c, E2.4d	E3.1B, E3.4C	E4.1A, E4.1C	E5.4A, E5.4C, E5.4D, E5.4j
9.9 An Earth-science-literate public, informed by current and accurate scientific understanding of Earth, is critical to the promotion of good stewardship, sound policy, and international cooperation.	E2.4B, E2.4c, E2.4d		E4.p1C, E4.1A, E4.1C	