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THE IMPACT OF A STUDENT-TEACHER-SCIENTIST PARTNERSHIP (STSP)
ON STUDENTS' AND TEACHERS' CONTENT KNOWLEDGE
AND ATTITUDES TOWARD SCIENCE

BY

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DISSERTATION

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Abstract

Engaging elementary students in science through inquiry-based methodologies is at the center of science education reform efforts (AAAS, 1989, NRC 1996, 2000). Through scientific problem solving, students can learn that science is more than just learning facts and concepts (NRC, 2000) The process of scientific inquiry, as a way of approaching scientific problem solving, can be taught to students through experiential, authentic (or real-world) science experiences. Student-teacher-scientist partnerships (STSPs) are one vehicle used to connect students to these science experiences with practicing research scientists. However, the literature on STSPs demonstrates they are fraught with challenges and very little is known of their effects on teachers' and students' content knowledge growth or changes in their attitudes about science and scientists. This study addressed these two areas by researching a particular STSP. The STSP, called Students, Teachers, and Rangers and Research Scientists (STaRRS), designed to be incorporated into the existing long-standing education program Expedition: Yellowstone! (E:Y!) was the focus of this study. For teachers, a pre-test, intervention, post-test research design addressing content knowledge gains, attitude changes, and pedagogical changes was used. A quasi-experimental pre- post-test design using treatment and comparison groups of students addressed content knowledge gains and attitude changes. Findings provided evidence of significant positive shifts in teachers' attitudes regarding science and scientists, and trends of shifting pedagogical choices made by teachers. Students showed significant content knowledge gains and an increased positive attitude regarding their perceptions of scientists.

to Greg, Elena, and Lucas.

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Chapter One

The Problem: Student-Teacher-Scientist Partnerships as Authentic Science Experiences for Teachers and Their Students

Introduction

Many of the science reform efforts have identified inquiry-based learning experiences as an important way of connecting students to science (American Association for the Advancement of Science (AAAS), 1989, 1993). However, scientific inquiry without a clear definition can cause confusion. The National Research Council (NRC) (1996) defines scientific inquiry in two ways in the *National Science Education Standards* (NSES). It is first framed as a process used by scientists, as the “diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work” (p. 23). Second, the NSES defined five essential features of inquiry-based learning as a methodology used to help frame science education. The learner: (a) engages in scientifically-oriented questions; (b) gives priority to evidence in responding to questions; (c) formulates explanations from evidence; (d) connects explanations to scientific knowledge; and (e) communicates and justifies explanations (NRC, 2000).

Even within this well-established definition, the NRC (2000) is careful to point out that the standards are not a curriculum or a strategy. Rather, there are multiple ways to provide inquiry experiences for students. One way of bridging the process of scientific inquiry with inquiry-based learning is through experiential learning. The roots of experiential learning go back to Dewey (1938) and Schwab (1960, 1962). They felt that it

was important to create science education experiences that resemble scientific practice. In this way students became immersed in the practice of science beyond learning content alone.

More recently, these experiences have been referred to as *authentic science experiences* as they are created to provide students with problems to which there are no pre-determined solutions in contexts where the problems occur naturally (McKay & McGrath 2006; McKay et al., 2007). These experiences offer students involvement in active learning situations where they will acquire scientific knowledge in context. It is believed they will be more meaningful for students.

Student-Teacher-Scientist Partnerships. One strategy that employs authentic, inquiry-based experiential learning, which also seems to be intuitively appealing, is the Student-Scientist Partnership SSPs¹ or Student-Teacher-Scientist-Partnership (STSP). STSPs are partnerships in which students, teachers, and scientists work together to answer real-world questions about a phenomenon or problem the scientist is studying. These partnerships are built and maintained between research scientists and classroom teachers and their students. They are based on scientific research that is enhanced by Kindergarten through 12th grade (K-12) student participation (Tinker, 1997).

¹Student-Scientist Partnerships (SSPs) are actually misnamed. The name alludes to a partnership between K-12 students and research scientists while leaving out the key third party; the teachers. A few studies have addressed this by referring to them as Student-Teacher-Scientist Partnerships (STSPs) (Ledley et al., 2003; Wurstner et al., 2005; Wormstead, Becker, & Congalton, 2002), but most refer to them as SSPs. For the purposes of this discussion, I will use the STSP acronym to fully include all partners.

These partnerships are believed to provide teachers and their students access to the scientific community and ways in which research science is carried out. One would expect the outcomes for scientists and students should be positive and easy to identify. However, although STSPs appear to contain all elements necessary for interactive, authentic experiences for students, they have had a history fraught with challenges. Developing and sustaining partnerships is difficult.

Also, there is a limited amount of literature that may belie the number and types of STSPs currently in existence. Approximately a dozen studies regarding aspects of these partnerships have been published in the past 10 years. Two journals devoted space in issues highlighting STSPs: the entire *Journal of Geoscience Education*, (Harnik & Ross, (eds.) 2003c); and a special section in *Cell Biology Education* (Points of View, 2005). In spite of the lack of research literature, popular news articles about specific partnerships are found in local and national media sources fairly frequently. National Lab Day (2010), a new nationwide initiative with a proposed launch date for May 2010, is one example. This privately supported initiative is designed to “...bring discovery-based science experiences to students in grades K-12” through the building of STSPs (www.nationallabday.org/about, para. 2). The interactive map on the beta website (www.nationallabday.org/projects_map) boasts 986 current projects in the United States.

Some issues cited in the literature highlighting problems with STSPs include cultural differences between the sciences and education (e.g., Carr, 2002), lack of background knowledge for both scientists and educators in opposing fields (e.g., Caton, Brewer, & Brown, 2000), limitations imposed by national, district and school mandates, and other outside factors such as time and monetary constraints.

The existing literature focuses mainly on essential characteristics necessary to ensure success in the partnership. However, success is not well-defined. Two areas that have received careful attention are data collection and accuracy (Harnik & Ross, 2003a, 2003b; Ross et al., 2003) and differences in goals and approach of research and school science (Carr, 2002; Caton et al., 2000). It is logical that these areas have received critical attention. Needs of students and scientists differ and this reality challenges the accuracy of data collected. The end goal of these partnerships remains: data that is useable for both scientists and students.

Given the fact that STSPs are not well-researched, little can be said regarding actual outcomes and value of these projects. By their nature, they are time and resource intensive. Do these experiences actually affect teachers and students in ways we expect they should?

Statement of the Problem

Existing literature on STSPs focuses on identifying essential or necessary characteristics for successful implementation of STSPs and the challenges that need to be addressed in current STSPs. However, there is limited research showing direct impacts on teacher and student learning and none on the effectiveness of models used in STSPs. Since the only studies that have addressed outcomes are focused on data collection, there is a gap in the literature. This creates a need to research STSPs which have attempted to address the identified challenges and to identify and communicate the results of these attempts.

Research is limited on whether partnerships are an effective way of changing attitudes or increasing content knowledge. In a study of four participants, Gilmer (1997) found that participation in teacher-scientist partnerships did increase the teachers' content knowledge, and the content and processes they taught in their classrooms. Thus, though the teachers were the participants, in the end their students were also recipients. However, this study did not include pre- and post-assessments on students. Also, the noted changes were based on observations and self-reporting by teachers through logs, meetings with the researcher and a final report. Since the teachers' perceptions were mainly self-reported and anecdotal in nature, they cannot be generalized to other partnerships. Other descriptive studies included discussions of changes in student attitudes and achievement as related and linked to participation in STSPs. Based on comments from teachers, scientists, and students, these studies seem to indicate that changes may be occurring. However, there have been no empirical studies published looking directly at these changes using data collected on participating students. Finally, there is a lack of theoretical work published on STSP's, with the notable exception of work by Rahm, Miller, Hartley, and Moore (2003). They defined the emergent notion of authenticity in science within the context of these partnerships.

Purpose

This study aims to assess the impact of a particular STSP on teachers and on their students' content knowledge and attitudes toward science. Some of the effects of the accompanying professional development on the pedagogical strategies of the teachers are also explored. This STSP was developed with the intention of addressing some of the challenges cited in the literature including: (a) dealing with data accuracy issues; (b) providing open and frequent communication; (c) making resources accessible and available to the teachers; (d) attending to the needs of all participants (e.g., teachers' content knowledge) and (e) addressing cultural differences through the use of a third-party liaison (Carr, 2002; Caton et al., 2000; Doubler, 1996; Harnik & Ross, 2003b; Lawless & Rock 1998; Ledley, Haddad, Lockwood, & Brooks 2004; Moreno, 2005; Tinker, 1997). In addition, the focus of student participation included data collection for the research scientists and investigating scientific phenomena using student-developed questions.

This partnership, called Students, Teachers, and Rangers & Research Scientists: Investigating Earth Systems at Mammoth (STaRRS), is an embedded STSP. Embedded means that the components of the STSP were designed to be integrated into an existing educational program: Expedition: Yellowstone! (E:Y!). E:Y! is a residential environmental education program located in Yellowstone National Park (YNP). This long-standing curriculum-based educational program provides four and five-day residential experiences to fourth through eighth grade teachers and students.

Research Questions

To explore the possible impact of the STaRRS STSP on STaRRS teachers and students, the current study posed the following research questions. These questions were developed to help understand the possible impact of the STSP on content knowledge, attitude about science and scientists, and the pedagogical strategies of the STaRRS teachers.

1. What is the impact of participation in the STaRRS partnership on teachers' science content knowledge, attitudes toward science and scientists, and pedagogical strategies?
2. What is the impact of participation in the STaRRS partnership on students' science content knowledge and attitudes toward science and scientists?

Chapter Two

Review of the Literature

Introduction

The ability to involve more middle level students (grades four through eight) in science is dependent on their attitudes about science and their personal engagement in science. Inquiry-based methodology has been lauded as a means to that end (AAAS, 1993; NRC, 1996), using “authentic science experiences” one of the stated strategies. However, the term *inquiry* is used by scientists and educators in different ways, making the definitions ambiguous. Neither *authentic* nor an *authentic science experience* have common well-understood definitions. On the surface, authentic science experiences appear to be related closely to experiential learning as defined by scholars such as Piaget and Dewey. However, clear definitions of what this means are needed. The first section of this chapter will focus on clarification of these definitions.

Even after inquiry and authentic science experience concepts are defined, there are many strategies that could be employed to assist teachers and increase student involvement in these types of experiences. STSPs have been put forward as one strategy to engage students in authentic science experiences. Their relatively short history has been fraught with challenges; as of yet their apparent benefits have not been fully explored empirically. This second section will describe the different types of partnerships and their perceived benefits and challenges. Next it will frame the discussion decisions made in the development of the STSP in this study. This section will also explore some of the complexities of these partnerships through a critical look at the literature.

The third section explores the professional development aspect of this partnership, which by the definitions put forth is authentic and experiential, and expected to have an impact on the teachers. That professional development influences teaching is well-established in the literature. This section will discuss two aspects of professional development: (a) the order of occurrence of changes in practice and strategies and beliefs, and (b) the philosophical stance by which decisions were made for this partnership.

Missing in the literature is evidence of gains of content knowledge and changes in teachers and students who participate in partnerships. Although this study was not designed to elicit attitude change about science through the use of specific strategies, the impact of STSP participation on teachers' and students' attitudes will be measured. The fourth section will explore a definition of attitude toward science. The final section will address the progression of the development of this particular STSP and how addressing solutions may lead to changes in teachers and their students.

Inquiry

Inquiry, like many terms used in education, is multi-faceted. DeBoer (1991) noted confusion regarding the term, which he observed was often used in two very different ways. Scientific inquiry is used to describe a specific type of scientific work. It is a process of doing science that facilitates ways of thinking about and understanding how scientific knowledge is generated. Inquiry has also been used extensively to describe a particular teaching methodology. Methodological inquiry is a way of presenting material to students that requires them to be active, thinking, and engaged participants. In this way, inquiry in science education is not just about learning the process of doing science,

but also may be used as a way of introducing scientific concepts. Additionally, inquiry as a methodology may not be well understood by educational practitioners, who may simply equate it with doing hands-on or active activities with students which may or may not be inquiry-based.

Experiential Learning

The roots of experiential learning can be traced back to Dewey's (1943) progressive education with its emphasis on learning through experience. Rogers (1959) further posited that experiential education is meaningful when there is (a) personal involvement; (b) self-initiation; and (c) freedom to learn. Later, Maslow (1968) added a focus on a learner-centered process which he felt led to self-actualization.

Kolb (1984) defined experiential learning as "knowledge that results from the combination of grasping and transforming experience" (p. 41). He developed a cyclical model to illustrate his definition of experiential learning. This model can be entered by the learner at any point and contains the following four elements: (a) concrete experiences, (b) observation and reflection, (c) formation of abstract concepts, and (d) application of knowledge in new situations/contexts. Many of Kolb's components align well with current definitions of inquiry-based methodology and provide a foundation for the definition of authentic science experiences explored in the next section.

In their study of the effectiveness of three different experiential educational experiences for fifth grade students, Powell and Wells (2002), found experiential activities, specifically adapted to meet Kolb's (1984) four-step model of learning to be effective in promoting content knowledge. Their results demonstrated an overall

significant effect on students' knowledge gains, regardless of treatment. These gains have the added benefit of helping to meet state education standards.

Determining Authenticity

In much of the current education literature, the word *authentic* is frequently used to describe activities and contexts students engage in that mirror activities conducted by practitioners outside of the classroom (e.g., Wormstead, Becker, & Congalton, 2002; Harnik & Ross, 2003c). *Authentic* is also used to describe community-based activities. These are defined as learning experiences that happen outside the classroom (e.g., Donahue, Lewis, Price, & Schmidt, 1998). These activities can be found in many subject areas or combinations of disciplines. For example, an *authentic experience* combining language arts and social studies might include drafting a persuasive letter about a key political issue to the editor of the local newspaper, with the intention of publication. However, there are many other times when the term authentic is used without a specific definition. This causes a variation in how authentic experiences are interpreted by researchers and practitioners alike. When authentic is used in reference to K-12 student science experiences, definitions of what authenticity entails differ as well. These definitions range from modeling what scientists do (NRC, 1996), to addressing contextual needs of students and their communities (Eisenhart, 2001), to focusing on student-designed investigations that produce artifacts representing student learning (Marx, Blumenfeld, Krajcik, & Soloway, 1997).

In their work with real-time Internet data at the community college level, McKay and McGrath (2006), and McKay, Lowes, McGrath, Lin, & Leach (2007) defined

authentic problems as real-world problems with no predetermined solutions. They described them as dynamic, ill-structured, containing multiple, often conflicting goals, and requiring collaboration to solve. Authentic problems “force students to actively participate in the learning process in order to construct meaningful knowledge” (McKay et al. 2007, p. 11). To solve authentic problems, students must use critical thinking skills, collaboration, and creativity. These types of open-ended learning experiences are difficult to implement and assess.

Furthermore, authentic science for STSPs was defined by Barstow (1996) as “...real science (that) must contribute [to the development of] new knowledge. Thus, research must be central to the scientists' work and the student participation must contribute in a meaningful way to this research” (p. 15).

Because of definitions like Barstow's, sometimes there is an assumption that students involved in authentic experiences should be performing tasks in a manner which is exactly the same as scientists. However, as Lee and Songer (2003) note, distinctions between professional scientific inquiry and student scientific inquiry must be made. Pre-college students are not in the position to do professional scientific inquiry due to their age and training. In college-level science, skills learned, course work taken, and activities conducted are done primarily with the purpose of solving real-world problems. This is not the main goal of K-12 science education. Instead there is a presumption that the skills taught to students will be authentic in the way that A. Brown (1993) defines them; as the skills that will help students beyond the classroom regardless of whether the tasks are ones that resemble experiences outside of the classroom.

Brown, Collins, and Duguid (1989) felt that students need to wrestle with *emergent problems* that contain *authentic activity*. They also note that often activities conducted by students are not the same types that would be conducted by actual practitioners. In addition, they would not be endorsed by the cultures the practitioners belong to. However, *hybrid activities* is a term they used to frame experiential authentic science learning experiences. These are activities framed by one culture but attributed to another. Examples might include scientific investigations in which the practitioner would have a good idea of the outcome, but the student might not. This would make it an authentic activity for a student, but not a practitioner. The students would use the same or similar tools to investigate the phenomenon and learn the processes of scientific investigation.

Although *Benchmarks for Scientific Literacy* (AAAS, 1993) and *NSES* (NRC, 1996) do not specifically define authentic science experiences, their descriptions of what scientists do within the definition of scientific inquiry serve well to help frame the definition of these experiences in this project. They define inquiry experiences as complex, flexible, inclusive of imagination and inventiveness, and that go beyond simplistic observation and investigation (NRC, 1996). Windschitl (2004), although he does not specifically define the term authentic, speaks of inquiry activities as “practice within scientific communities” (p. 483). In other words, students are engaged in doing the work that scientists do.

Windschitl (2004) also argues that the scientific method, portrayed by textbooks and many science teachers, is a misrepresentation of scientific inquiry, which “obscures the complex methodological strategies... and involved logic... of authentic science” (p.

483). In this way he frames inquiry activities to include paying attention to how methodological issues of inquiry-based instruction are constructed and presented, thus connecting the two areas of inquiry.

I join Windschitl (2004), McKay and McGrath (2006), and NSES (NRC, 1996), in believing that direct experiences investigating scientific phenomenon are needed for students to begin to understand the complexity of scientific work. However, not all inquiry or authentic science experiences are created equal. The developmental capability of any given group of students must be taken into account when an authentic science experience is identified or designed. Students do not have the cognitive background or the life-experience to be full participants in the process of scientific inquiry of practicing scientists. Therefore, authentic science experiences need to take into account their needs. Some science experiences labeled *authentic* are not going to include all components necessary to make them precisely match experiences of practicing research scientists. Instead they may resemble Brown, Collins, and Duguid's (1989) hybrid activities described earlier.

Definition of Authentic Science Experiences for STaRRS

Based on the above discussion, the definition of authentic science experiences used in this project is closely aligned to scientific inquiry definitions put forth by NSES (NRC, 1996) and AAAS (1993). The definition takes into account the developmental and cognitive needs of middle level students; hence, this definition is somewhat flexible.

Authentic science experiences allow students to:

1. Participate in processes that parallel activities considered to be crucial for doing research science (western canonical). Examples include, but are not limited to: development of answerable questions, accurate and careful data collection, analyses, and communication of results.
2. Work to solve problems or answer questions that go beyond their classroom community.
3. Be directly involved in the scientific inquiry process.
4. Engage an audience beyond their classmates and teacher for their products.

In summary, authentic science experiences are those that are provided for students grounded in the tools, techniques, attitudes and skills of science. They invite students to explore questions of their own interest and include communicating these processes and results to audiences beyond their classrooms.

Student-Teacher-Scientist Partnerships

Defining STSPs. STSPs are partnerships in which students, teachers, and scientists work together to answer real-world questions about a phenomenon or problem the scientist is studying. Usually, these partnerships are built and maintained between university scientists and K-12 public and private school teachers and students. If data collection requires specific, sophisticated equipment, they are sometimes funded by the research scientist's granting organization. Partnerships can be vehicles used to fulfill an "educational component" required by such grants (e.g., The National Science Foundation).

Types of Participation. In an STSP, the participating students' primary involvement can take place in four types of settings: (a) in their classroom; (b) within the

school or on the school grounds; (c) off site; and (d) virtually, such as through a computer website based experience. In addition, some partnerships combine two or more of the above settings.

The first type, one in which the experiences take place within the classroom, usually uses outside materials delivered to teachers and students. An example of this is a collections-based project such as the Mastodon Matrix Project (Ross et al., 2003). In this STSP, bags of fossils, dirt, and debris were requested by teachers and sent to classrooms where they were sorted, identified, and catalogued by students.

A second type takes place in the school setting though the activities for data collection may take place outside the classroom. For example, Project FeederWatch (Bonney & Dhondt, 1997) is one such partnership that monitors local bird populations. Another example is a small component of the huge partnership called Global student Observations to Benefit the Environment (GLOBE) (Rock, Blackwell, Miller, & Hardison, 1996). GLOBE engages students in monitoring atmospheric data at their school's location through the use of a weather station located nearby or on the school grounds. GLOBE offers a multitude of other such activities in its partnership program.

A third type of STSP requires student travel to other locations. An example of this is the environmental water monitoring project Delaware Stream Watch (Delaware Nature Society, 2005). School groups choose a stream located near their school and visit the stream on a regular basis. Students make observations, take measurements, and report findings to the Stream Watch coordinator.

Finally, there are on-line projects where students use remote sensing equipment and/or databases to participate, such as Mars Exploration, (Barstow & Diarra, 1997). This

category also includes partnerships sponsored by museums such as the Challenger Learning Centre, in which students participate in computer simulations in special laboratories at science museums (Jarvis & Pell, 2002).

More recently, other partnerships employ a combination of the types of partnerships mentioned above. An example is GLOBE's Land Cover Survey, which requires both fieldwork identifying nearby land cover, remote sensing using LandSat imagery, and a large database at the website maintained for GLOBE participants (www.globe.gov). The website that students and teachers use for data entry includes electronic tools that assist participants in recording and manipulating collected and archived data. In partnerships employing more than one strategy or location, students are often involved in some or all of the following activities: learning about the phenomena; collecting and reporting data; analyzing data and reporting findings; and asking their own questions and using their data to answer them. These four activities are listed in order from the most to those least frequently employed.

STSPs - Benefits and Challenges

A discussion of STSPs requires highlighting identified benefits and challenges associated with the success of these partnerships. The first part of this section is dedicated to illuminating some of the benefits and challenges. Challenges reviewed will include cultural differences between practices of K-12 educators and those of partnering research scientists. Collaborative dimensions identified in recent literature provide a partial foundation to understand some of these challenges.

Benefits. Stated benefits of STSPs fall into two categories: (a) benefits for education (participating teachers and their students) and (b) benefits for scientists (the research group or particular scientists wanting specific data). Perceived benefits for education include providing authentic experiences (Donahue et al., 1998; Harnik & Ross 2003b; Moss, Abrams, & Kull, 1998; Tinker 1997), which in turn give students increased understanding of the scientific research process (Evans, Abrams, Rock, & Spencer, 2001; Finarelli 1998; Harnik & Ross 2003b; Ross et al., 2003; Wurstner, Herr, Andrews, & Alley, 2005). In addition, STSPs have been described as vehicles for changing students' attitudes toward and interest in science (Caton et al., 2000; Comeaux & Huber, 2001; Ross et al., 2003; Wormstead et al., 2002; Wurstner et al., 2005). Other studies have found that in particular partnerships there was a perceived increase in students' understanding of specific content. This was considered to be an important feature even though no empirical data were collected (Finarelli, 1998; Gilmer, 1997). Benefits for teachers, including gains in content knowledge and an increase in the use of inquiry-based instructional strategies, have been noted as well (Caton et al., 2000; Comeaux & Huber 2001; Evans et al., 2001; Ross et al. 2003; Wormstead et al., 2002).

For scientists, the benefits of STSPs are twofold. Many studies found that STSPs give scientists the ability to collect data that would be difficult or impossible to acquire without extra help (Lawless & Rock, 1998; Wormstead et al., 2002; Ross et al., 2003, Tinker, 1997; Wurstner et al., 2005). Secondly, partnerships provide a vehicle to engage with K-12 education in a way that brings more effective teaching strategies to college level instructors through the scientists' personal engagement with K-12 educators (Caton et al., 2000; Donahue et al., 1998). Although the strategies are mentioned in the literature,

at this point no studies have been conducted to assess changes in college level instructors' teaching strategies.

Challenges. Challenges for STSPs often mirror the benefits. For example, the need for extensive, wide-ranging data collection challenges data accuracy. The use of student data and data quality has been the focus of much of the literature on STSPs (Dolen & Tanner, 2005; Evans et al., 2001; Harnik & Ross, 2003a; Lawless & Rock 1998; Ross et al., 2003; Tanner, Chatman & Allen, 2003). Other general challenges for STSPs have been identified by a small body of literature. They include cultural similarities and differences (Barstow, 1996; Carr, 2002, Moreno, 2005, and Tinker, 1997) and identification of good questions, projects, or studies for partnerships (Doubler, 1996: and Tinker, 1997).

Carr (2002) and others, including Barstow (1996), Caton et al. (2000), Haddad, Lockwood, and Brooks (2003), Moreno (2005), and Tomanak (2005) identified many cultural challenges facing STSPs, which at times are invisible to each set of participants. There are basic differences in the knowledge base and disparities in the ways conflict is viewed and dealt with. These and other differences can create misunderstanding between the partnering university research science and education cultures. Table 1 is a synopsis of the major cultural differences.

Table 1

A Synopsis of Major Cultural Differences Between University Research Science and K-12 Education

Differences	University Science	K-12 Education
Educational context	Teacher-centered; lecture-based; competitive; valuing objective measures of assessment	Student-centered; discussion-based; cooperative; valuing multiple subjective methods of assessment
Conflict is dealt with	Head-on	Avoided
Orientation	Product-oriented	Process-oriented
Communication	Not tied to a school schedule, may not provide feedback as immediately as needed	Time constraints are tied to length of school year, day, and class periods. Immediate feedback is considered essential
Knowledge base	Specific to one area that may have been studied for years	Broad and multi-disciplinary; content knowledge is only part of the knowledge base
Access to resources	Resources are available through the university system; extra resources and materials are obtained through grants, negotiation of contracts, etc.	Few resources spread very thin; often individual teachers subsidize purchase of needed materials
Timing of work/ Time limitations	Projects can be extensive –cycles measured in years rather than months; not tied to traditional September-May schedule	Projects range in length from 45 minutes to weeks, rarely lasting an entire school year or multiple years; tied to traditional school year; inhibited by interruptions and time constraints
Goals	Produce rigorous, high quality scientific research and increase knowledge base within a particular field	Provide authentic educational scientific research experiences for students; rigor in data collection is not a primary goal
Myths	Both groups subscribe to the same one: Science is hard; teaching is easy (conflicting epistemologies)	
Vocabulary	Same words often have different meanings (e.g., model, control, theory)	

Challenges beyond cultural differences fall loosely into five categories: (a) content knowledge background needs of teachers and scientists; (b) accuracy and relevance in student data collection; (c) resources for both scientists and teachers (materials, time, and personnel); (d) communication needs and barriers; and (e) outside factors affecting both the educational and research communities. One example on the university research science side is the lack of professional recognition in the research community for scientists who attempt to work in partnerships. Time spent working within partnerships is outside of the activities considered essential for obtaining tenure and being a professional in an individual's field (e.g., Williams, Pane, Tananis, & Olmsted, 2005; Townsend, Boca, & Owens, 2003). In many cases, existing literature tells us that if the above challenges inherent in STSPs are not addressed, they can impede the partnership (Evans et al., 2001; Ledley et al., 2003; Moreno, 2005; Tanner et al., 2003).

Many of the same studies identifying the challenges make recommendations for addressing them. These recommendations can be condensed into seven areas:

1. True partnerships need to be developed to address hierarchical issues and power imbalances between scientists and teachers.
2. Partnerships must include open and frequent communication among the partners.
3. Research questions being pursued by students need to be carefully selected so that they are appropriate for partnerships.
4. Data quality and use must be addressed.
5. Long-term relationships must be actively developed with attention to sustainability.
6. All participants' needs must be addressed, including those of the research scientists and the students.
7. A third-party liaison should be included in the partnership. This is a person who is familiar with both the education and scientific community and works in the

partnership as a facilitator. Through their familiarity of both cultures, their role is to assist relationships in the partnership by helping the scientists and educators understand each other's needs (Carr, 2002; Caton et al., 2000; Doubler, 1996; Harnik & Ross, 2003b; Lawless & Rock 1998; Ledley et al., 2004; Moreno, 2005; Tinker, 1997).

Collaboration. Recent work by Drayton and Falk (2006) identified five dimensions that affected collaboration efforts within teacher-scientist partnerships. Students were not included in their study of practicing K-12 teachers and research scientists. In this way their focus differs from the type of STSPs defined above. However, they provide a good framework for assessing partnerships that cross the cultural differences between the K-12 educators and research scientists. The dimensions they identified included: (a) Whose question was being investigated, the teachers' or scientists'? (b) What was the primary focus for the data – collection or analysis? (c) Whose expertise was the research based on – teachers' or scientists'? (d) Was the focus on teacher learning or student classroom learning? and (e) Who is the research for, that is, who is the audience?

In each of these dimensions, the partnership will fall along a continuum between the two partners. The perceptions of the partners may have profound implications in the success of the partnership. In addition, the fourth and fifth dimensions (d) and (e) could have direct implications for content knowledge acquisition by both teachers and students, and dimension three (c) could affect student and teacher attitudes about science and scientists. A facilitator may analyze and work within the dynamics of the collaborative dimensions of the partnership. That person's insights and ideas can increase the success of the STSP.

Other than the literature mentioned above, there are no empirical studies researching outcomes of STSPs on teachers or students. Gaps in the current research are broad; the bulk of studies have focused on identifying and caring for challenges. If STSPs are to be considered a strategy for reaching K-12 students and, more specifically, middle level students (grades four through eight) by increasing content knowledge and improving attitudes towards science, there needs to be new research showing that participants are making these gains. The research also must include the identification of components that may facilitate student growth and the theories that support those components.

Authenticity in STSPs

Authentic science for STSPs was defined as the generation of new scientific knowledge using the participation of K-12 students to make meaningful contributions that were central to scientists' work (Barstow, 1996). Moss et al. (1998) reiterated this definition of authentic science in STSPs adding that they support both science and education. However, they "(believed) that in order for students to be involved in the process of doing scientific research, they must first begin to develop an understanding of what that process entails" (p. 150).

Moss et al., (1998) found that limiting student involvement to specified protocols that simply went towards answering the scientists' question in the STSP also was "limiting the scope of the project for the students" (p. 159). They recommended that students also be allowed to explore questions they developed themselves. Connections of

student data to the research scientists in the partnership were considered to be less important than the participation in the process. They noted,

Whether scientists make use of data from student generated areas of inquiry is unimportant. What is important is that students will be both contributing to authentic research, by following provided protocols, and will be experiencing a broader range of what the research process entails by exploring their own questions (p. 159).

Most important, as Moss et al. (1998) note, is the excitement produced by the STSP. They wondered if it would have been increased with the addition of student-generated research. This study highlights the importance of students doing more than just collecting data for the scientists' research project, as this offers limited opportunities for them to be involved in the "process of doing scientific research" mentioned previously.

Based on recommendations of researchers such as Moss et al. (1998), three components were developed to make up the framework of the STaRRS STSP scientific fieldwork. These were the use of: (a) whole-group collection of photographic data at specific locations; (b) small group collection of descriptive data using specified protocols to study small parts of the hot springs system; and (c) small group investigation of student-generated research questions.

Professional Development

Often, in reform movements, high quality professional development is linked to improving education (NRC, 1996, among many). One assumption that follows this linkage is that teachers enter the professional development process in order to expand their knowledge and skills, become better teachers, and enhance student outcomes. The goals of professional development are to change attitudes, beliefs, and teacher practice,

therefore initiating changes in student outcomes. The classic model of occurrence of changes in teacher practice and beliefs has been that teachers must first change their beliefs and attitudes and this will in turn alter their practice, which will lead to changes in student outcomes. Guskey (2002) proposed a new model for thinking about the order of occurrence for these events. He linked change in attitude and belief to evidence of student outcomes rather than the activity of professional development. In other words, the teachers believed the new practices or strategies worked only after they had evidence in the form of positive student outcomes. Guskey's model proposed that the role of professional development was not to change attitudes and beliefs, but to help facilitate change in teacher practice and support identification of changes in student outcomes. Observations of improved student outcomes would then lead to changes in teachers' beliefs and attitudes. One of the reasons professional development researchers concern themselves with the teachers' beliefs and attitudes is because they can be measured and are thought to be predictive in terms of behavior change.

Experienced-based change for teachers is not new. Often, when teachers find strategies that are helpful in changing student outcomes, these strategies will be retained and repeated. However, if they are not found to be helpful, no matter how strongly they are promoted from the outside, they are usually abandoned as soon as outside pressure is removed.

Guskey (2002) proposed three principles that he considers essential for planning professional development based on his model. The first principle states that there needs to be recognition that change is a gradual and difficult process for teachers. New learning takes time and the extra effort involved often requires a heavier workload for those who

engage in it. In addition, high anxiety can be felt by those engaging in new practices. This anxiety is sometimes increased due to exposure teachers put themselves through by risking failure. Their professional competency may be called into question if their students produce or learn less rather than more with the implemented changes.

The second principle focuses on the need for teachers to receive feedback on students' learning processes. Guskey (2002) stated that one way to accomplish this is to make sure the professional development includes ideas for formative assessment coupled with corrective activity suggestions built into it. This feedback, he feels, is critical to implementation and sustainability of the changes.

Finally, since according to this model, belief comes after student outcomes are realized, the third principle focuses on the need for continual follow-up and support. Both are seen as crucial to sustainability. For new practices or strategies to become sustainable, they must become a natural part of a teacher's repertoire. Continual professional development follow-up can provide opportunities to help lessen anxiety as teachers become more proficient with emerging skills. It could also help to provide continued support in identifying and measuring student changes (Guskey, 2002).

Science Education Professional Development

It is widely believed that on-going professional development for science teachers is critical in changing how science is taught in classrooms. A shift within professional development models from the didactic transmission of skills and knowledge through lecture toward inquiry-based methodologies is well-documented and generally accepted within the science education community. Part of this shift reflects movement from the

view of teachers as “targets” of professional development to one in which they are intellectual consumers, and valued collaborations. In this view, they are active participants in the process of their development. In short, we are moving from a deficit model to a participatory additive model, as recommended by NSES (NRC, 1996).

Professional development, states NSES,

Must include experiences that engage prospective and practicing teachers in active learning that builds their knowledge, understanding, and ability. The vision of science and how it is learned ... will be nearly impossible to convey to students in schools if the teachers themselves have never experienced it. Simply put, pre-service programs and professional development activities for practicing teachers must model good science teaching (NRC, p. 56).

At the same time, their professional development must be appropriately connected within the context of the schools where it will be used. For this to happen, NSES recommends that professional development for science include experiences that: (a) actively involve teachers in studying scientific phenomena; (b) address significant issues, events and topics in science; (c) expand teachers’ ability to access further knowledge; (d) build on current ability understanding and attitude; (e) incorporate reflection; and (f) encourage collaboration (NRC 1996).

One difficulty noted in the literature is a problem with fidelity in using inquiry-based methodology by facilitators within the professional development model. Lack of fidelity may be the result of epistemological and philosophical differences between scientists and educators. This issue aligns directly with the cultural differences noted earlier between STSP partners, namely the scientists and the educators. The proposed recommendations for dealing with them are also similar. The following review of a research study illustrates this issue.

Although science education standards specifically call for a move away from didactic methods towards inquiry, they also acknowledge that the state of professional development for science teachers does not necessarily match that call. In a recent study at a number of NASA summer workshops, Schuster and Carlsen (2008) used multiple methods to evaluate teacher development. They compared the intent of science education professional development with data and supported claims of what actually occurred. Scientists, the workshop leaders in this case, seemed to understand the need for more experiential-syntactic activities within the scheduled workshops. In fact, pre-workshop brochures highlighted experiential approaches and, in all cases, the extra time necessary was allocated to include these types of activities.

Observations and other types of data showed that the workshop leaders did exactly the opposite of what pre-workshop brochures advertised. The sessions were content-dense, requiring only passivity on the part of the participants. In some cases the “inquiry activities” were merely confirmation labs, used to reinforce content already presented. The main reason provided to the authors by the workshop leaders to explain this disconnect was “time limitations”. Other workshop leaders were candid in expressing their feelings that teachers would not be up to the task (of doing experiential activities) without the content knowledge that only they could provide. There was an assumption (both implicit and explicit), that the teachers were not capable of doing science based on the leaders’ perception of teacher’s lack of ability, background, and/or willingness to follow through (Schuster & Carlsen, 2008).

I would argue that their perceptions were due to three factors: (a) the scientists’ personal past experiences presenting at workshops (e.g., we teach how we have been

taught); (b) the scientists' lack of understanding regarding how learning occurs. This lack of understanding includes both their own learning and that of their students; (c) the possibility that philosophical differences are creating epistemological barriers. For example, if you are a positivist, it will be nearly impossible for you to think about presenting your material using a post-positivist influenced methodology.

Attitudes

The body of literature defining attitude and attitude change is large and somewhat unwieldy. This reflects the fact theories are drawn from many disciplines: psychology, sociology, education and the natural sciences – to name only a few. Also relevant is the struggle throughout most of the last four decades to refine this field (e.g., Klopfer 1971; Gardner, 1983; Ormerod and Duckworth 1975; Bandura, 1977). Often these theories are very complex as may be required by the complexity of the construct (e.g., Fishbein & Ajzen, 1975). Although my study is not focused on theories about changing attitudes, I will devote this final section to defining attitude as it relates to my research.

Definitions of attitude can cover a range of elements, such as those characterized by Shaw and Wright (1968); usually encompassing positive or negative responses, derived from concepts or understandings that people have of people, places, things, or ideas; causing them to behave in certain ways toward these understandings

In attitude research, attitude is often described as having three dimensions; affective (also referred to as emotional); cognitive; and behavioral (sometimes referred to as psycho-motor) (Simpson, Koballa, Oliver, & Crawley, 1994). Further, attitudes toward science have been referred to as positive and/or negative feelings regarding different

aspects of the scientific process, procedures, physical environment, people involved, and interests outside of school science (Koball & Crawley, 1985; Simpson & Troost, 1982).

Osborne, Simon, and Collins (2003) conducted an extensive review of the literature on attitudes in science. They noted significant challenges inherent to attitude research. The first challenge was that "...such attitudes do not consist of a single unitary construct, but rather consist of a large number of sub-constructs all of which contribute in varying proportions towards an individual's attitudes towards science" (page1054). They listed eleven sub-constructs identified by multiple studies ranging from self-esteem, to parents' perceptions of science, to enjoyment of science. Since there is no single construct, the construct used for attitude need to be isolated and defined independently in each study.

A second challenge Osborne et al. (2003) noted was the difficulty in matching preferences and feelings towards science with expressed behaviors relating to those preferences and feelings. In spite of a fairly large body of science education literature researching attitude changes, there are no straightforward generalizations that can be made about the changes in attitude resulting in changes in behavior. There is also a shortage of generalizations regarding attitudes change.

In all attitude research, the selection of the measure used to assess the construct helps to define attitude. In this study, the Test of Science Related Attitudes, (ToSRA) (Fraser, 1978) provided the framework for the definition of attitudes. The ToSRA development was based on Klopfer's (1971) work defining attitudes towards science. He defined a set of desirable affective behaviors in science education as: (a) the manifestation of favorable attitudes towards science and scientists; (b) the acceptance of

scientific inquiry as a way of thought; (c) the adoption of ‘scientific attitudes’; (d) the enjoyment of science learning experiences; (e) the development of interests in science and science-related activities; and (f) the development of an interest in pursuing a career in science-related work.

The six ToSRA scales used in this research define the measure of attitudes about science and scientists. They were: (1) Social Implications of Science; (2) Normality of Scientists; (c) Attitude to Inquiry; (d) Adoption of Scientific Attitude; (e) Enjoyment of Science Classes; and (d) Leisure Interest in Science. A closer look at the statements used in each of these scales reveals that they covered all three dimensions of the classic definition mentioned previously.

For example, the affective dimension of attitude was measured by the Enjoyment of Science scale, which presented phrases such as “I do NOT like science activities.” The Leisure Interest in Science scale was one of the scales that measured the behavioral dimension with phrases such as “I would enjoy visiting a science museum on the weekend.” The cognitive dimension was only found in one scale, Adoption of Scientific Attitudes. An example phrase from this scale is: “I enjoy reading about things that disagree with my previous ideas.” Each of the scales, their construct, attitude dimension, and example phrases, can be found in Table 2.

Table 2

ToSRA and the Dimensions of Attitude to Science and Scientists

ToSRA Scale	Construct	Attitude Dimension	Example Phrase
Social Implications of Science	Role of science in society	Affective	Science helps to make life better.
Normality of Scientists	Scientists as “normal” people	Affective	Scientists like sports as much as other people do.
Attitude to Science Inquiry	Inquiry as a scientific way of thinking	Behavioral	I would prefer to do experiments than to read about them.
Adoption of Scientific Attitudes	Use of scientific attitudes to guide thinking	Cognitive	I enjoy reading about things that disagree with my previous ideas.
Enjoyment of Science Classes	Interest in science in school	Affective	I do NOT like science activities.
Leisure Interest in Science	Interest in science outside of school	Behavioral	I would enjoy visiting a science museum on the weekend.

Conclusion

Inquiry, defined as the process used by scientists to develop new knowledge, is the starting point for this project. This process is what we want students to learn through the means of inquiry-based methodology used by their teachers. Experiential learning is one of the strategies used to teach scientific inquiry through the use of authentic science experiences. The proposed strategy for directly involving students in the processes, skills, and attitudes of scientific inquiry in this research project is through STSPs. These partnerships, by their nature, are challenging to create and sustain. Student involvement within an STSP must be closely matched to meet both the needs of the students and the

scientists. The STSP also must be developed in a way that they will become sustainable. Additionally, the professional development accompanying the STSP must address the needs of the teachers in their ability to carry out their roles in the partnership as facilitators of their students' knowledge and participation. This needs to happen not only for content and process knowledge but also in the use of resources and the ability of the teachers to be able to appropriately integrate the activities of the partnership into the curriculum of their school and district.

Powell and Wells (2002) supported embedding a partnership within an existing experiential learning program. They found experiential learning to be effective in creating overall significant content knowledge gains in fifth grade students regardless of treatment. Thus, variation in the implementation of experiential learning situations among the various partnering teachers would not be considered a hindrance. In other words, the development of experiential authentic science experiences within an STSP can lead to a natural outgrowth of increasing content knowledge gains.

Science education professional development for teachers has its share of challenges. Designing professional development models that are effective and appropriate inquiry-based teaching strategies may help to facilitate changes in teachers' pedagogical strategies. Therefore, the professional development model used in this project followed the parallel recommendations for STSPs and science teacher professional development with the inclusion of a liaison in the development of both the partnership and accompanying professional development (Lawless & Rock, 1998; Schuster & Carlsen, 2008). The role of the liaison is to use his or her familiarity with both the science and

education cultures to bridge gaps between the cultures, expectations, and needs of the two groups.

Gaps in the current research regarding STSPs are broad, as the bulk of studies have focused on identifying and caring for challenges. Addressing some of the known challenges may help to ensure success of these partnerships. If STSPs are to be considered a viable strategy for reaching middle level students and increasing content knowledge and improving attitudes towards science, there needs to be research showing that gains are being made by participants. The research would also include identification of factors that may facilitate the growth of participants and the theories that support them. This study attempts to address some of the gaps, through development of an STSP that addresses some of the identified challenges: (a) focusing on different types of data collection for both the students and the scientists; (b) providing resources in the form of professional development and tools to help facilitate the data collection and content teaching aspects of the partnership; and (c) addressing communication and teacher support issues through the use of a liaison. Further, this study will provide evidence that shows growth and changes in teachers and students who participate in STSPs. These results will add to the depth of research in this field.

Chapter Three

Methodology

Introduction

This research investigated the impact of participation in the STaRRS partnership on a group of teachers and their students. Pre- and post-assessment data were collected from the STaRRS teachers in three areas: earth science content knowledge; attitudes about science and scientists; and pedagogical strategies used while teaching science. Pre- and post-assessment data in the areas of content knowledge and attitudes toward science and scientists were collected from STaRRS students and a group of comparison students who attended E:Y! but did not participate in the partnership.

Research Questions

1. What is the impact of participation in the STaRRS partnership on teachers' science content knowledge, attitudes toward science and scientists, and pedagogical strategies?
2. What is the impact of participation in the STaRRS partnership on students' science content knowledge and attitudes toward science and scientists?

A pre-test, intervention, post-test single group design was used to address the first research question. The intervention consisted of a week-long summer institute for participant teachers followed by on-going support throughout the school year. Hereafter, teachers participating in the partnership will be referred to as STaRRS teachers.

A different design was used to answer research question two. For this question, a pre-test, intervention, post-test comparison group quasi-experimental design was used. Treatment students were students of the STaRRS teachers. These students experienced the STaRRS partnership in their classrooms and embedded in their E:Y! experience. The

comparison group was composed of students engaged in a typical E:Y! expedition during the same school year as the STaRRS intervention. Hereafter, all treatment students will be referred to as STaRRS students, and comparison group students will be referred to as E:Y! students. Pre- and Post-expedition data were collected from both the E:Y! and STaRRS students. This consisted of two assessments. The first assessment focused on specific earth science content knowledge including some questions specifically related to the E:Y! experience and the partnership. The second assessment focused on students' attitudes regarding science and scientists.

Context

The Residential Environmental Education Program – Expedition:

Yellowstone! (E:Y!). Established in 1985, E:Y! is Yellowstone National Park's (YNP) curriculum-based residential student education program for fourth through eighth grade students. It consists of a four- or five-day residential program offering students a thorough investigation of YNP and many of its natural and historical resources. E:Y! includes a pre-expedition component in which the teachers choose and teach lessons and activities from a well-established, award-winning curriculum provided by the Park (Yellowstone Association Institute (YAI) & Yellowstone National Park (YNP), 2004a). Curriculum materials are presented online and in hard copies and cover content from three main curricular areas: geology, ecology, and human history. Lessons selected prior to the expedition are used to engage students and help prepare for the residential field trip. Park rangers also use the lessons as background for some of the in-park activities.

During the expedition, students participate in a variety of environmental education activities. These activities focused on stewardship and the experiential nature of science through hikes and activities that demonstrate natural processes. E:Y! groups typically spend from two to three hours at Mammoth Hot Springs (MHS) doing activities related to the hot springs systems including the testing of pH and surface temperature at a single location. They travel frequently to Norris Geyser Basin where they view geysers and take surface temperature and pH levels at a single location there. These two parameters are compared. In the winter, when the roads are closed to Norris Geyser Basin and the temperatures are very cold, Geology Day is often a short day in the field. In place of the trip to Norris Geyser Basin, students begin the day in class watching the DVD *Yellowstone: A Symphony of Fire and Water*, a production about the geysers (YAI & YNP, 2004b).

Both the four- and five-day expeditions focus on geology, biology, and stewardship topics using hands-on, interactive strategies. On a five-day expedition, students are exposed to additional topics relating to historical and current human impact on the Park. Human impact is defined by the National Park Service as any change (positive or negative) that occurs due to human presence. Differences in the length of the expeditions tend to be logistical and practical in nature. Rangers feel that the overall impact of the expedition is not affected by time differences (personal communication E. Petrick and B. Fuhrmann, March, 2006). Since the focus of the STaRRS STSP involved the E:Y! expedition day devoted to geology, expedition length was not considered to be an important factor.

Geomicrobiology Research at Mammoth Hot Springs (MHS). The partnering geomicrobiology research group (hereafter referred to as the university research group), is located at a large Midwestern university. The group consists of a cross-disciplinary mixture of geologists, microbiologists, genomocists, physicists, veterinarian medicine scientists, and educational specialists. Their ongoing integrated research efforts conducted at MHS focus on ways in which the environment influences and controls microbial life and ways microbial life rises to influence and alter the environment. Understanding the carbonate rock record and the relationships between both the biotic (living) and abiotic (non-living) components of the system can assist in understanding of ancient and modern landscapes both on earth and potentially other planets. The group's research is producing models of water-mineral-microbe interactions that effectively predict system-scale dynamics across large spatial and temporal scales. They have identified four basic parameters within the MHS geo-ecosystems that can effectively track and predict key water-mineral-microbe interactions. The parameters are: (a) spring water temperature; (b) pH; (c) flow rate and dynamics; and (d) basic contextual observations of the systems (i.e., travertine and microbial mat color, shape, size, growth rates and distance along the drainage system away from the water source (called *the vent*). These parameters can be used to test hypotheses. The equipment needed to measure them is fairly inexpensive and easy to use. The concepts behind the parameters are universally applicable to multiple sciences and can be translated to a broad range of grade levels. The parameters form the scientific foundation of the STSP.

Basis of the STaRRS STSP. The main link between the university geomicrobiology research group and E:Y! is MHS. The STaRRS partners visit MHS

frequently. Within the E:Y! curriculum, school groups have been casually gathering pH and temperature measurements there for over two decades. In addition, several important factors coincided to help create the STaRRS STSP partnership. These included: (a) the desire to establish an active connection between university researchers and middle level students in which students would be offered opportunities to develop a deeper understanding of current research being conducted in Yellowstone; (b) the need to have more year-round observations and data coverage at MHS for the university research team; and (c) an expansion of the E:Y! curriculum to include more specific scientific activities and investigations. These three factors made the formation of this partnership a logical consequence.

The workshop activities developed and tools chosen to be used with this partnership were based on four dimensions: (a) the existing E:Y! curriculum; (b) the needs of the research scientists; (c) the cognitive and social needs of the students; and (d) constraints of specific safety issues specific to conducting research in an area with thermal features. For example, infrared (IR) surface temperature thermometers which can take the temperature of features up to two meters away were used to gather temperatures data at the hot springs. Use of tools that can measure from a distance, while not as accurate as probes inserted into the springs, have the benefit of enabling students to monitor springs that may otherwise be unsafe due to high temperatures or distance from solid ground. Also, the travertine structures are very fragile and are not safe to walk on. Using IR thermometers allowed students to gather data without changing or harming the features.

Intervention. For teachers, the embedded STSP had two main components: a summer professional development workshop; and an integrated school-year component.

The four-day 45-hour intensive workshop in YNP covered four areas: (a) geomicrobiology content specifically geared towards understanding the hot spring system at MHS; (b) introduction and use of seven specific field tools; (c) conducting field science on a small component (one particular spring) of the hot spring system; and (d) integration and transfer of field science tools and processes to classrooms. The workshop was led by the researcher, the university scientist, and two graduate students. It was also attended by some of the interpretation and education rangers who work closely with E:Y! A schedule of the workshop can be found in Appendix A.

Teachers and rangers experienced the entire field research process that STaRRS students were expected to undertake while attending E:Y! Scientific tools for field work (e.g., thermometers, a Kestrel® hand-held weather monitoring device, pH test strips, transect grids, cameras, and protocols) were provided to the teachers. Teachers left the workshop with preliminary plans for carrying out the pre-expedition requirements. The summer workshop was intended to enable teachers to prepare STaRRS students for field experiences prior to the expeditions.

STaRRS teachers spent approximately two additional weeks of class time preparing for the STaRRS portion of the expedition. Their students were expected to arrive at E:Y! with possible questions and a battery of field methods ready to use for data collection. Additional assistance during the school year was provided for all the STaRRS teachers. This assistance consisted of one to two-day school visits by the researcher with each STaRRS teacher. These visits included planning for and co-teaching of pre-expedition activities. Other STaRRS pre-expedition support was provided through bimonthly electronic communication and phone calls.

Once at E:Y!, STaRRS students spent more time at MHS than regular E:Y! groups (up to six hours versus two to three) within the expedition schedule. For the STaRRS students, the Monday evening geology activities were supplemented by an hour of preparation for Tuesday's fieldwork. In addition, STaRRS students spent another hour on Tuesday morning preparing for their fieldwork at MHS.

Out in the field, rangers led some of the usual Geology Day activities. Then the STaRRS students participated in the three components of the partnership. First, students helped to collect photo point images. Photo points are specific locations within the MHS complex from which field photographs are repeatedly taken over time. Second, the students worked in groups to obtain specific temperature, pH, atmospheric, and spring water flow data within a 50 cm x 50 cm transect at locations within two different hot spring systems on the Upper Terraces. The locations were selected by the research team and were assigned to groups during their expeditions. After the expedition, these data were collected and sent back to the university research team. A copy of the transect protocol can be found in Appendix D. Finally, students developed answerable scientific questions and then conducted experiments in the field to test their hypotheses. The students completed analysis and synthesis of their data and observations immediately after returning from the field. Each of the student presentation at E:Y! was framed by five focus questions:

1. What was your question and hypothesis?
2. How did you go about answering it [procedure]?
3. What were your findings?
4. What were some challenges you faced? and

5. What is next? Discuss new questions and recommendations for future study.

Presentations took place at E:Y! prior to dinner on Geology Day. Further analysis and more formal presentations were made later to a broad range of audiences back in their home communities. Table 3 summarizes the differences between a regular E:Y! and a STaRRS expedition.

Table 3

Summary of Instructional Focus and Time Spent During E:Y! and STaRRS Expeditions

Days and Instructional Focus	Time Spent	
	E:Y!	STaRRS
Day 1		
YNP & Stewardship	1-2 hours	1-2 hours
Evening		
Geology content	2 hours	1 hour +1 hour STaRRS*
Day 2: Geology Day		
Geology content	1 hour	1 hour STaRRS*
Norris Geyser Basin hike	2-3 hours	N/A*
Mammoth Hot Springs hike	2-3 hours	5-6 hours including field work
Evening		
Ecology content	2 hours	+1-2 hours presenting*
Day 3: Ecology Day		
Ecology content & hike	6-7 hours	6-7 hours
Evening		
Human History content	2 hours	2 hours
Day 4: Human History Day		
Human History content & hikes	6-7 hours	6-7 hours
Evening		
Wrap up	2 hours	2 hours
Day 5: Wrap up, clean up	2 hours	2 hours

Note: *indicate differences

Following the expedition, STaRRS teachers spent approximately two more weeks of instructional time leading students in further analysis and processing and preparing

data in the form of posters or electronic slides for a presentation to a community group. These presentations mirrored the requirements of E:Y! laid out in *The Nuts and Bolt of Your Expedition to Yellowstone*, which says “students (must share) their new found knowledge and their Expedition with community members (YNP nd, p. 10)”, however, STaRRS teachers changed the focus from general E:Y! experiences to scientific research experiences.

Finally, STaRRS teachers attended a 20-hour, two-day follow-up workshop in Yellowstone in July, 2009. The focus of the workshop was on additional hot springs systems content, reflection, and future planning of STaRRS components within E:Y!. The post-assessment data were collected just prior to this follow-up workshop so it was not considered part of the intervention in this research. Table 4 summarizes the STaRRS intervention and timeline.

Table 4

A Summary of the STaRRS Intervention and Timeline

Intervention components	2008						2009						
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
STaRRS summer workshop	A-H												
Expedition preparation		A-E	C-E	C-F	E-F	E-F	E-G	F-G	H	H			
STaRRS expeditions			A	B	C, D			E	F, G		H		
Post expedition presentations				A	B	C, D		E	F	G	H		
STaRRS follow-up workshop													A-H

Key: A-H = STaRRS teachers' groups; participation varied depending on their expedition schedule, and scheduled classes with students

Participants

Population. The target population for this research was teachers who bring their students to E:Y!. These are not typical teachers. They are highly motivated and dedicated to providing extraordinary experiences for their students. This four or five-day experience often requires months of preparation, fund raising, and planning. Groups furnish their own equipment, food, chaperones, and transportation. They do all the cooking and cleaning during their expedition. The days are long, beginning at 6:30 a.m. in the kitchen, with classes ending at 9:00 p.m. each evening. Six to eight hours are spent outside each day regardless of the season or weather. In addition, requirements of the program include pre-expedition instruction and post-expedition follow-up communication with the E:Y! staff.

E:Y! groups come from cities like New York, NY, Detroit, MI, and St. Louis, MO as well as small towns like Red Lodge, MT, and Driggs, ID. Eighty percent of the groups are from the Greater Yellowstone Ecosystem, meaning that they reside within 200 miles of the park. About 60% of the groups in 2008-09 were from public schools. Remaining groups came from private schools.

Teachers. The teachers who agreed to participate in the study were selected from this pool of E:Y! teachers. Recruitment of STaRRS teachers occurred in December 2007. Participation in the project was voluntary but required attendance at the July 2008 workshop and a scheduled E:Y! trip during the 2008-09 school year. Since E:Y! is a huge commitment in itself, it was deemed too much to ask a new E:Y! teacher to participate in the STaRRS program during their first expedition. So, the recruitment pool did not

include any first-year E:Y! teachers. In addition, the summer workshop content and limited workshop time was based on a familiarity with YNP and MHS.

Nine teachers from eight schools in six states volunteered to participate. Six of the schools were located within the Greater Yellowstone Ecosystem. Three schools were private, the rest were public institutions. Two schools were located in urban areas (population >1,000,000), two were from small cities (population 20,000-40,000), and the other five were from towns or communities with fewer than 5,000 people.

Five of the STaRRS student groups were fifth grade classes, one was a combination of fifth and sixth graders, one was a seventh grade class, and the final group consisted of eighth grade students. Five groups were self-contained with one teacher instructing students in all subject areas. Each of these five groups brought all students from that particular grade level to E:Y! Of the remaining three groups, one was self-contained, with all students of that age from the school attending E:Y! However, the STaRRS teacher was not their regular classroom teacher. The final two groups had only a portion of the school's students attend E:Y! In both cases, students applied to attend and spent extra time outside of regular classes preparing for the trip. The STaRRS teachers for the latter two groups were far removed from their students' everyday classes; one was a second grade teacher, the other a resource reading specialist. Table 5, following the next section summarizes the E:Y! and STaRRS groups according to grade level, and includes initial student numbers.

To maintain anonymity, all teacher data were coded upon receipt. These codes included demographic information about the teachers' teaching assignment, educational background, and professional experience. The codes were detailed enough to allow the

teacher data to be linked to the student data. Each of the teachers, including the teachers of the comparison students were given pseudonym for use during data analysis and beyond.

Students of STaRRS teachers. All students of the STaRRS teachers who attended E:Y! were included in the population of STaRRS students. There were no limitations for student involvement, and all students who attended E:Y! opted to participate in the study with less than 1% denying permission to use their data. To maintain student anonymity, all students were assigned codes by their teachers on their pre-test instruments. These codes included numbers and/or initials for identification, month and year of birth, and gender. The same codes were used on the post-test data by the researcher and research assistant to match pre- and post-test data. Other data collected in person by the researcher were re-coded to match the quantitative codes.

E:Y! Comparison Student Groups. Teachers from nine schools in three states volunteered to participate as comparison E:Y! groups. Most years, approximately 45 groups attend E:Y!. During the 2008-09 school year, 40 groups attended E:Y!. Approximately 25% of all E:Y! groups were fourth grade groups (including one fourth and fifth grade mixed group), 28% were fifth or mixed fifth and sixth grade groups, 33% were sixth grade groups, and 12% were seventh, eighth or mixed seventh and eighth grade groups. The STaRRS group, by chance, recruited six fifth grade groups. This constituted almost two thirds of all the fifth grade groups scheduled for the 2008-09 school year, thus the E:Y! groups tended to be more heavily represented by fourth and sixth grade groups.

All but one of the E:Y! groups resided within the Greater Yellowstone Ecosystem. The group from outside the area was from a small community in north central Montana. Four of the nine groups were sixth grade classes, four were fourth, and the last one was a combination fifth and sixth grade class. Only one school from this group was private. All groups were self-contained and taught by their E:Y! teacher.

E:Y! teachers were recruited via email after each of the expeditions had been assigned. Assignments to expedition dates take place in the late spring and summer for fall semester, and during December-January for spring semester. Five E:Y! teachers were recruited in the fall, and five more in January. One E:Y! group did not submit pre-test data in time to be used in the study and was removed from the study. Groups were chosen based on willingness to gather student data pre and post expedition, and participation in at least one expedition prior to the 2008-09 school year. Summaries for E:Y! groups can be found in Table 5.

Table 5

A Summary of E:Y! and STaRRS Student Groups

Grade Level	E:Y! Student Groups	Number of Students	STaRRS Student Groups	Number of Students
Fourth	3	75	0	0
Fifth	0	0	6	120
Fifth - sixth	1	10	1	38
Sixth	5	102	0	0
Seventh and eighth	0	0	2	35
Totals	9	187	9	193

Students of comparison group teachers who attended E:Y! were included in the E:Y! comparison group population without any limitations. Since the teachers sent the researcher only the data from students whose parents consented to their child's participation, an accurate percentage of the population cannot be calculated. However, matching numbers of students attending E:Y! from park records and numbers of assessments received from these groups gives a rough estimate of 97% participation by students from E:Y! comparison schools. Like their STaRRS counterparts, E:Y! students were assigned codes by their teachers, which included numbers and/or initials for identification, month and year of birth, and gender. These codes were used to match pre- and post-test data and used throughout the study to maintain student anonymity.

The E:Y! teachers (and, by association their students) benefitted from participation by receiving two pieces of STaRRS equipment for their schools and accompanying protocols for their use if they choose to implement STaRRS curriculum activities in the future. Lessons and activities developed over the research year related to the STaRRS activities and field science were made available to all future E:Y! groups through electronic supplements to the curriculum following the conclusion of the research.

Sampling Limitations

Given ideal research circumstances, a selection of each grade level would have been represented by the STaRRS and E:Y! groups. Even though this was not possible, there is no reason to believe the over-representation of fifth grade groups in the STaRRS sample and the greater number of fourth and sixth grade groups in the E:Y! sample was

anything but chance based on circumstances of individual teachers. In fact, two of the comparison group teachers had originally wanted to participate in the STaRRS partnership, but were unable to attend the workshop thus making them ineligible for that part of the project. It seems that the fifth grade groups had been inadvertently “mined” out of the pool of E:Y! groups, so it makes sense that the E:Y! groups were made up of the two other groups (fourth and sixth grade students) most frequently attending E:Y!

Data Collection

To answer the first research question (RQ #1), examining impact of participation on STaRRS teachers, a battery of measures was used including pre- and post-assessments in the areas of: (a) earth science content; (b) attitudes regarding science and scientists; and (c) enacted curriculum and pedagogical strategies of the teachers.

Research question two (RQ #2), focusing on effects on the students, was informed by a similar battery of pre- and post-assessments covering the areas of earth science content and attitudes regarding science and scientists. Instruments were administered to both STaRRS and E:Y! groups. Descriptions of each of the measures with corresponding reliability and validity measures follow below beginning with the instruments associated with RQ #1 followed by RQ #2.

Instruments: Assessing Impacts on Teacher Outcomes

Geoscience content measure. The Geoscience Concept Inventory (GCI) is a multiple-choice instrument of 70 questions originally developed to assess knowledge gains in college level geoscience courses. Validity and reliability of the GCI was

established through the work of Libarkin and Anderson (2005) using item response theory (IRT). The theory dictates a rigorous process of test question development that takes into account the relationship between concepts and item responses and difficulty of items on the assessment. In addition to the Rasch reliability, they reported a KR-20 classic test reliability of 0.69 with an item separation reliability of 0.99 (Libarkin & Anderson, 2008a). This instrument was determined to be generalizable to large and diverse populations of students and was subsequently used with pre-service and in-service teachers (Dahl, Anderson, & Libarkin, 2005). The GCI can be used as a whole or questions can be selected that focus on the concepts of interest for a study (Libarkin & Anderson, 2005).

For this study, 25 questions were selected for STaRRS teachers covering the following topics: earth's formation and the origins of life; plate tectonics and relationships to volcanoes and earthquakes; and rock formation and erosion. The selection of questions followed the GCI sub-test construction guidelines (Libarkin & Anderson, 2008b) in order to ensure reliability of this subtest. In addition to the required 15 subtest items required for reliability of the final instrument, 10 other questions that were closely related to the professional development for this project were selected. The test was further reviewed by the researcher and E:Y! rangers to identify the questions most closely related to the educational programming of E:Y! These questions were analyzed as a subsection of E:Y! content and the remaining questions were analyzed as a general knowledge subsection.

In addition, relationship between the items selected and curriculum content required by state and national standards were considered. A table showing the

relationship between the GCI and NSES and benchmarks for the states of Idaho, Wyoming, and Montana can be found in Appendix E. A copy of the GCI for teachers can be found in Appendix B.

Scoring. The tests were scored by the researcher using guidelines developed from the original instrument's answer key (Libarkin & Anderson, 2005). The pre- and post-test data were entered onto spreadsheets. Next, averages, standard deviations, and differences were calculated. All instruments and spreadsheets were checked a second time by two independent scorers. Accuracy was calculated at > 99%. There was no missing content data from the teachers.

Attitudes Toward Science and Scientists. The Test of Science Related Attitudes (ToSRA) developed by Barry Fraser (1981) was determined to be the best instrument to measure teacher and student attitudes about science and scientists. The original instrument is divided into seven sections, each with ten Likert-scale type questions measuring different aspects of science-related attitudes. These are: (a) Social Implications of Science; (b) Normality of Scientists; (c) Adoption of Scientific Attitudes; (d) Adoption of Scientific Inquiry; (e) Enjoyment of Science Lessons; (f) Leisure Interest in Science; and (g) Career Interest in Science. Fraser (1978) defined the Normality of Scientists subscale as a measurement of "students' appreciation that scientists are normal people rather than the eccentrics often depicted in the mass media" (p. 80).

After reviewing the full 70-item instrument, five 10-question scales were chosen for teachers. These were: (a) Social Implications of Science; (b) Normality of Scientists; (c) Adoption of Scientific Inquiry; (d) Adoption of Scientific Attitudes; and (e) Leisure Interest in Science. Questions on the Enjoyment of Science Lessons scale pertained to

being a student in a science class and were not easily adapted to teaching. Likewise, the Career Interest scale was neither applicable for participant teachers nor appropriate for this study. These scales were not used.

The original instrument was developed for use with middle and high school level students. However, it has been used in a few studies on adults including undergraduates (Newbill, 2005). Newbill reported reliability coefficients for the scales at .82, which she determined to be sufficiently close to Fraser's (1981) original reliability (.84) to use with adults. A small pilot study using 15 volunteer E:Y! teachers and rangers in 2008 produced a reliability rating of an average of .68 for the five scales being used with the teachers. Based on this moderate reliability value and Newbill's higher rating, I concluded that the ToSRA was sufficiently reliable for the purposes of this research.

Scoring. Each of the ToSRA scales consists of 10 statements for which the survey participant rates their agreement using a five-point Likert-type scale. Five of the points are phrased positively and are scored as follows: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree. The other five are phrased negatively, and the points for the agreement scale are reversed. Therefore "Neutral" for both was equal to the score of 3. Examples of these questions can be found in Table 6. For each scale, when the sum of the ten individual scores is reviewed, larger totals indicate more positive attitudes. So, a score of 45-50 would correlate to a very strongly positive attitude and a score of 10-15 to a highly negative attitude towards the particular construct being surveyed.

Table 6

ToSRA Scales for Teachers and Students – Description and Examples of Positive and Negatively Phrased Statements

Scale	Description	Example Phrases	
		Positive	Negative
Social Implications of Science (SIS) ¹	Manifestation of attitudes towards the role of science in society	Money spent on science is well worth spending.	Scientific discoveries are doing more harm than good.
Normality of Scientists (NS)	Manifestation of attitudes towards scientists as “normal people”	Scientists like sports as much as other people do.	Scientists are LESS friendly than other people.
Attitude to Scientific Inquiry (INQ)	Acceptance of inquiry as a scientific way of thinking	I would prefer to find out why something happened by doing an experiment than by being told.	Doing experiments are not as good as finding out the information from teachers.
Enjoyment of Science Lessons (ENJ) ²	Enjoyment of learning experience in science classes.	Science lessons are fun.	I do NOT like science activities.
Adoption of Scientific Attitudes (AD-ATT) ¹	Adoption of scientific attitudes and habits of mind	In science reports I report unexpected results as well as expected ones.	I am unwilling to change my ideas when evidence shows the ideas are poor.
Leisure Interest in Science (LEI)	Interest in science-related activities outside of school	I would enjoy visiting a science museum on the weekend.	Listening to a talk on the radio about science would be boring.

Note: ¹Scale present on teacher version of ToSRA only.

²Scale is present on student version of ToSRA only.

All other scales are present on teacher and student versions of the ToSRA.

All of the STaRRS teachers' ToSRA instruments were scored by the researcher using the original instruments' scoring instructions (Fraser & Butts, 1982). Answer sheets were first checked for omitted responses or multiple answers. There were none. Each phrase was given a score based on the direction of the phrase and the corresponding score was assigned. Scores were entered in a spreadsheet and totals and averages were calculated. All instruments and spreadsheets were checked a second time for accuracy by two independent scorers and was calculated at >99%. There was no missing attitude data from the teachers.

Pedagogical Strategies. The Surveys of Enacted Curriculum (SEC) is a large multiple-choice inventory that assesses a number of areas of teacher decision-making. This instrument was developed primarily for use in school districts to assess curriculum enactment, compare districts to a national database of enacted curriculum, and to aid teachers in making connections between their instruction and student outcomes. There are three sets of surveys covering Mathematics, Science, and Language Arts. The Science surveys contain more than 150 questions in three areas: (a) Instructional Practice; (b) Subject Content; and (c) Teacher Characteristics. According to the Council of Chief State School Officers (CCSSO), the SEC instruments were thoroughly field tested to ensure validity and reliability (Blank, Porter, & Smithson, 2001). This instrument was administered to STaRRS teachers in an on-line format for the first time in July 2008 and then again in May 2009. STaRRS teachers filled in the science surveys, with the exception of the one teacher who teaches language arts; she filled in those surveys instead.

On the SEC's measure of overall instructional time, teachers are asked to determine the amount of time spent throughout the entire school year in 27 broad science content areas. Each of these areas is further divided into sub-content topics. For example, the broad content area Ecology is subdivided into 10 topics including food webs and chains, ecosystems, and adaptations. At this level, teachers are asked to identify the amount of class time spent on each of the following five student expectations: (a) memorization and recall; (b) performing procedures; (c) communicating understanding; (d) analyzing information; and (e) applying concepts. These are referred to in the SEC analysis as Cognitive Demand.

The overall instructional time spent, content areas, and cognitive demand can then be represented by a three-dimensional graphic that shows the amount of time spent in each content area crossed within the corresponding cognitive demand areas during any given school year. These maps, when viewed side by side, provide a visual picture of the changes teachers reported in their teaching practice from pre- to post-STaRRS intervention.

For this research, the SEC data were used to focus on pre- and post-STaRRS intervention reporting differences in areas that were matched to the goals of the STaRRS partnership. There were 16 topic areas identified by the entire group of teachers as having taken up more than 2% of the overall instructional time. Areas (such as biochemistry) that are not usually topics of instruction for fifth through eighth grade students were dropped from the data analysis. Topic areas of particular interest for this research were ones that closely matched the focus of the STaRRS workshop and related instruction

during the school year. These five topic areas were measurement in science, nature of science, ecology, science and technology, and acids, bases, and salts.

Instruments: Assessing Impacts on Student Outcomes

Geoscience content measure. A parallel instrument, the Geoscience Concept Inventory for Middle Level Students (GCI-MLS), was developed for this study. The Inventory consists of 22 questions based on the original GCI which were rewritten using language appropriate for fourth through eighth grade students. A pilot of two types of the instrument (an open-ended question version and a multiple choice version) was conducted in May 2008. The researcher, a geologist, and a fourth grade teacher reviewed each version to establish face validity. The questions, presented to a group of 20 fourth grade students in the pilot, had an additional component in which the students rated (easy, medium, or hard) their perceived difficulty of the questions. The pilot, including student perceptions was compared, as the original instrument was, to the Rasch scale of relative difficulty of questions (Libarkin & Anderson, 2006) and used to guide the development of the GCI-MLS. The final GCI-MLS instrument included 11 multiple choice questions and 11 short answer questions. The questions in the instrument covered three areas of geosciences content: general knowledge; E:Y!-related concepts; and STaRRS-related concepts. Content validity of the instrument was established by comparing test items to NSES earth science content standards and the earth science state standards and benchmarks for the states of Idaho, Wyoming, and Montana. These three states are included in the Greater Yellowstone Ecosystem which is the home of the greatest number of E:Y! participants.

The general knowledge (GK) subsection was made up of questions that were most closely matched to the NSES and state standards and benchmarks. The Expedition: Yellowstone! content (E:Y! content) subsection was composed of items that corresponded with concepts taught by rangers during a typical expedition. These content items were selected with the help of four E:Y! rangers. The STaRRS content items were written specifically for assessing specific geoscience concepts taught to the STaRRS teachers and passed along to their students. These concepts included hot spring-related vocabulary. A visual-conceptual model, the Facies Model of Hot Springs Systems, was used to help students understand the hot springs system. Other critical areas in the STaRRS content were the uses of the metric system and powers of ten as conceptual tools. Appendix F shows these subsections in more detail.

Two scientists, two middle level science teachers, and the researcher determined content of the final version. E:Y! rangers also helped the researcher determine the final grouping of sub-test questions. Table F1 found in Appendix F contains a summary of the correlations among the questions selected for the subsections and the content areas.

In order to determine reliability of the GCI-MLS, test-retest reliability was used. In the fall of 2008, a group of 36 sixth grade E:Y! students from a small town in Wyoming were administered the GCI-MLS prior to their expedition. After returning from Yellowstone, the same test was re-administered within two weeks. According to their teacher, the time between the assessments was approximately four weeks. This group was determined to be similar to the student groups participating in the STaRRS project – both the treatment and comparison groups. Using the Spearman coefficient, the GCI-MLS was found to have a test-retest reliability of 0.69.

Test-retest reliability is often discouraged due to a learning/practice effect, maturation effect, or non-response bias. The maturation effect would have been minimal in this case because of the short period of time between administrations. A learning/practice effect may have occurred. However, students were not graded by their teacher for their scores on either test administration so there was no pressure to perform at a higher level on the second administration. There is a possibility that students may have remembered the questions on the test and focused on some of the concepts introduced (especially the E:Y!-related concepts) on their expedition. Since this cannot either be confirmed or disconfirmed, the reliability should be taken with this in mind. A copy of the GCI-MLS can be found in Appendix C.

Scoring. The GCI-MLS items were scored using a key developed by the researcher. Answer sheets were first checked for omitted responses. These were given a score of “0.” Questions with multiple responses were given scores based on the total number of responses possible. Scores for these questions were entered in separate columns on spreadsheets. In other words, if a question had a possibility of three correct responses, three columns were dedicated to this question. A student with two of the three responses correct would have a score of one in two of the three columns and a zero in the third column. This allowed for equal weighting of all responses. A rubric was used to score the open-ended responses. Student responses that varied from the rubric but could be considered correct on the pre-test were discussed by the research assistant, a fourth grade teacher, an E:Y! ranger, and the researcher; the rubric was revised if necessary. The rubric was not revised for the post-test scoring. The total number of questions was 22, but the total number of responses was 42. A randomly selected 10% percent of the pre- and

post-assessments were selected from each school group and scored by the researcher, producing an inter-rater reliability of 0.97 for the pre-test and 0.99 for the post-test.

Attitudes Toward Science and Scientists. The ToSRA assesses many of the areas I was interested in including how students view science as a subject, science as a leisure interest, and their views on scientists as people. Alteration of the instrument, aside from selection of areas pertinent to this study, was not necessary since it has been used extensively with middle school students. Four subsections of the ToSRA were selected for student use: (a) Normality of Scientists; (b) Adoption of Scientific Attitudes; (c) Enjoyment of Science Lessons; and (d) Leisure Interest in Science.

Using all the pre-test data ($n = 366$) to calculate Cronbach's alpha, the four scales chosen for students in this project from the original ToSRA were found to have a high degree of internal consistency with values ranging from 0.67 to 0.93. The average of all the scales (0.81) was close to the averages reported by Fraser (1981) of 0.80 for Year 7 Australian students and 0.78 for 9th grade students in the United States. The ToSRA was administered pre and post E:Y! expedition for both the STaRRS and E:Y! students.

Scoring. All of the ToSRA student instruments were scored by a single research assistant under the supervision of the researcher using a key developed for the instrument adhering to the original instrument's instructions (Fraser & Butts, 1982).

Answer sheets were first checked for omitted responses or multiple answers in responses. These items were amended to a response of "N" or a numeric score of "3" Then each phrase was given a score based on the direction of the phrase and the corresponding score was given. These scores were entered into a spreadsheet and totals and averages were calculated. Again, the researcher selected a random 10% of the

instruments to re-score. There were fewer than 10 errors in a total of 3500 responses, so the accuracy rate of the research assistant was determined to be greater than 0.99.

For all teacher and student data, spreadsheet data were reviewed, checked for accuracy, and cleaned by the researcher. Missing data from a single student in either the pre- or post-test resulted in the removal of all of that students' data. Table 7 shows the timeline for data collection for all participants.

Table 7

A Timeline of Data Collection Based on Research Question

Data collection tools	Research question	2008-2009 School Year												
		Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
GCI-Teachers	1	●												●
ToSRA-Teachers	1	●												●
SEC	1	●												●
GCI-Middle Level Students	2				●■(5)						■(4)		●■	
ToSRA-Students	2				●■(5)						■(4)		●■	

Key: ●(STaRRS) ■(E:Y!) = data collection occurred with entire group at the same time; ■(E:Y!) = data collection was variable according to scheduled expeditions; (#) = numbers of groups of data that were collected at that time.

Data Analysis

Data Analysis for Research Question One. The three assessments used to answer this question were administered to STaRRS teachers pre- and post-intervention, approximately a year apart. The following section contains a description of how the instruments were analyzed.

Initially, descriptive statistics were used to examine the averages of the group's scores. The hypothesis was directional, meaning that there was an expectation that the intervention would produce positive changes in the post-test scores. Therefore, a one-tailed *t*-test model was used to analyze the data. This also increased the power for this small sample size. Dependent *t*-tests were used to look at pre- and post-test scores for the entire GCI. Next, the GK and E:Y! subsections were separated and analyzed independently.

Each of the five ToSRA scales was defined using descriptive statistics showing means and standard deviations. Next, pre-test post-test differences were analyzed using dependent *t*-tests. Since each of the scales measures a different construct, combining them does not produce a meaningful score (Fraser & Butts, 1982). Thus, no total scores were analyzed.

Teachers were instructed in 2008 and again in 2009 to fill in the SEC surveys keeping in mind their most recent school year and corresponding set of students. The sections of particular interest for the SEC included the Overall Percentage of Time Spent on all science topics and Cognitive Demand related to the topic areas corresponding most closely to the STaRRS partnership goals. These three constructs (topics, time and cognitive demand) were visually inspected and compared using maps produced by SEC

showing graphic representations of these constructs. Table 8 presents a summary of the data analysis for RQ #1.

Table 8

Summary of Data Analysis for Research Question One

Instrument	Subsection or items used	Analysis
GCI	Entire test, Subsection EY content items: 2, 6, 14, 21, 23, & 24 Subsection GK items: 1, 3-5, 7-13, 15-20, 22, & 25	Descriptive statistics, <i>t</i> -tests
ToSRA	Subsections: Social implications of science (SIS) Normality of scientists (NS) Adoption of scientific attitudes (AD-ATT) Adoption of scientific inquiry (INQ) Leisure interest in science (LEI)	Descriptive statistics, <i>t</i> -tests
SEC	Instructional Content Percentage of science instructional time and type of instruction (content, time spent, and cognitive demand) <ul style="list-style-type: none"> a. All Science Content b. Measurement in Science c. Nature of Science Ecology d. Ecology e. Science and Technology f. Acids, Bases, and Salts 	Visual inspection and comparison of pre- post-STaRRS results of 3-D maps produced by SEC for a-f

Data Analysis for Research Question Two. For RQ #2 two assessments, the GCI-MLS and the ToSRA were administered to STaRRS and E:Y! students before and after E:Y! experiences. The differences in the students' scores from pre- to post-test were analyzed.

The numbers in Table 9 reflect the total number of completed sets of assessments. They are separated by treatment group, grade level, and assessment. Although there was no attrition of STaRRS teachers or their E:Y! counterparts, there was some attrition within student groups caused by missing assessments or students leaving during the school year. Since this was calculated to be less than 2% of the participant students, I determined that this did not have a measureable effect on the overall averages. However, the greatest amount of attrition was found in the seventh and eighth grade groups within the STaRRS student groups. Thus, the seventh grade numbers seem particularly small. This seventh grade class originally had only 18 students to begin with so the loss of three students brought the numbers down even further. Another noticeably small number is the fifth grade E:Y! group. These students were part of a mixed level (fifth-sixth) class from a small rural school.

Table 9

Cross Tabulation for Students' GCI-MLS/ToSRA Assessments

Grade in 2008-09	E:Y!	STaRRS
4	70/69	0
5	4	134/135
6	106/109	18
7	0	15
8	0	19
Totals	180/182	186/187

Note: Double numbers in a column indicate differences in final sets of assessments for the two instruments (GCI-MLS/ToSRA).

Both the GCI and the ToSRA were analyzed using an Analysis of Covariance (ANCOVA) with the pre-test scores as the covariate. The purpose of using this statistical analysis was to equalize the pre-test scores so that significant differences in post-test scores could be identified. In addition to the covariate, the GCI data were analyzed in four sections. The first was the entire test or Total Test (TT) score. Three other analyses were done with each of the subsections of the test covering general knowledge (GK), E:Y! content (E:Y!), and STaRRS content (STaRRS). The ToSRA was analyzed as four separate scales. Again, because of the nature of the instrument to assess different constructs within each scale, no total scores were analyzed. A summary of the analyses for research question two can be found in Table 10.

Table 10

Summary of Data Analysis for Research Question Two

Instrument	Subsections	Covariate	Analysis
GCI	Total test (TT) General knowledge (GK) E:Y! content (EY) STaRRS content (STaRRS)	E:Y!/STaRRS pre-test scores	ANCOVA
ToSRA	Scales: Normality of scientists (NS) Adoption of Scientific Inquiry (INQ) Enjoyment of Science (ENJ) Leisure Interest in Science (LEI)	E:Y!/STaRRS pre-test scores	ANCOVA

Limitations

Because this study was specifically focused on the target population of E:Y! participants, this specific population is the only one the study can generalize to. This is in part due to the fact that teachers who make the effort to bring groups of 12-32 students on a four to five day field expedition at YNP are not representative of the typical population of teachers (Bob Fuhrmann, Director of E:Y!, Personal communication, March 2006). The longevity of E:Y! as a residential experience coupled with the lack of frequent turnover in their staff may pose other issues of generalizability, even among other National Park Service residential education programs.

Chapter Four

Findings

Introduction

In this chapter, I present the findings for each of the two research questions. The first research question focused on the impact of STaRRS STSP participation on teachers' content knowledge, attitudes about science and scientists and pedagogical strategies. The second research question explores the impact of the partnership on STaRRS students' content knowledge and attitudes toward science and scientists.

Findings for Research Question One: Impact on STaRRS Teachers

Content knowledge. Content knowledge, measured using the Geoscience Concept Inventory (GCI), was administered during the summer in 2008 and again early summer 2009. The pre-post differences were analyzed in three sections using dependent sample *t*-tests. The first analysis covered the entire test or Total Test (TT) and included all 25 items. This was followed by analysis of two subsections called General knowledge (GK) and Expedition: Yellowstone! content (E:Y! content).

Table 11

Descriptive Statistics and Dependent Samples t-tests for STaRRS Teachers' GCI Findings

Subsection (# of items)	Pre-test <i>M</i> (<i>SD</i>)	Range	Post-test <i>M</i> (<i>SD</i>)	Range	Difference <i>M</i> (<i>SD</i>)	Significance
TT (25)	17.76 (2.87)	14-22	18.82 (2.80)	15-23	1.06 (1.72)	0.042†
GK (19)	13.40 (2.54)	10-17	13.77 (2.38)	11-17	0.37 (0.96)	0.130
E:Y! (6)	4.36 (1.29)	1-6	5.05 (0.66)	4-6	0.69 (1.19)	0.050

Note: n = 9

†*p* < .05, one-tailed.

Table 11 presents descriptive statistics and *t*-test findings for the GCI. Although the teachers showed small gains in all three areas, only the TT score was statistically significant. The average one point gain on a 25-question test is not considered to be practically significant in terms of teachers achieving meaningful gains.

The fact that teachers had significant, though not practical, differences in pre-post content knowledge is a little surprising when the whole picture is taken into account. However, there is a possibility that due to the fact that the teachers scored fairly high (for the GCI) on the pretest, the instrument was not sensitive enough to show change.

Libarkin and Anderson's (2005) initial study of their test on undergraduate students ($n = 2215$) found the pre-test average score to be 41%. Other studies using pre-service and in-service teachers found similar averages (e.g., Petcovic & Ruhf, 2008; Dahl et al., 2005; Elkins and Elkins, 2007). Libarkin and Anderson (2005) also found that students in their initial study who pre-tested high (defined as above 60%) exhibited no change in their post-test scores. STaRRS teachers' pre-test average was 71%, which was around 30% higher than other pre-test averages reported in the literature.

Why would these teachers have such high scores to begin with? First of all, there is a possibility that this particular group of teachers was more knowledgeable about geoscience concepts. After all, they were a self-selected group of teachers who already had experience bringing their students to Yellowstone, considered by many to be one of the most interesting geologic areas in the world. In addition, they all agreed to participate in a partnership with a geoscience focus when they volunteered for the STaRRS partnership.

Teachers' attitudes. Attitude data for teachers were collected using five of the seven original ToSRA scales (Fraser, 1981). These scales were: Social Implications of Science (SIS): Normality of Scientists (NS): Attitude to Scientific Inquiry (INQ): Adoption of Scientific Attitudes (AD-ATT): and Leisure Interest in Science (LEI). Each scale was analyzed separately.

Table 12 presents the descriptive statistics and statistical significance established using *t*-tests. The scoring of the ToSRA takes into account all ten questions in each subsection. Since this was a Likert scale assessment, a score of 40.1 represents an average score of 4.0 (or Agree) so the movement from 37.3 to 40.1, as in the scale Normality of Scientists, would represent an average change of 3.7 (the upper end of Neutral) to 4.0 (Agree).

Table 12

Dependent Samples t-tests for STaRRS Teachers' ToSRA Pre-Post-Assessment Differences by Scale

Scale	Pre <i>M</i> (<i>SD</i>)	Range	Post <i>M</i> (<i>SD</i>)	Range	Difference <i>M</i> (<i>SD</i>)	Significance
SIS	40.1 (3.28)	35-45	41.9 (3.00)	37-46	1.80 (2.15)	0.014†
NS	37.3 (3.97)	31-43	40.1 (4.60)	32-48	2.80 (2.90)	0.007††
INQ	39.6 (2.88)	33-42	39.8 (2.25)	37-44	0.20 (2.78)	0.413
AD-ATT	40.6 (2.07)	37-43	42.4 (1.51)	40-45	1.80 (2.39)	0.021†
LEI	39.4 (3.10)	34-44	41.4 (2.59)	38-45	2.00 (1.83)	0.004††

† $p < 0.05$, one-tailed. †† $p < 0.01$, one-tailed.

STaRRS teachers showed statistically significant gains on four of the five ToSRA scales. The greatest gains were in teacher attitudes on the NS and LEI scales. Smaller gains were detected in SIS and AD-ATT. INQ showed no change. These findings demonstrate the possibility of STaRRS affecting teachers' attitudes within these constructs. This signifies practical changes as well since each of the attitude differences are greater than one third of a standard deviation, which was defined by Cohen (1988) as a moderate effect size. In fact, the effect size of NS was nearly a whole standard deviation, and LEI was greater than 1.0 *SD*.

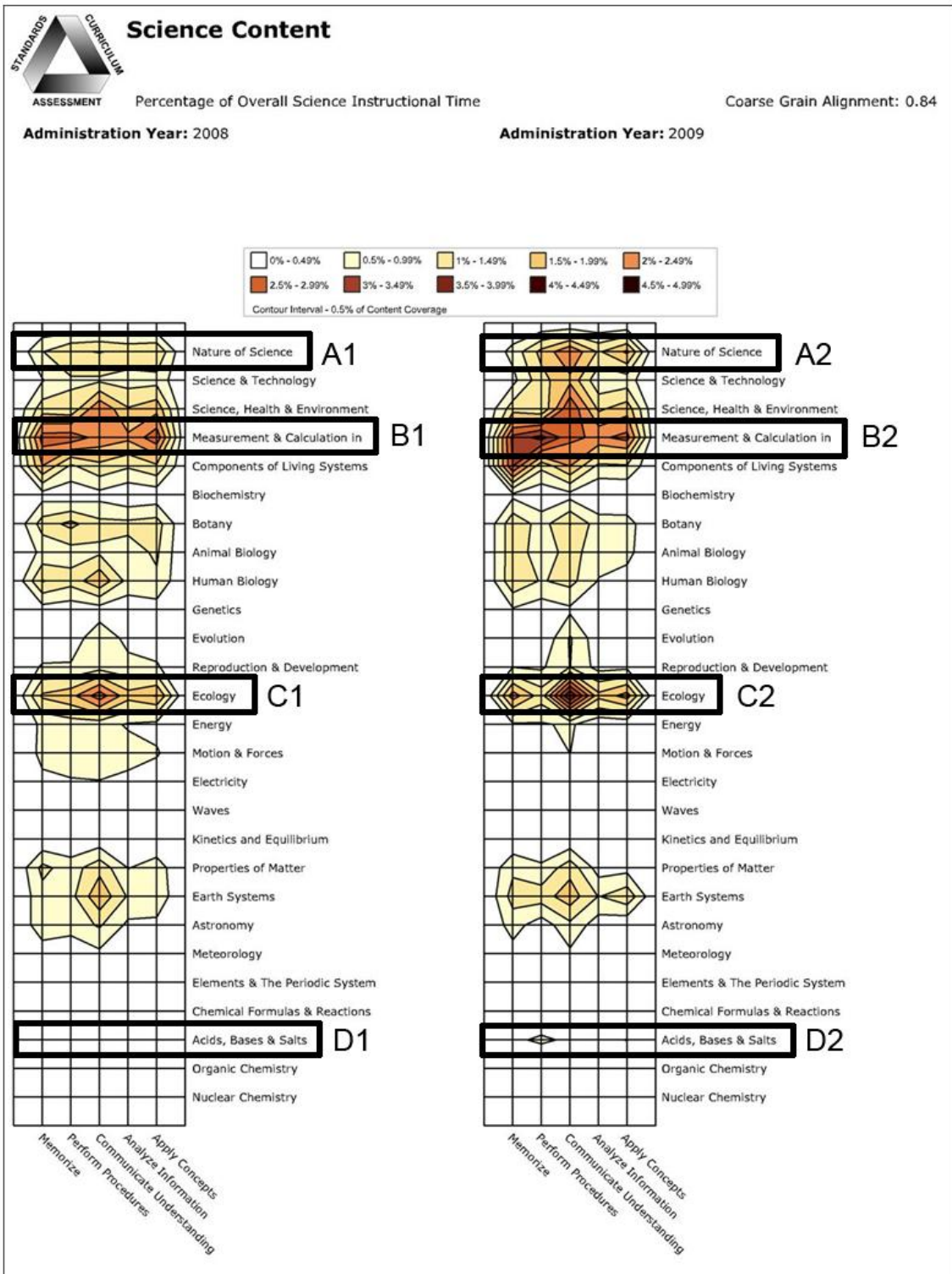
Pedagogical Strategies Findings. To assess the impact of STaRRS participation on the pedagogical strategies of the teachers, I used the extensive and comprehensive Surveys of Enacted Curriculum (SEC). These surveys provide a wealth of information on the depth and breadth of teaching practice. Only a small portion of the data has been selected for presentation here. I chose the Content Maps developed by the SEC software to present the visual changes in pedagogy reported by STaRRS teachers.

SEC content maps. Content maps allow for viewing these data in three dimensions. The maps show how science content topics align with the cognitive demand expectations of the teachers. These data are then overlaid with shading and contour lines representing the percentage of instructional time.

The maps resemble topographic maps and are read in a similar manner. The horizontal grid lines correspond with the topic areas and the vertical ones correspond with the six categories of student cognitive expectations. These expectations correlate with Bloom's Taxonomy (Bloom, Hastings, & Madaus, 1971). Lower level thinking skills are on the left and more complexity and higher level thinking skills are on the right.

The locations where the grid lines intersect are called “measurement nodes.” At each of the nodes, increases or decreases in time are represented by the shaded bands of color.

First, I will present a content map showing broad picture of all content topic areas. After that, I have selected five fine-grained topic maps which include subtopics that highlight changes in STaRRS teachers’ reported pedagogy. These maps correspond with E:Y! and STaRRS curriculum focus.



All science content areas. Figure 1 provides a basis for viewing broad changes between the pre-STaRRS and post-STaRRS school years based on the teacher-reported surveys. Darker areas indicate more time spent on a given topic. When comparing the 2008 and 2009 maps, the most interesting areas showing increases in time spent include nodes at nature of science (A1) and (A2), measurement in science (B1) and (B2), and ecology (C1) and (C2). In addition, teachers reported increases in cognitive demand for nature of science (A2) and ecology (C2) in the center where they meet with the cognitive demands (found along the bottom axis) communicate understanding (A2) and measurement and calculation (B2) in two cognitive demand areas (memorize and performing procedures). Practically speaking, these are all areas of focus for either the regular E:Y! or the STaRRS curriculum.

Fine-grained maps of all of these specific topic areas are presented next. Additional fine-grained maps are presented for Science and Technology and Acids, Bases, and Salts (D1 and D2) since these were topic areas highlighted in the STaRRS teacher workshop.

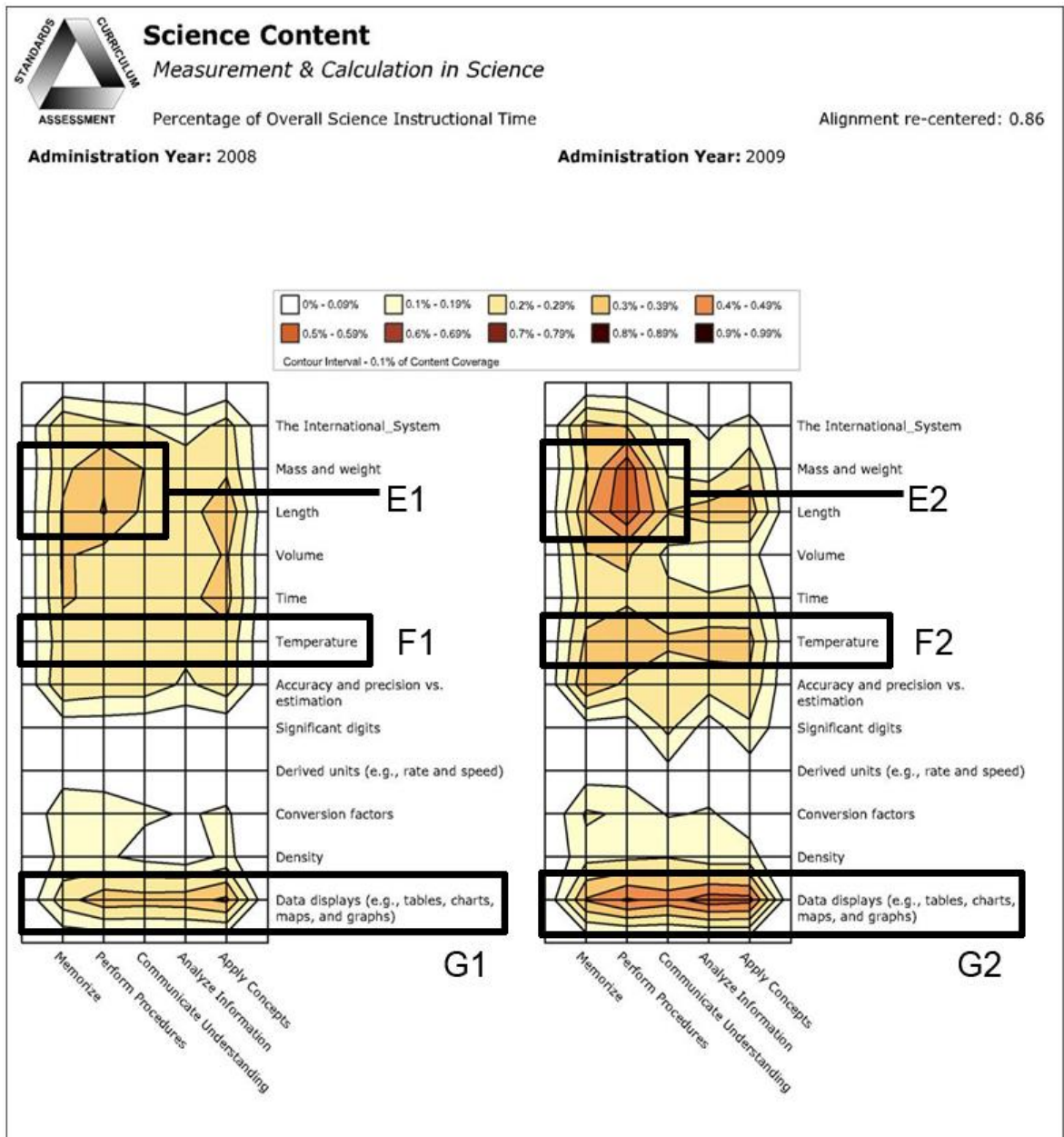


Figure 2. SEC – Measurement in science.

Measurement in science. Figure 2 shows teacher reported shifts in instructional focus for the subtopic areas covered in measurement in science between 2008 and 2009 in both content and student expectations. The most noticeable shifts are in three areas. The first is found at the nodes where mass and weight and length intersect with performing procedures (E1) and (E2). The second applies to temperature (F1) and (F2)

across all expectations areas. The final one is found at data displays (G1 and G2). In the last two topic areas, teachers' reports of content show an increased distribution of breadth of cognitive expectations in 2009.

All three areas could have been affected by the STaRRS professional development and the teaching requirements to prepare for the STaRRS expeditions. Students were expected not only to be ready to conduct field science when they arrived at Yellowstone but also to be versed in the process of data collection including the use of measurement tools using SI measurements. The teachers reported spending additional time focusing on teaching these skills prior to their expeditions. This is also evidenced in a separate journal entry data set.

Further, all of the STaRRS teachers reported (again, via regularly submitted journals) using their students' STaRRS research as a part of their post-E:Y!-required community presentation. In most cases, students' used visual aids such as posters and Power Point presentations and included data displays in all their presentations. The teachers' report of greater emphasis on time spent in the subtopic area data displays in 2009 correlates with these experiences. The reported percentage of time increases amount to approximately two to four more days spent on these topics throughout school year.

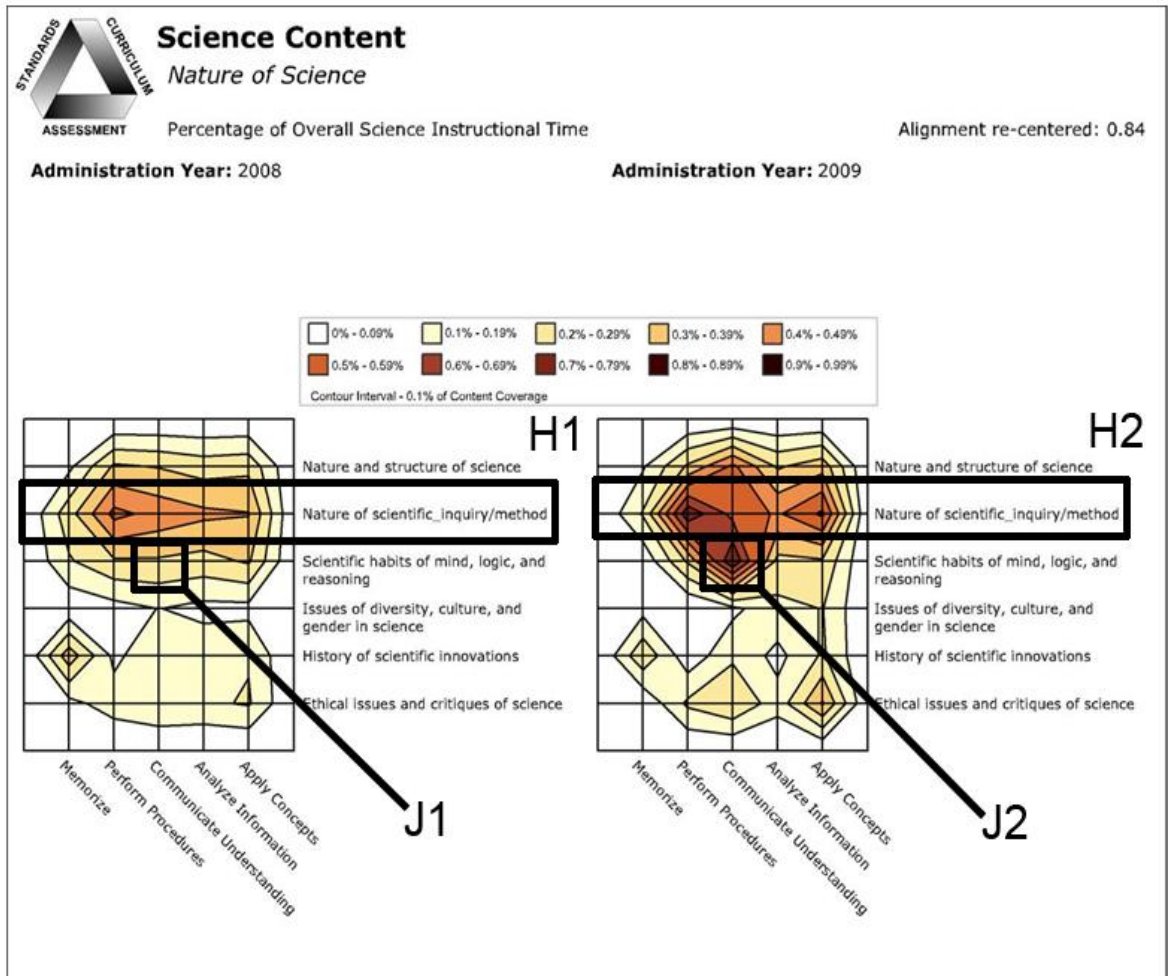


Figure 3. SEC – Nature of science.

Nature of science. On the nature of science maps (Figure 3), three measurement nodes stand out. The first two can be seen where nature of scientific inquiry/method intersects with perform procedure and apply concepts at (H1) and (H2). Teachers reported increased time spent in both areas. The largest shift, however, was reported by teachers at the node where scientific habits of mind meets communicate understanding (J1) and (J2). Although the STaRRS professional development did not include any methodological instruction, all of the workshop instruction modeled inquiry-based methodologies. In addition, the structure of the student investigations proposed by the

partnership was a full guided inquiry cycle. These findings may represent one of the partnership's effects on teachers' practice of inquiry-based science teaching.

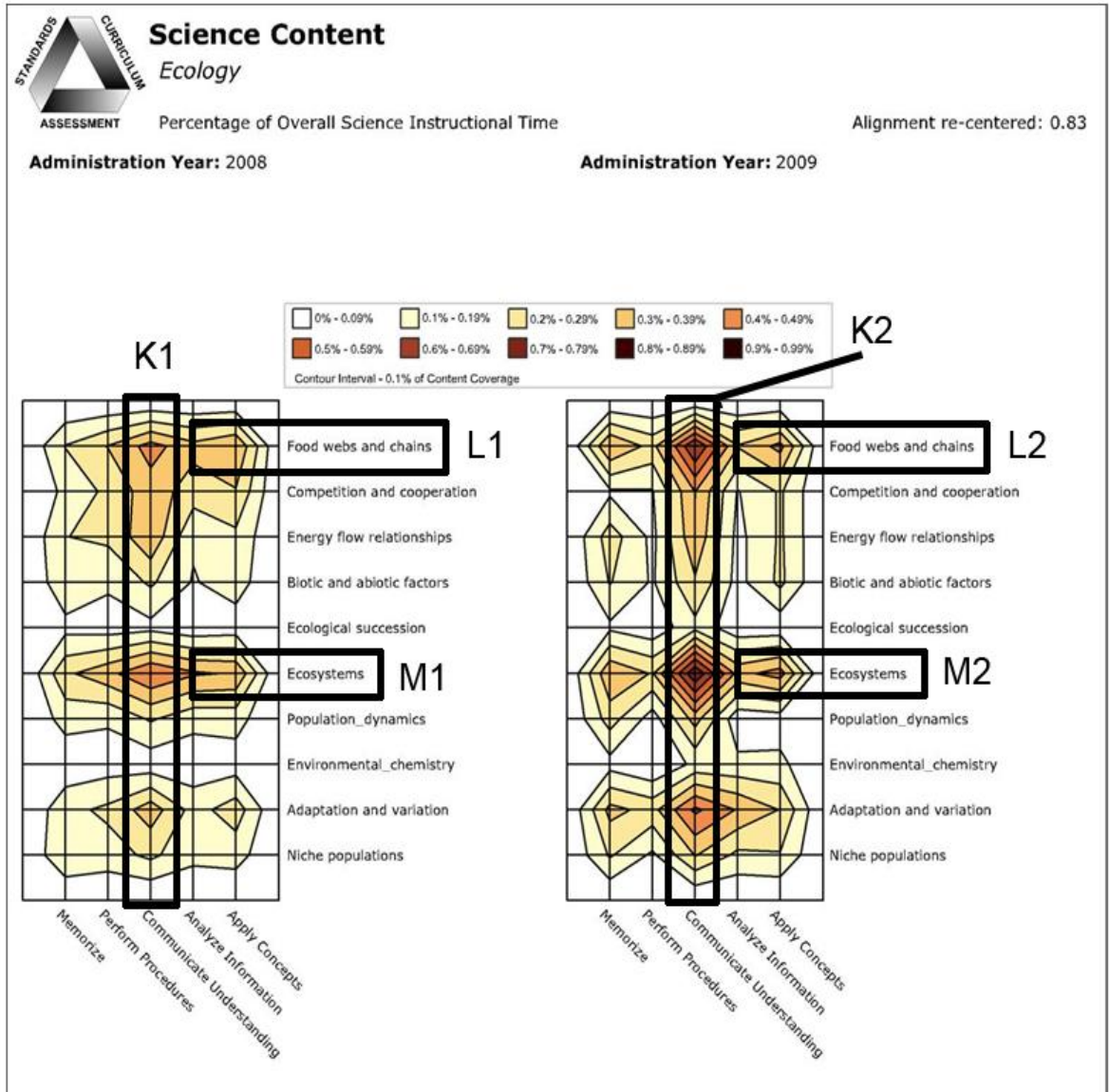


Figure 4. SEC – Ecology.

Ecology. Three areas of interest in Figure 4 can be seen in the center of the ecology maps along K1 and K2. The 2008 map shows this topic was already present in the STaRRS teachers' curriculum and teacher expectations were mostly focused on engaging student in communicating their understanding. However, these maps

demonstrate that in 2009 the teachers reported substantial increases in time spent having student communicating understanding (K2) in three subtopic areas: (a) food webs and chains; (b) ecosystems; and (c) adaptations and variations. Additionally, teachers reported spending more time having students apply concepts about food webs and chains (L1) and (L2) and ecosystems (M1) and (M2). All of the concepts on this map are specific to E:Y! and their Ecology Day curriculum which followed the Geology Day/STaRRS curriculum during the expedition.

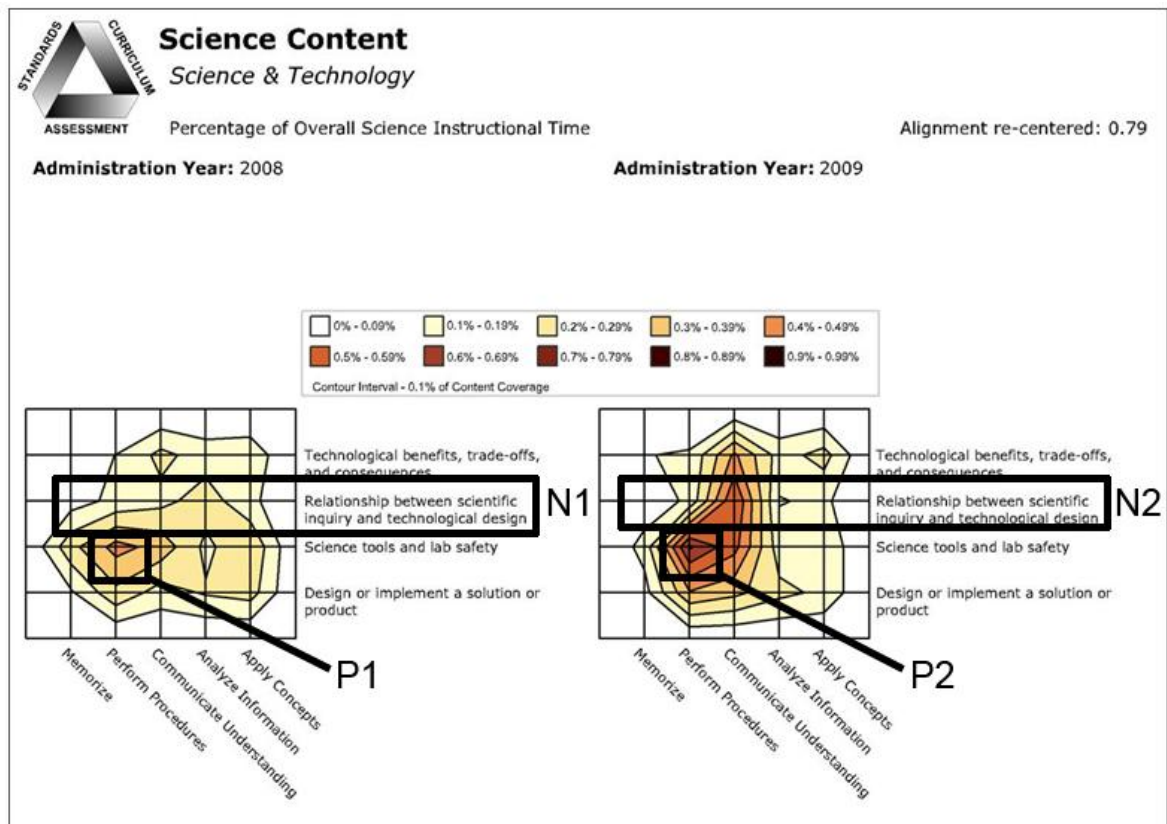


Figure 5. SEC – Science and technology.

Science and technology. The findings apparent in the science and technology fine-grained maps (Figure 5) were somewhat hidden in the large grained map (Figure 1). This is partly because none of the specific nodes (where the crosshairs meet) on the broad

topic area map were reported by teachers to be of primary focus. However, a greater distribution of increase in time reported in 2009 across this topic area is easier to see in Figure 5. In 2008, STaRRS teachers reported their strongest area of focus to be at (P1) where performing procedures intersects with lab tools and safety. The increase in this subtopic area in 2009 (P2) could represent an increase in emphasis on the safe use of tools in the field and behavior around the hot springs during data collection. Both safety and behavior are covered in detail at all expeditions but field notes from the STaRRS expeditions match the teachers' reported increases in time spent because more time was spent at the springs conducting field research.

Another area showing an increased emphasis is found at the node where the relationship between scientific inquiry and technological design and communicating understanding intersect (N1) and (N2). This finding may represent the increased time spent designing field research projects prior to and during the expeditions.

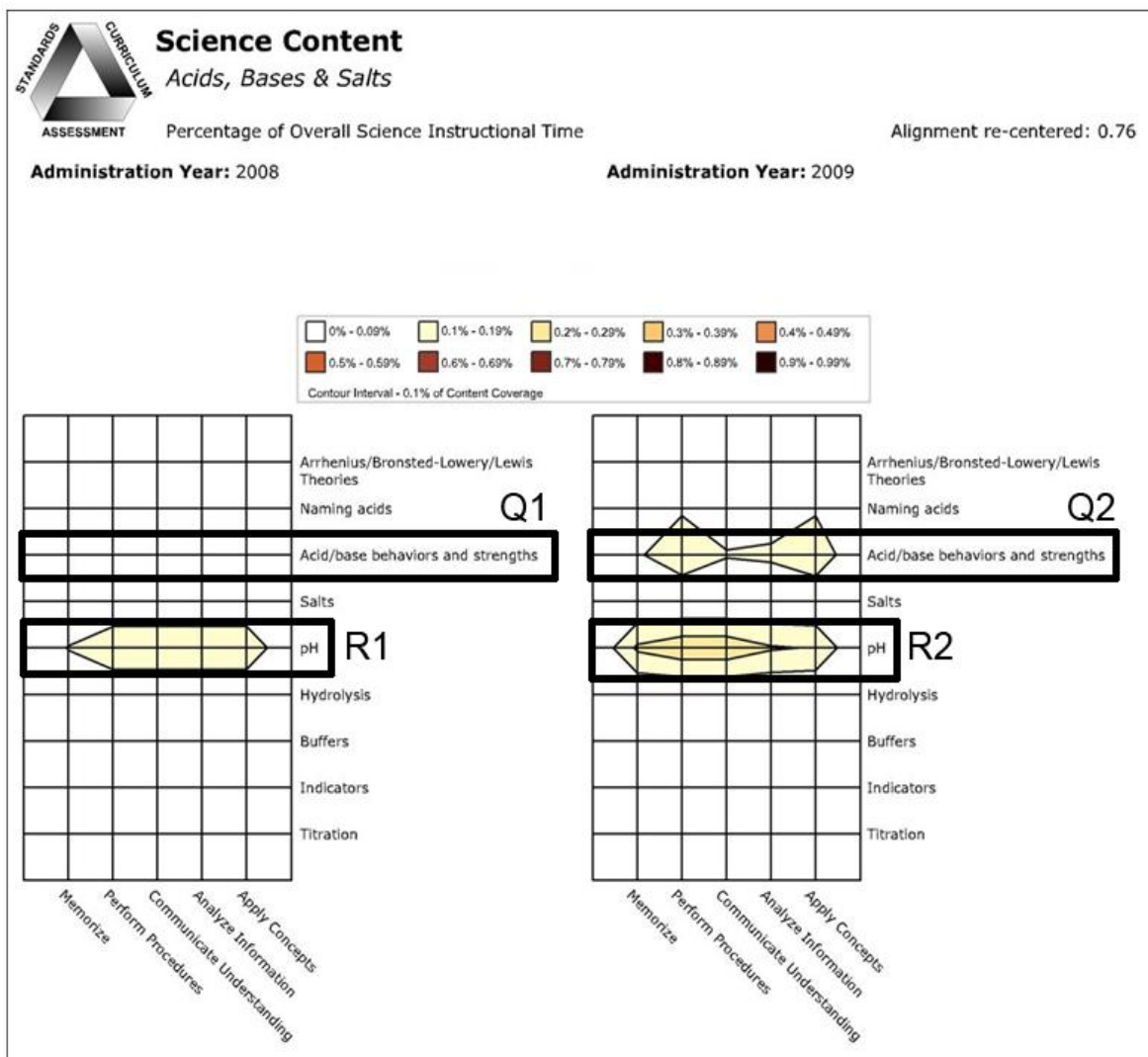


Figure 6. SEC – Acids, bases, and salts.

Acids, bases, and salts ($n=7$). The final content map (Figure 6) showing the topic areas related to acids, bases, and salts is a content area usually covered more in-depth above the eighth grade level (NSES, 1996). However, pH was an area of minimal focus in 2008 and was most likely related to the regular E:Y! curriculum (YAI & YNP 2004a). Small increases represented in the 2009 maps of time spent across all cognitive demand areas in acids, bases, behaviors and strengths (P2) and pH (Q2) may have been due to attention to pH as a result of the development and selection of field research questions by

students. Both STaRRS teachers and their students were especially interested in colors produced by microbial mats observed at MHS. Because of this interest, every teacher had at least one student group exploring the relationships between the colors and pH levels of the spring water. This would have necessitated extra instructional time and focus on pH.

It is important to note that of the nine teachers only seven reported teaching pH within their classrooms. This is most likely an artifact of the difference in the grade level and subject matter taught by the teachers versus the groups they brought to Yellowstone. For example, as mentioned earlier, the Language Arts teacher taught science topics to STaRRS students outside of her regular classroom teaching but was not able to report this on the SEC. One other teacher taught much younger students in the regular classroom (second grade) and pH is not an appropriate topic for primary grades. Therefore, no data was reported by this teacher for either year.

Findings for Research Question Two: Impact on STaRRS and E:Y! Students

Content knowledge. The first part of research question two explored the impact of students' participation in STaRRS on their content knowledge gains. Identical versions of the GCI-MLS were used to measure geoscience content knowledge (Appendix C). ANCOVA was used to analyze the students' data in four sections: (a) GCI-MLS total test (TT); (b) general knowledge (GK) subsection; (c) E:Y! content subsection; and (d) STaRRS content subsection. Descriptive statistics, including pre- and post-test means, standard deviations, ranges, differences, and percentage gains for the TT and the three subsections, can be found in Table 13.

Table 13

GCI-MLS – E:Y! and STaRRS Students' Pre-test/Post-test/Difference Scores and Percentage Gains

Groups	Pre-test <i>M</i> (<i>SD</i>)	Range	Post-test <i>M</i> (<i>SD</i>)	Range	Difference <i>M</i> (<i>SD</i>)	% Gains
TT (42 items)						
E:Y!	11.60(4.47)	2-24	13.68 (4.81)	3-25	2.09 (4.18)	4.8%
STaRRS	13.18 (4.87)	2-28	20.12 (6.66)	4-35	6.93 (6.18)	16.7%
GK (21 items)						
E:Y!	8.33 (3.27)	2-17	9.28 (3.44)	1-17	0.95 (3.36)	4.5%
STaRRS	9.24 (3.33)	1-19	10.98 (3.68)	3-18	1.74 (3.61)	8.2%
E:Y! content (7 items)						
E:Y!	1.64 (1.24)	0-5	1.93 (1.33)	0-6	0.29 (1.46)	4.1%
STaRRS	1.77 (1.37)	0-5	2.75 (1.50)	0-6	0.98 (1.75)	14.0 %
STaRRS content (14 items)						
E:Y!	1.63 (1.37)	0-6	2.47 (1.62)	0-6	0.84 (1.71)	6.0%
STaRRS	2.16 (1.64)	0-6	6.39 (3.18)	0-12	4.23 (3.16)	30.0%

Table 14 shows the ANCOVA findings. These findings reveal that students in the STaRRS group made significant gains in all areas ($p < .01$) compared to the E:Y! students, after correcting for pre-test differences. Another look at the descriptive statistics gives a better idea of the practicality of these gains. On the TT, STaRRS students averaged a nearly seven point gain as opposed to a two point gain for the E:Y! students. The percentage gained by STaRRS students is nearly 12% greater than for the E:Y! students. The GK subsection revealed 4% greater gains by STaRRS students. For the seven point subsection covering E:Y! content, STaRRS students showed gains nearly 10% greater than E:Y! students. The high percentage for the E:Y! content subsection is an artifact of the small number of questions on this section of the test. However, on the 14-question the STaRRS content subsection, STaRRS students made average gains 24% greater than their E:Y! counterparts.

Cohen's d was calculated for each of the results using Thalheimer and Cook's (2002) methodology for calculating effect size. Practically speaking, the effect size of the gains on the TT (0.91) and the STaRRS subsection (1.33) are very large, while the E:Y! subsection had a moderate gain of 0.43 and the GK subsection had the smallest gain of 0.23. The gains on the GCI-MLS, with the exception of GK, are above Cohen's (1988) standard of 0.33 SD . Based on that standard, they can be viewed as moderate to large changes.

Table 14

ANCOVA GCI-MLS with Pre-test Covariates

Source	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
TT Pre-test Covariate					
E:Y!/STaRRS	2604.57	1	2604.57	103.85	.000**
TT Pre-test	3185.46	1	3185.46	127.01	.000
Error	9053.73	361	25.08		
GK Pre-test Covariate					
E:Y!/STaRRS	133.01	1	133.01	13.67	.000**
GK Pre-test	1079.31	1	1079.31	110.92	.000
Error	3512.71	361	9.73		
E:Y! Content Pre-test Covariate					
E:Y!/STaRRS	54.37	1	54.37	29.74	.000**
E:Y! Pre-test	63.84	1	63.84	34.93	.000
Error	659.86	361	1.82		
STaRRS Content Pre-test Covariate					
E:Y!/STaRRS	1178.50	1	1178.50	199.71	.000**
STaRRS Pre-test	195.53	1	195.53	32.97	.000
Error	2130.30	361	5.90		

** $p < .01$, two-tailed.

Attitudes. The scales used for the student version of the ToSRA included Normality of Scientists (NS), Attitude to Scientific Inquiry (INQ), Enjoyment of Science Lessons (ENJ), and Leisure Interest in Science (LEI). Table 15 presents the raw means

and *SD* for each of the scales, ranges, and pre- and post-test differences. The raw score on the each scale of the ToSRA has a range of 10-50.

Table 15

ToSRA Gain Scores, Differences and Percentage Change for E:Y! for STaRRS Students

Scale	Pre-test <i>M (SD)</i>	Range	Post-test <i>M (SD)</i>	Range	Difference <i>M (SD)</i>
Normality of Scientists (NS)					
E:Y!	33.86 (5.20)	21-47	34.34 (5.84)	14-50	0.48 (5.99)
STaRRS	35.95 (5.06)	23-48	38.51 (6.25)	18-49	2.56 (5.85)
Attitude To Inquiry (INQ)					
E:Y!	40.17 (7.31)	21-50	40.25 (8.20)	10-50	0.08 (7.38)
STaRRS	38.93 (6.38)	20-50	38.58 (7.05)	10-50	-0.35 (6.60)
Enjoyment of Science Lessons (ENJ)					
E:Y!	39.60 (8.06)	15-50	36.79 (11.19)	10-50	-2.82 (8.89)
STaRRS	37.29 (8.61)	11-50	36.12 (8.85)	10-50	-1.17 (7.75)
Leisure Interest in Science (LEI)					
E:Y!	33.94 (8.80)	11-50	30.19 (8.51)	10-50	-3.75 (9.22)
STaRRS	30.72 (8.51)	12-50	29.78 (8.24)	10-50	-0.94 (6.70)

Note: 10 questions in each subscale.

When the STaRRS and E:Y! students were compared using ANCOVA, STaRRS students' showed significant differences on two scales. Table 16 shows these results. On the NS scale, this was a positive difference ($p < .01$), with STaRRS students demonstrating increased positive attitudes regarding the idea that scientist are regular people. This change was calculated to have an effect size of 0.35, so it this change is considered to be of moderate practical importance. On the second scale, LEI, the change was a reported as a decrease in positive attitude ($p < .05$) However, STaRRS students decreased significantly less than their E:Y! counterparts. In other words, although E:Y! and STaRRS students all exhibited more negative attitudes on the post-test towards engaging in science-type activities in their leisure time, the STaRRS students' decrease was significantly less than that of the E:Y! students. The effect size of this difference was also was calculated at 0.35, which indicates moderate practical significance. The percentage of increase on the NS scale and decrease on the LEI scale are shown graphically in Figure 7. The other two ToSRA scales, measuring students' attitude to inquiry (INQ) and their enjoyment of science classes (ENJ), did not show any significant pre-post differences.

Table 16

ANCOVA ToSRA Scales with Pre-test Covariate

Source	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
NS – Pre-test Covariate					
E:Y!/STaRRS	827.35	1	827.35	28.211	.000**
NS – Pre-test	2173.92	1	2713.92	92.54	.000
Error	10733.70	366	29.33		
INQ – Pre-test Covariate					
E:Y!/STaRRS	77.82	1	77.82	1.87	.172
INQ – Pre-test	6209.78	1	6209.78	149.45	.000
Error	15207.72	366	41.51		
ENJ – Pre-test Covariate					
E:Y!/STaRRS	94.81	1	94.81	1.47	.226
ENJ – Pre-test	13615.19	1	13615.19	211.19	.000
Error	23595.62	366	64.47		
LEI Pre-test Covariate					
E:Y!/STaRRS	243.85	1	243.85	4.26	.040*
LEI – Pre-test	11226.78	1	11226.78	196.86	.000
Error	20946.88	366	57.23		

* $p < .05$, two-tailed.** $p < .01$, two-tailed

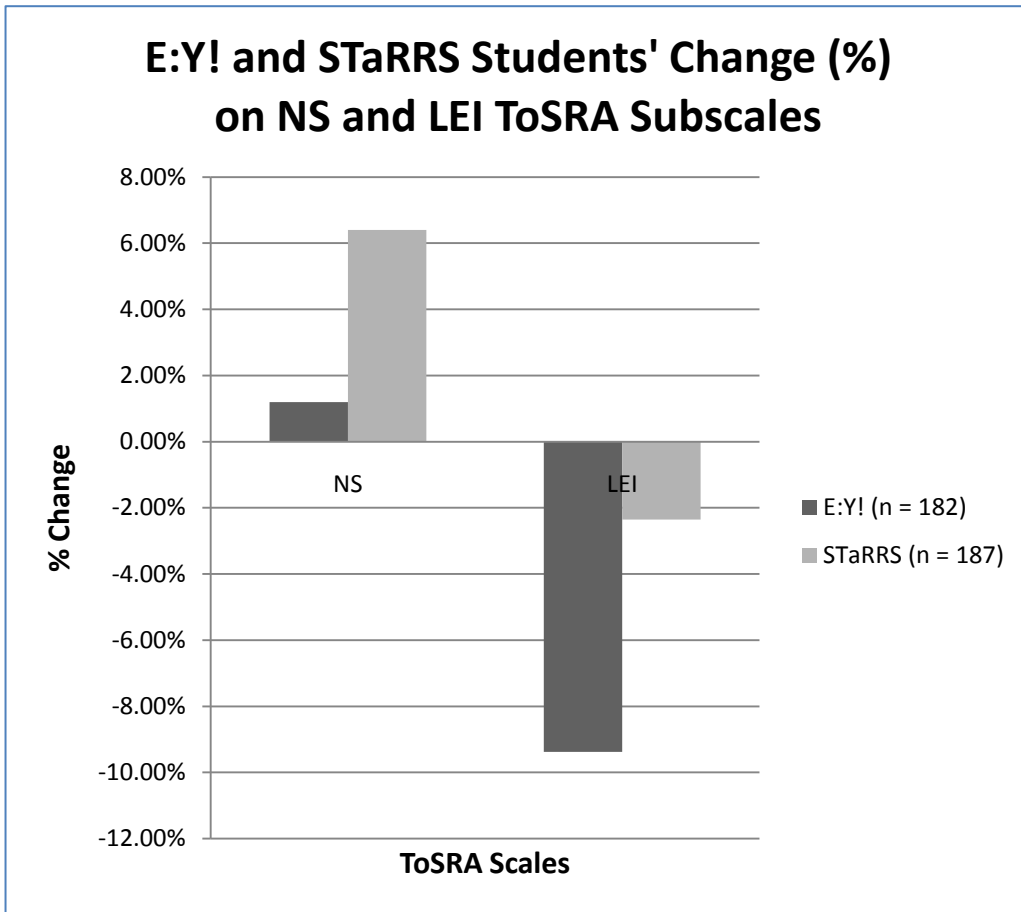


Figure 7. Percentage differences in changes on students' ToSRA – NS and LEI scales.

Summary

The findings presented in this chapter help to answer the research questions regarding the impact of the STaRRS STSP participation. They confirm and illustrate significant effects on both teachers and students. The teachers, who did not have a comparison group, demonstrated small gains in content knowledge on the GCI. Teachers did show significant changes in their attitudes on four of the five ToSRA scales. Visual comparisons of content maps from the SEC provide evidence of pedagogical changes in the STaRRS teachers' classrooms post intervention. These shifts were found in time

spent on various science topics and teachers' cognitive expectations of students related to E:Y! and STaRRS curriculum content areas.

Student findings demonstrated statistically significant gains for STaRRS students on the GCI-MLS as compared to the E:Y! comparison group. Attitude changes as measured by the ToSRA, showed STaRRS students' results significantly differed from E:Y! students in two areas. A positive significant change was found for STaRRS students on the scale measuring attitudes of their view of scientists. On the scale that measured their leisure interest in science, E:Y! (comparison) students showed an increased negative attitude that was significantly larger than shown by the STaRRS students.

Chapter Five

Discussion

Introduction

This research study was based on the development of an STSP that addressed inquiry-based, experiential, authentic science experiences. The research questions sought to identify the impact of STSP participation on the STaRRS teachers' content knowledge gains, attitude changes, and pedagogical strategies, as well as STaRRS students' content knowledge gains and attitude changes. The STSP literature to date has not provided evidence of content knowledge gains and attitude changes in teachers or students who participate in STSPs. The findings presented in this study may be the first to verify their existence.

The findings are clear. Participation in STaRRS did impact the attitudes and geoscience knowledge among students and teachers and the pedagogy of teachers. Now, it is time to take a step back and look again at the larger picture of the partnership. Why did attending to some of the needs of the scientists, teachers, students, and park rangers result in measurable change?

Three themes that emerged during the course of the study will drive this discussion. Though they are not completely distinct and overlap in many areas, they can be broadly defined as: (a) Research science as a catalyst for change within E:Y!, within classrooms, and in teachers' and students' attitudes; (b) Professional development effects through interactions with partners and experiential activities; and (c) The liaison as a vital component to the partnership in addressing challenges and aiding change.

Scientific research as a catalyst for change. In the context of attempting to answer scientific questions about the hot springs systems at Yellowstone, three main research activities connected the students, teachers, YNP E:Y! rangers, and scientists: (a) gathering photo point data of changes in hot springs at specific pre-selected locations; (b) collecting specific transect data for small sections of hot springs for the research scientists; and (c) generating student-driven field research studies. These STaRRS research activities provided a full inquiry cycle and research experience for the teachers and students while at the same time connecting them and their classroom communities to a larger scientific research project.

Moss et al. (1998) discussed the fact that STSPs need not limit student involvement to protocol data collection and analysis by scientists. They felt that encouraging the students to explore scientific-related areas of interest regarding their own questions might make the experience more authentic for students. The STaRRS partnership followed Moss et al.'s recommendations by including student-driven research projects.

In retrospect, however, the benefits did not arise just from the research experience itself. Connecting to the content focus of the university research group's geobiology science, learning how to use the tools and their limitations, and learning about the characteristics of the hot springs system gave the students a foundation on which to ask and research their own questions. I believe strongly that it was the combination of these activities that gave the students their initial purpose, which was helping with the university research that led to their own successful research experiences.

Participating in a full cycle of inquiry, including presenting their findings to their classmates and later to a broader audience, provided students with strong ownership. In fact, a judge of one of the E:Y! STaRRS projects in a Montana regional science fair told two teachers that he “loved that the students weren’t parroting their projects, they *owned* the knowledge” (Personal communication, Siri and Anna, April, 2009).

A full cycle of scientific inquiry was heavily encouraged with all STaRRS groups, even within the already packed expedition schedule. In spite of expedition time constraints, the analysis of field data and presentations of findings were carried out by students at the end of Geology Day. In retrospect, these presentations seemed to serve two purposes. First, they completed the cycle for the students, refining their thinking and helping them make connections. Many students reported in post-evaluation interviews that it was during the presentations (giving their own and watching others) that they really understood what they were doing and how scientific inquiry processes worked.

As students presented their results to their classmates, they were able to make connections between their own work and that of their classmates because of their common experiences in the use of the tools and development of their research projects. In one case, a group exploring the relationship between the colors of the microbial mats and pH realized that perhaps the colors may also be related to the spring water temperatures. They made the decision to use another tool to collect temperature data in addition to their pH data. And they were able to corroborate their results with other groups’ data during the aforementioned presentations.

The presentations also served to provide feedback for the teachers and gave them evidence of student learning long before the post-test was given. This could have helped

to change the teachers' attitudes and beliefs about using the STaRRS strategies and activities. The following story highlights this point more clearly. One of the STaRRS groups brings only teachers (rather than parents) as chaperones. Two of these teachers, not including the STaRRS teacher from this school, approached me (in my role as liaison) at the end of the field experience just prior to the student analysis of data and presentation of findings. They said they were very concerned about the time spent on the project including the extra week spent prior to the expedition teaching STaRRS content and processes. In addition, extra time had been spent in the E:Y! classroom and now, after more than six hours in the field including data collection, they felt that the students didn't "get it." In fact, they weren't sure if they themselves got it!

I asked them to give me two more hours during which the processing and presentations would take place. They agreed. They returned to me immediately following the student presentations saying "They got it! And now, so do we!" The evidence of student understanding was overwhelming and had produced a verbal attitude change in these teachers. This change matches Guskey's (2002) model of the order of occurrence in the change of teacher attitudes and beliefs. Unlike the traditional model that proposes belief and attitude change in teachers happens prior to changing teaching strategy, Guskey suggested these changes are followed by evidence of changes in student outcomes. I believe there may have been similar experiences for my STaRRS teachers that were then manifested in their ToSRA results.

The trends indicating changes in teachers' pedagogical strategies are encouraging. These changes simply could be attributed to compliance by teachers to the STaRRS curriculum and the requirements of the partnership. However, evidence of changes in a

content area (Ecology) that was not a part of the STaRRS curriculum but instead a topic area specific to E:Y!, may provide evidence that participation affected the teachers' pedagogical strategies beyond the STaRRS curriculum. Other evidence of this carry-over can be found in a story about Amy's trout.

Amy is a fifth grade teacher from Idaho who raises trout each year with her class. She had been having difficulty keeping all the trout alive. During the follow-up workshop, she approached me and excitedly told me, "Ana, all of our trout lived this year, we released all 11!" "What was the difference?" I asked. She looked at me seriously and said, "I understood pH better and was able to teach it to my kids better and this year they all lived." Though pH is generally a topic reserved for older students, STaRRS and students' interest in pH in the hot springs provided Amy with the opportunity to understand it better. Because of her experience, she was able to use this knowledge to help her teach another science unit.

Student content knowledge gains also showed both expected and unexpected outcomes. On the STaRRS content subsection of the GCI-MLS, E:Y! students, whose teachers were not privy to the new science content, tools, and techniques of studying hot springs were not expected to do as well on these questions and they did not. However, the STaRRS students did significantly better on all sections of the GCI-MLS including the portion attributed to E:Y! content. This subsection was made up of content that is taught at all expeditions.

The STaRRS students also performed better on the GK portion of the test. This subsection was matched to NSES (NRC, 1996) and state standards and is knowledge that is expected to match curricula in most schools. These findings may indicate that the

STaRRS experience enhanced students' science education in more areas than just the ones directly presented to them in pre-expedition class work and in expedition experiences and instruction. In addition, students' experiences as a whole may have led them to learn other geoscience topics with greater understanding.

Professional development effects. Many of the teachers' attitude changes can be attributed to specific partnership goals of the STaRRS scientists and activities conducted at the workshop. The first goal was focused on making science more accessible to students by involving them in data collection processes. The second goal was making explicit connections to how studying Mammoth Hot Springs (MHS) helps us (and the broader scientific community) to understand early earth environments, ancient and modern coral reef systems, and the search for life on other planets. It is possible that the latter of these goals, emphasized in the classroom and in the field at the workshop, helped teachers make personal connections and become more aware of the societal value of scientific research.

Attitudes were also most likely affected by teachers' interactions with the research science team, which included the primary research scientist and graduate students, at the professional development workshop. There were numerous occasions during the workshop when teachers were able to interact with the team on the same level, as peers. An example of this occurred when the transect grids (used for the second set of data collection by students) were presented for the first time at the workshop. Almost immediately these protocols were subjected to critical revision by the teachers and rangers due to factors that would inhibit data collection as it was originally envisioned.

Originally, the transect grid measured one meter by one meter. Although this may have been an appropriate size for an adult to carry into the field, the focus in E:Y! STaRRS was on student engagement; participation by students required a revision of the frame to a smaller 50 x 50 cm size to match the stature of a 10-14 year-old. Other aspects of the protocol, which involved scientific inquiry skills such as sketching, photographic data collection, and communication with scientists, were also revised to match the student abilities while still meeting the scientists' need for accurate data collection.

These intense interactions with the research science team, carried out as peer-to-peer discussions, may have helped to reshape some of the teachers' attitudes about scientists. Since the protocols presented were not finalized, involving the teachers and rangers in the revision process allowed them to take part in this aspect of the scientific process. In addition, while revising the protocols, the teachers and rangers became the experts because of their experiences with 10-14 year old students at Yellowstone in various types of weather (including expeditions in the winter that necessitated the use of snowshoes). These aspects, which had not originally been considered by scientists in the development of the protocols, were given equal weight in these discussions. This gave the teachers' and rangers' opinions credibility.

Although this type of iteration is common in science, it is not often seen in action by the general public, most of whom, including teachers, receive most scientific news in already cleaned-up sound bites. Participating in the revision process may have given the teachers new insights into how field research is planned and set up, and altered their views of and attitudes about science and scientists.

The student research component of the partnership was, in many ways, the capstone experience of STaRRS. Initially, these experiences were modeled first for teachers during the workshop. Later, they were used as the framework for the STaRRS curriculum. The professional development literature reinforces the importance of teachers being able to experience this process fully for themselves so that they can understand it, work out any difficulties they anticipate for their students, and use their experiences to integrate newly learned material and procedures into their own classrooms (e.g., NRC, 1996).

Developing answerable questions was a new skill for most of the teachers. For many of them, their only experience developing their own questions was at the workshop. They had not taught this skill to their students before. This is not surprising as most science curricula, including guided inquiry, often provide the actual questions or suggestions of questions for teachers to use in student exploration. The teachers' need for support in this area was addressed through the development of a set of activities. These activities were fleshed out in the STaRRS classrooms during the year and shared with the rest of the group through bimonthly communications and web-conferences.

Question development was complicated further by the fact that weather, safety, and the quality of the hot springs at the time of data collection could limit the use of specific questions. The springs are incredibly variable in their flow rate. When the groups arrived at the study site, over half of the groups had to change their questions to fit the current conditions of the spring. The first STaRRS group shared these glitches with the upcoming groups and teachers spent more time on developing questions than was originally planned. It made a difference. Students who came up with their first set of

questions prior to their field experience were able to do so again on the spot with ease. The STaRRS experience highlights the importance of actively and explicitly teaching this skill within a professional development workshop and providing activities and support to help teachers implement it in the classroom.

The liaison as a vital component in the partnership. Because they were not involved in the data collection and analysis, the rangers' role has faded somewhat into the background. However, they were also important players in this partnership. The Yellowstone education staff has experienced minimal turn-over in the past two decades. Thus, most of the rangers have been working with E:Y! for many years. They are comfortable in their roles and are highly effective at teaching the regular E:Y! content and activities to visiting teachers and students. When the project began, they were able to make immediate connections between the current E:Y! curriculum and the proposed STaRRS work.

Only one of the regular E:Y! rangers and three other education rangers, including Ben, who was the E:Y! ranger's supervisor, were able to attend the summer workshop. The other three regular E:Y! rangers were not able to attend. During the week-long pre-E:Y! staff development in the fall of 2008, I spent eight hours with the education staff reviewing the professional development from the summer workshop in preparation for the STaRRS groups arrival. However, it became clear that in order for the rangers to be able to assist with the STaRRS instruction, they would have needed more training than I was able to provide during that time. Thus, my role as the liaison included some STaRRS instruction during the expeditions.

Though low turnover has added to the stability of E:Y!, it may have hindered change within the STaRRS project. Two of the E:Y! rangers were very worried that eliminating the usual E:Y! trip to Norris Geyser Basin in lieu of spending more time at Mammoth Hot Springs (MHS) would mean students did not learn as much about Yellowstone's geothermal features and would become bored staying in one place for so long. In reality, the extra time spent on research at MHS for STaRRS students gave them much more time to gain a deeper understanding of the hot springs systems. Teachers confirmed this in their post-expedition interviews which reported their perceptions of differences in regular E:Y! versus STaRRS. For example, Gretta said:

I think that the geology day was fundamentally different, it was good, in a positive way ... what [the students] are going to remember about what they did is maybe more intense because of the research ... I think when I ask this group in two years about geology day, they are going ... to remember the research pieces that they did and they are going to have a different attachment to [YNP].

Student knowledge was demonstrated again in their post-E:Y! community presentations and science fair entries. In addition, many of the students talked about bringing their families back to show them the hot springs where they conducted their research. Also, there were no behavioral issues to indicate boredom on the part of students during their extended time at MHS. Even the rangers admitted that this did not end up being a problem.

In some cases, it was not only the rangers who were resistant to changes. Although STaRRS was meant to replace some of the Geology Day content of a regular expedition, this caused an additive effect, which caused a problem for some of the STaRRS groups. Even though all STaRRS teachers wanted the new content and activities for their students, they, like the rangers, were also reluctant to give up some of their

favorite E:Y! activities. This overloaded some of the expeditions. For example, some teachers scheduled extra hikes outside of the expedition time. They visited Norris Hot Springs with a ranger for an extra final hike on their way back through the park after the expedition. It is important to note here that both the teachers and rangers admitted during the post-STaRRS workshop that they were the ones who wanted to retain all of the original activities and they realized that their students, at E:Y! for the first time, would not have known if they had eliminated a certain hike, field activity or classroom session. But it was difficult for the teachers and rangers to let these go.

STaRRS was enthusiastically supported by the E:Y! rangers' supervisor, Ben. His support became important especially when there was resistance to removing regular E:Y! lessons to make room for the STaRRS preparation and follow-up activities. On a few occasions, Ben and another education ranger were able to join STaRRS groups on Geology Day to add support for the research data collection activities or be an authentic audience for student presentations in the evenings. These rangers' presence helped to establish legitimacy for the project both for the students and the regular E:Y! rangers.

One of the reasons STaRRS worked in spite of the overload was my role as the liaison. I helped both the rangers and the teachers ease their tensions and worries about the project. Understanding the needs of the teachers (as a former classroom teacher of fifth and eighth grade students) and the rangers (by spending time with them participating in expeditions and learning about E:Y! from an evaluative standpoint (Houseal, 2007)) was critical to the success of this partnership.

Although this was an STSP, the students' interactions with the lead scientists in the project were limited. With the exception of one group, who happened to be in

Yellowstone when the principal investigator (PI) was doing research in the park, none of the students met the PI or the other main research scientist from the group except through a five minute video-recording presented to the students at the beginning of the year.

However, the STaRRS students as a whole demonstrated increased positive attitudes regarding scientists at the end of the year. There could be several reasons for this change.

First, as a liaison, I visited and worked with every group of students prior to their expedition and spent the week in Yellowstone with them working alongside their teachers and the rangers. My familiarity with the research, tools, scientific inquiry, and education placed me in a position of being portrayed by some of the teachers as a geobiology scientist to their students. In the role of the liaison and researcher, I also helped cook and clean, ate meals, hiked, and participated in all aspects of the expeditions with the students. It is possible that students used me as a scientist role model when they filled in the final ToSRA.

Secondly, the experiences of the teachers at the professional development workshop with the scientists were well-documented in their classrooms by bulletin boards filled with photos, maps, and materials related to the summer workshop. On more than one occasion I personally heard teachers sharing exciting and positive stories about the scientists with their students. In these ways, the teachers' enthusiasm may have also influenced their students' attitudes.

A third possibility for their positive attitude is that the students were convinced that what they were doing in their STaRRS work was what scientists do. Seeing themselves and each other in this role may have added a familiar face to their views of scientists. Finally, my role as liaison likely mitigated difficulties within partnerships such

as lack of communication among the scientists, teachers, and students as noted in earlier STSP literature (e.g. Carr, 2002).

Implications

There are several implications that can be derived from this study. First, I believe that the attention paid to finding solutions to some of the challenges faced by past partnerships in the development of STaRRS may have helped with its success and the changes documented in this research. The key component was having a liaison in place to facilitate the implementation of the partnership and much needed on-going communication.

The implications for the role of the liaison should not be underestimated. In this partnership, this role was vital in convincing the partners that the change was ‘good’ and worth the sacrifice of some of the original EY! activities. The liaison role also included: (a) facilitating communication as needed among the university research scientists, rangers, and teachers within the individual schools and expedition contexts; (b) developing lessons and activities that supported the teaching of the content, skills, and processes needed to carry out the research data collection; (c) establishing communication among the teachers throughout the year so that they could share lessons learned after each of the expeditions; and (d) providing a follow-up workshop for the scientists, teachers, and rangers to share of the challenges and successes of the year, and look to the future.

The focus of these implications need not be on the work of a single person, but on the different roles played by the liaison in this partnership. Institutionalizing these roles

by using one or more individuals within an STSP should be considered. For example, planning and implementing the STSP's professional development workshops, development of accompanying curriculum, and the STSP's intra-partnership communication could be distinct jobs carried out by up to three different people. Also, once the curriculum is developed, it would become a fixed component of the partnership, and would not require continual attention.

These implications bring up the question of generalizability. A distinct limitation of the potential for generalizing the findings of this project is the fact that it was well-funded (NSF RET: EAR-0221743) and located in a popular national park. As the liaison and researcher, I was able to commit my full attention to it during the research year. Equipment for teachers and students, the workshops, and follow-up support during the school year were all funded by the grant. Teachers were also paid a stipend for participation, though the amount was minimal when compared to the number of hours worked by the teachers.

However, these limitations should not be seen as impediments to implementation for other similar STSPs. There are interesting science research projects being conducted in national, state, and local parks all over the country. With creative planning, these scientific research projects could be connected to local school groups and developed into successful STSPs. The real shifts in the E:Y! program that occurred due to the addition of STaRRS was the way that the teachers and rangers thought about and implemented the geology day portion of the experience. This made the field experience richer by involving students directly in learning about the system using research as the vehicle.

Future Directions

Overall, positive findings produced by the STaRRS STSP warrant further research to see if similar findings can be reproduced in the future. During the follow-up workshop, many participants agreed that the STaRRS portion of E:Y! was too large for teachers to carry out each year without some revision to the E:Y! or STaRRS curriculum. Whether or not the same results would be obtained with a decreased student research or scientific data collection component would be worth exploring.

During the development and facilitation of STaRRS, I became suspicious that my role as a liaison might not only be vital to the success of the partnership but also make this success person-dependent. In retrospect, these suspicions were well-founded. My understanding the particular university scientific research (geobiology), middle level education and the cultures of both education and scientific research along with my National Park Service experience (in particular with E:Y!) prepared me to be the best person to navigate the year with all partners.

At their schools and E:Y!, teachers indicated to me that STaRRS would not have been possible to carry out without my assistance. The rangers agreed. Even at the eighth (and final) STaRRS expedition in May 2009, the E:Y! rangers did not feel comfortable enough to direct any of the pre- or on site field work. In some ways, my presence and role at all the expeditions enabled them to not take primary ownership in the partnership, since they were only asked to provide flexibility in the schedule and support in the field to allow for the complete inquiry cycle to take place.

In the end, the four E:Y! rangers all agreed that the STaRRS program was valuable, and provided benefits for the students. But they were divided equally on

whether or not it should continue within E:Y! Changes in the leadership within the Education and Interpretation Division at YNP and in some of the STaRRS schools meant that it was unclear how many teachers would attempt to incorporate STaRRS components into E:Y! the following year. However, new resources will be available. By August 2010, curriculum developed in conjunction with the project will be available on-line and there are plans for another STaRRS workshop in July, 2011. My hope is these resources will provide a catalyst for future iterations of this partnership.

Use of qualitative data such as field notes, artifacts produced by the partnership, and teacher and student interviews could give a richer picture of the lived experiences within the partnership and changes that were not assessed by the instruments. I plan to explore this rich data set looking for other findings related to teachers' and students' participation in the partnership.

Similarly, research on other STSPs with similar professional development components and student research focus would be important to see if the findings could be reproduced outside of this particular STSP. In addition, research is needed to explore the roles of liaisons within partnerships and the development of models for this critical component. National Lab Day, an initiative to connect current science projects with teachers and classrooms across the nation boasts over 980 partnerships as of March 2010. These partnerships could provide a wealth of research opportunities.

Conclusion

Scientific inquiry, both the processes used by scientists to build new knowledge and the methodology used to frame science education for students, were present within

STaRRS. In fact, the combination of being part of a larger research project coupled with the full cycle of scientific inquiry appears to have been fundamental to the changes found in the teachers and students.

Attending to the challenges inherent in this and many partnerships required a full-time liaison, the cooperation of the rangers, and substantial commitment from the teachers. Is this reproducible? I would venture a cautious “yes” with a caveat. A partnership such as this is like any complex relationship. It requires planning, attention, and flexibility. National Lab Day, an initiative to connect current science projects with teachers and classrooms across the nation boasts over 980 partnerships as of the spring of 2010. The number and scope of these partnership means there is an even greater need for continuing research into the characteristics of successful partnerships and their outcomes.

The idea behind these partnerships is too enticing for them to be dismissed. Key attributes include their ability to: (a) connect teachers and students to research science; (b) use accompanying experiential inquiry-based professional development that addresses the needs of the scientists, teachers, and students; and (c) provide student ownership of new knowledge through their participation in their own research projects within the partnership. Developers of future STSPs should consider the critical importance of connecting the two types of research activities by having accurate scientific data collection lead to the development and implementation of student-driven research. Further research on these key attributes will enable us to develop more solid and sustainable models for future STSPs

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Appendix A
Teacher Workshop Schedule

E:Y! STaRRS Teacher Workshop Schedule

	Monday July 14, 2008	Tuesday July 15, 2008	Wednesday July 16, 2008	Thursday July 17, 2008	Friday July 18, 2008				
7:30-8	Workshop preparation at Mammoth and the school	Breakfast available at the school -- pack lunches	Breakfast available at the school -- pack lunches	Breakfast available at the school -- pack lunches	Breakfast available at the school				
8-8:30		Field work on terraces Content: scale, facies, powers of ten, field research Observation activity at NG preparation for fieldwork on Tuesday and Wednesday	Big Picture discussion of workshop goals, questions, discussion prior to field	Final preparations for data collection	Work time at the school Whole group discussions re: Content, Processes, Curriculum integration, Question development. Small group work time				
8:30-9									
9-9:30									
9:30-10									
10-10:30									
10:30-11									
11-11:30									
11:30-12pm									
12-12:30						Ending field work at Mammoth Hotel -- Lunch on own -- be back at the school by 1:30 pm	Ending field work at Mammoth Hotel -- Lunch on own -- be back at the school by 1:30 pm	Ending field work at Mammoth Hotel -- Lunch on own -- be back at the school at 1:30 pm	Working Lunch at School
12:30-1									
1-1:30									
1:30-2	Review of morning content	Discussion, activities at the school -- team work time	Holly and Amanda's presentations of their research Group team work time at school, for analysis of data and presentation preparation	Group presentations (15-20 minutes each including discussion). Sharing of school-year plans.					
2-2:30	Introduction of new tools: IR thermometers, Kestrel weather stations, Grids	Preparation for Thursday's fieldwork							
2:30-3			STaRRS RESEARCH TEAM MEETING	Computer work time in Gardiner -- STaRRS website (Amanda)					
3-3:30	Teachers arrive at school: Check in preassessments	Discussion of BIG questions related to NSF and student research	Review tools, Review answerable questions		STaRRS RESEARCH TEAM MEETING				
3:30-4	Introductions, etc. at the school/Observation activities: Potato candle, Prolonged observations, Obs-certainers, discussion			HW: Have plan ready to go for Thursday field work	Clean up and pack up school, return materials to Education				
4-4:30		STaRRS RESEARCH TEAM MEETING	Dinner at Mammoth Hotel, entire group!!!		Dinner together in Gardiner for those who want to/are able to stay				
4:30-5	Dinner -- Pizza from Gardiner -- delivered to school	Dinner on your own (reimbursed Wednesday morning)-- Free evening -- well, with HW! Research team will be available for anyone		Dinner on your own -- Free evening -- Research team will be available for anyone					
5-5:30	Content introduction: Hot Springs Systems	Research team will be available for anyone	Continued field work planning if needed; possible field trip to Lamar Valley or Boiling River						
5:30-6									
6-6:30	Tool Introduction: Cameras	Discussion, logistics, housekeeping, & HW-							
6:30-7									
7-7:30	Discussion, logistics, housekeeping, & HW-								
7:30-8									
8-8:30									
8:30-9									

Figure A1. Teacher workshop schedule.

Appendix B
GCI for Teachers

Pseudonym: _____

DEMOGRAPHICS

Please answer the following questions about your background.

Gender _____

Birthdate: Day _____ Month _____ Year _____

Undergraduate Major(s) _____

Graduate Degree _____

Racial Background (check all that apply):

White Hispanic Asian

African-American Pacific Islander

American Indian Other _____

In which high school grade did you take:

Physics 8 9 10 11 12 Never

Chemistry 8 9 10 11 12 Never

Biology 8 9 10 11 12 Never

Earth Science 8 9 10 11 12 Never

(optional)

Highest degree of

Female Parent:

Elementary School

some High School

High School

some College

Bachelor's Degree

some Graduate School

Master's Degree

Doctoral Degree

Male Parent:

Elementary School

some High School

High School

some College

Bachelor's Degree

some Graduate School

Master's Degree

Doctoral Degree

GCI TEST QUESTIONS

Please answer the following questions to the best of your ability.

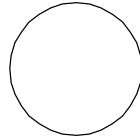
1. Some scientists claim that they can determine when the Earth first formed as a planet. Which technique(s) do scientists use today to determine when the Earth first formed? **Choose all that apply.**
 - (A) Comparison of fossils found in rocks
 - (B) Comparison of different layers of rock
 - (C) Analysis of uranium and lead in rock
 - (D) Analysis of carbon in rock
 - (E) Scientists cannot calculate the age of the Earth
2. Which of the following can greatly affect erosion rates? **Choose all that apply.**
 - (A) Rock type
 - (B) Earthquakes
 - (C) Time
 - (D) Climate
3. Which is the best definition of a tectonic plate?
 - (A) All solid, rigid rock beneath the continents and above deeper, moving rock
 - (B) All solid, rigid rock beneath the continents and oceans and above deeper, moving rock
 - (C) All solid, rigid rock that lies beneath the layer of loose dirt at the Earth's surface and above deeper, moving rock
 - (D) All solid, rigid rock and loose dirt beneath the Earth's surface and above deeper, moving rock
 - (E) The rigid material of the outer core

4. What did the Earth's surface look like when it first formed?



A

A. One large landmass



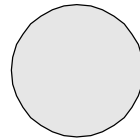
B

B. All water and no land



C

C. Similar to today



D

D. Mostly molten rock



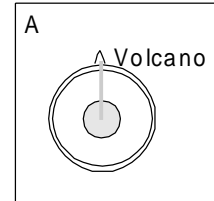
E

E. We have no way of knowing

5. Which of the following are associated with events that cause large earthquakes? **Choose all that apply.**

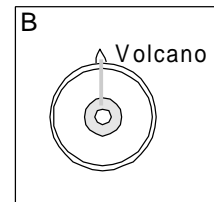
- (A) The construction and demolition of buildings
- (B) Weather
- (C) Bombs being dropped during a war
- (D) Continents moving
- (E) Changes in the Earth's core

6. On continents, where does most volcanic material come from?



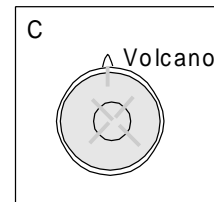
A

A. Material comes from the Earth's center, which is completely molten.



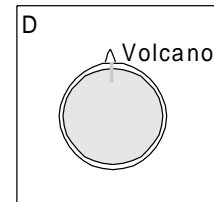
B

B. Material comes from a molten layer near the Earth's center



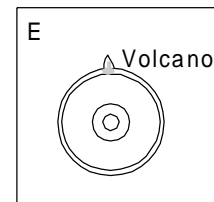
C

C. Material travels from the Earth's center to a molten layer just beneath the surface, mixes with this molten layer and then travels to the volcano.



D

D. Material comes from the molten layer beneath the Earth's surface



E

E. Material comes from pockets of molten material beneath the Earth's surface

7. Rocks found in oceans can be _____. **Choose all that apply.**

- (A) Formed by animals
- (B) Made up of pieces of continental rocks
- (C) Formed by volcanic activity

If you could travel back in time to when the Earth first formed as a planet: (use this statement for #7 & #8)

8. What would the Earth look like?

- (A) The Earth would be mostly covered with water
- (B) The Earth would be mostly molten
- (C) The Earth would be mostly covered with ice
- (D) The Earth would be mostly rocky

9. What type(s) of life do you think you might encounter?

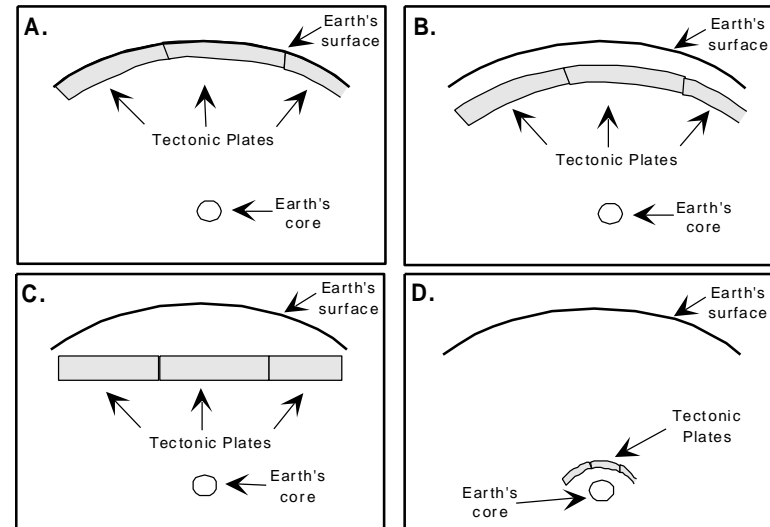
- (A) There would be no life on Earth
- (B) Simple, one-celled organisms
- (C) Animal and plant life in water, but none on land
- (D) All types of life in water and on land, except people
- (E) All types of life in water and on land, including people

10. Where are most rocks formed?

- (A) Most rocks form underground and are pushed to the surface by magma.
- (B) Most rocks form underground and are exposed when overlying rocks are removed.
- (C) Most rocks form underground, but can never travel to the surface.
- (D) Most rocks form at the Earth's surface.

11. Scientists often talk about the Earth's tectonic plates and their role in mountain formation, volcanism, and earthquake occurrence. Which of the following figures most closely represents the location of the Earth's tectonic plates?

Circle one: **A** **B** **C** **D**



12. If the single continent in #25 did exist, how long did it take for the single continent to break apart and form the arrangement of continents we see today?

- (A) Hundreds of years
- (B) Thousands of years
- (C) Millions of years
- (D) Billions of years
- (E) It is impossible to tell how long the break up would have taken

13. Which answer best describes what the surface of the Earth would be like if you could travel back to the time when the Earth first formed as a planet?

- (A) The Earth was about the same temperature as today, and covered with jungles at the surface
- (B) The Earth was about the same temperature as today, and covered with water at the surface
- (C) The Earth's surface and temperature were similar to today, although no cities existed yet
- (D) The Earth's surface was very hot and covered with melted rock
- (E) The Earth's surface was very cold and covered with ice

14. Fossils are studied by scientists interested in learning about the past. Which of the following can become fossils? **Circle all that apply.**

- (A) Bones
- (B) Plant material
- (C) Marks left by plants
- (D) Marks left by animals
- (E) Animal material

15. Over which of the following areas would the most clouds form?

- (A) One square-mile of land
- (B) One square-mile of ocean
- (C) One square mile of a region covered with plant life
- (D) One square-mile of a humid region along the equator

16. Which of the following responses best summarizes the relationship between volcanoes, large earthquakes, and tectonic plates?

- (A) Volcanoes are typically found on islands and earthquakes typically occur in continents. Both volcanoes and large earthquakes occur near tectonic plates.
- (B) Volcanoes and large earthquakes both typically occur along the edges of tectonic plates.
- (C) Volcanoes mostly occur in the center of tectonic plates and large earthquakes typically occur along the edges of tectonic plates.
- (D) Volcanoes and large earthquakes both typically occur in warm climates near tectonic plates.
- (E) Volcanoes, large earthquakes, and tectonic plates are not related, and each can occur in different places.

17. Why do tectonic plates move?

- (A) The eruption of underwater volcanoes pushes the tectonic plates
- (B) Currents in the ocean push against the tectonic plates
- (C) Earthquakes push the tectonic plates
- (D) Material is moving beneath the plates
- (E) Magnetism moves the tectonic plates

18. What is groundwater?

- (A) All liquid water that resides beneath the Earth's surface
- (B) Muddy mixture of water and dirt that lies beneath the Earth's surface
- (C) Only the water found in underground lakes and rivers that is clean enough to drink
- (D) Only water that is moving beneath the Earth's surface
- (E) Only water that is stationary beneath the Earth's surface

19. How big was the planet Earth when dinosaurs first appeared?

- (A) Smaller than today
- (B) Larger than today
- (C) Same size as today
- (D) We have no way of knowing

20. If you put a fist-sized rock in a room and left it alone for millions of years, what would happen to the rock?

- (A) The rock would almost completely turn into dirt
- (B) About half of the rock would turn into dirt
- (C) The top few inches of the rock would turn into dirt
- (D) The rock would be essentially unchanged

If you could travel back in time to when the Earth first formed as a planet:

21. How many years back in time would you have to travel?

- (A) 4 hundred years
- (B) 4 hundred-thousand years
- (C) 4 million years
- (D) 4 billion years
- (E) 4 trillion years

22. Which of the following best describes what scientists mean when they use the word “earthquake”?

- (A) All earthquakes create visible cracks on the Earth's surface
- (B) When an earthquake occurs, the earth shakes at least once every 10 seconds for a period of at least 1 minute
- (C) All earthquakes damage man-made structures
- (D) When an earthquake occurs, energy is released from inside the Earth
- (E) When an earthquake occurs, the gravitational pull of the Earth increases

23. How far do you think continents move in a single year?

- (A) A few inches
- (B) A few hundred feet
- (C) A few miles
- (D) Scientists do not have enough information to calculate the speed of continents
- (E) Continents do not move

24. Where can groundwater be found?

- (A) Only in wet climates
- (B) Only where there is dirt since water cannot move through rock
- (C) Groundwater can exist in rock or soil, but will not be found beneath the Earth's surface
- (D) Only where underground rivers connect to a spring
- (E) Almost anywhere beneath the Earth's surface

25. Some people believe there was once a single continent on Earth. Which of the following statements best describes what happened to this continent?

- (A) Meteors hit the Earth causing the continent to break into smaller pieces
- (B) The Earth lost heat over time and cracked, causing the continent to break into smaller pieces
- (C) Material beneath the continent moved, causing the continent to break into smaller pieces
- (D) The Earth gained heat over time and cracked, causing the continent to break into smaller pieces
- (E) Only a small number of people believe there was once a single continent, and it is more likely that the continents have always been in roughly the same place as they are today

Appendix C

GCI-MLS

Number and initials: _____

Male ___ Female ___ School name _____

Birthday Month _____ Year _____ Date _____

You may not know all the answers – that is fine. Answer them as best as you can. After you have answered the question – circle the emoticon that shows how sure you were of the answer you gave. For example if you wrote “I don’t know” and you are very sure of that, you would circle the first one. If you gave another answer but were unsure, you might circle the third one.

😊 = very sure 😐 = neither sure nor unsure ☹ = very unsure

If you could travel back in time to when the Earth first formed as a planet:

1. What would the Earth look like?

- (A) The Earth would be mostly covered with water
- (B) The Earth would be mostly molten/melted rock
- (C) The Earth would be mostly covered with ice
- (D) The Earth would be mostly rocky

😊 😐 ☹

2. What type(s) of life do you think you might encounter?

- (A) There would be no life on Earth
- (B) Simple, one-celled organisms
- (C) Animal and plant life in water, but none on land
- (D) All types of life in water and on land, except people
- (E) All types of life in water and on land, including people

😊 😐 ☹

Again, if you could travel back in time to when the Earth first formed as a planet:

3. What did life look like when it first appeared on earth? **You may draw a sketch or write or both**

😊 😐 ☹

4. How far do you think continents move in a single year?

- (A) A few inches
- (B) A few hundred feet
- (C) A few miles
- (D) Scientists do not have enough information to calculate the speed of continents
- (E) Continents do not move

😊 😐 ☹

5. What is a tectonic plate? **You may draw a sketch or write or do both**



6. Why do tectonic plates move?

- (A) The eruption of underwater volcanoes pushes the tectonic plates
- (B) Currents in the ocean push against the tectonic plates
- (C) Earthquakes push the tectonic plates
- (D) Material (like melted rock) is moving beneath the plates
- (E) Magnetism moves the tectonic plates



7. Which of the following responses best summarizes the relationship between volcanoes, large earthquakes, and tectonic plates?

- (A) Volcanoes are typically found on islands and earthquakes typically occur in continents.
- (B) Volcanoes and earthquakes both usually occur along the edges of tectonic plates.
- (C) Volcanoes mostly occur in the center of tectonic plates and large earthquakes typically occur along the edges of tectonic plates.
- (D) Volcanoes and earthquakes both occur in warm climates
- (E) Volcanoes, earthquakes, and tectonic plates are not related.



8. Why does Yellowstone National Park have hot springs?



9. Which of the following statements about the age of rocks is probably true?

- (A) Rocks found in the ocean are about the same age as rocks found on continents (large land masses)
- (B) Rocks found on continents are generally older than rocks found in the ocean
- (C) Rocks found in the ocean are generally older than rocks found on continents
- (D) None of the above; we cannot figure out the age of rocks precisely enough to figure out which rocks are older



10. How are fossils made? **You may draw a sketch or write or both**



11. Rocks found in oceans can be _____. **Choose all that apply.**

- (A) Formed by animals (either alive or after they have died)
- (B) Made up of pieces of continental rocks
- (C) Formed by volcanic activity



12. Why is studying fossils important?



13. Are rocks and minerals alive?

- (A) Yes, rocks and minerals grow
- (B) Yes, rocks are made up of minerals, and minerals are like plant cells
- (C) Yes, rocks and minerals are always changing
- (D) No, rocks and minerals don't reproduce



14. Fossils are studied by scientists interested in learning about the past. Which of the following can become fossils?

Circle all that apply.

- (A) Bones
- (B) Plant material
- (C) Marks left by plants
- (D) Marks left by animals
- (E) Animal material (like scat – animal feces)



15. What kinds of life are scientists looking for on Mars?



16. What is the key ingredient that might tell scientists that life was once on another planet?



17. Which of the following can make erosion happen faster or slower than usual? **Choose all that apply.**

- (A) Rock type
- (B) Earthquakes
- (C) Time
- (D) Climate



18. What is groundwater?

- (A) All liquid water that resides beneath the Earth's surface
- (B) Muddy mixture of water and dirt that lies beneath the Earth's surface
- (C) Only the water found in underground lakes and rivers that is clean enough to drink
- (D) Only water that is moving beneath the Earth's surface
- (E) Only water that is not moving beneath the Earth's surface



19. Are rocks and minerals alive? _____ YES _____ NO
Why do you think that?



20. Please fill in the Powers of Ten scale to be used when studying the following objects:

10^{-3} 10^{-2} 10^{-1} 10^0 10^1 10^2 10^3

- (A) The size of microbes _____
- (B) The size of the vent facies _____
- (C) The size of all of Mammoth Hot Springs _____
- (D) The size of the Yellowstone Caldera _____
- (E) The size of your hand _____



21. What are the five facies used to study Mammoth Hot Springs? (list the ones you know starting at the vent)

- (A) _____
- (B) _____
- (C) _____
- (D) _____
- (E) _____



22. Why do you think the Facies Model is used to study the hot springs?



Appendix D
Transect Protocol

Transect Protocol

STaRRS Grid Experimental Project Protocol

Flow rates, temperature, environmental conditions, and visual textual features are important factors contributing to the precipitation of calcium carbonate at Mammoth Hot Springs (MHS) in Yellowstone National Park (YNP). The _____ Research Group at the University of _____ has collected this type of data, although infrequently due to the expense of travel to the park, since starting this research. This experimental protocol directly involves students in collecting these data at a finer spatial resolution on a more frequent basis. Having these data will greatly enhance our understanding of the hot spring dynamics (geological and biological feature changes). The protocol uses tools that each student will know how to use and the data collection is facilitated with convenient data recording sheets (e.g., grids). Photographs and recorded data will be downloaded for sharing with all participating STaRRS groups. This will allow classrooms to make observation of changes at Yellowstone before and/or after they have visited the park. There will also be a web interface so teachers and students will be able to share their observations and questions. The STaRRS scientists will also use the data and share their on-going analysis.

Equipment needed:

Grid/Frame

Fishing pole and scale bar

Nikon P60 Digital Camera

Photo of location (if applicable)

Measuring tape

Stopwatch

Carbonate flakes/bark flakes

Protocol sheet, writing utensil

Infrared thermometer

Compass

Kestral3000

S'Cool Cloud Charts

Jobs to fulfill:

HOLDERS (2)

Photographer

Measurer

Timer

Sprinkler

Observer

Recorder

Number of people required: Minimum 5; Maximum 8

Objective: To record changes in a hot spring in a given location, over time.

Procedure:

1. Have two students hold the frame -- match it up to a previous photo if this is a designated STaRRS location. If not, choose a good spot and make sure to take close-up and wide-angle photos. Record the photo numbers on the data sheet.
2. A third student should hold the fishing pole with scale bar attached under the frame. The scale bar should be as close to the surface of the water but NOT touching it. It should be visible in the photograph and the scale bar should be parallel to the sides of the frame.
3. The recorder should also make a sketch of the area, using the compass to figure out and indicate N in relation to the frame and camera.
4. Note: the camera should be held parallel to the frame – See Sketch:

Recording atmosphere measurements:

5. Take Kestral3000 measurements: **average** wind speed, air temperature, relative humidity, dew point, wind direction and directional location (use compass to determine this). Take three measurements, 15 seconds apart and record the average measurements. Fill this information into the meta-data section of the field notes.

Recording temperature:

6. Using the infrared thermometer, point to the center of each 10x10 cm section (where the strings cross) and record the temperature across the section. Record this in **Grid #1** part of the field notes.

Recording flow path (including direction and speed if possible):

7. In **Grid #2**, draw the direction of the flow path, and record the rate of flow if possible (See below for directions. If not, indicate where the flow rates appear to be different.

Recording flow rate:

8. Measure the distance along the spring flow path across which flakes will be timed. A distance of 20 – 50 cm, may be sufficient. Record the distance in the second column of the flow rate data table.
9. Sprinkle a few flakes into spring water slightly upstream from the point where you want to begin your measurement.
10. Start timer as soon as flakes reach the starting point. The observer can call out “Start” as the timer begins timing.
11. Stop timer as soon as flakes reach the ending point. The observer can call out “Stop” as the timer stops the timer
12. Record this number (time in seconds) in the third column of the data table.
13. Repeat the measurement two more times, recording the numbers in the proper places.
14. Calculate the rate by dividing the “time of flight” by the distance traveled to obtain the flow rate of the spring water. For example: if your distance was 50 cm, and the time it took the flakes to travel that distance was 12 seconds, you would take 50 divided by 12 and your answer will be 4.16 cm/sec.
15. Figure out the averages for your trials, and make sure to fill in all the other information.

Other observations:

16. **Grid #3** is for other observations. Some ideas include texture and/or shape of travertine, color of microbes, etc. Be sure to label what you record.

VERY IMPORTANT: NO FLOW IS JUST AS IMPORTANT AS FLOW. For all designated STaRRS sites, please be sure to take photos and record data even if the spring has stopped!

Meta Data

Flow Rate Table:

	Time (in seconds)	Distance (in cm)	Rate = distance/time cm/sec
Trial #1			
Trial #2			
Trial #3			
Averages			

Location:

Where are you? Describe this spot in as much detail as you can (so that someone else can find it later). Indicate the specific facies as well as specific direction facing away from the facies

Photo numbers and camera name: _____

Weather observations

Use **S’Cool** cloud charts:

Cloud types _____ % of cloud cover _____

Use **Kestral3000**: (Take each measurement 3 times, 15 seconds apart and record the average – EXCEPT wind speed. Record the wind speed last after at least 2 minutes or more have elapsed.)

Average wind speed _____ Air temperature _____ Wind Chill _____

Relative Humidity _____ Dew point _____ **Wind Direction** _____

Directional Location _____

Grid # _____

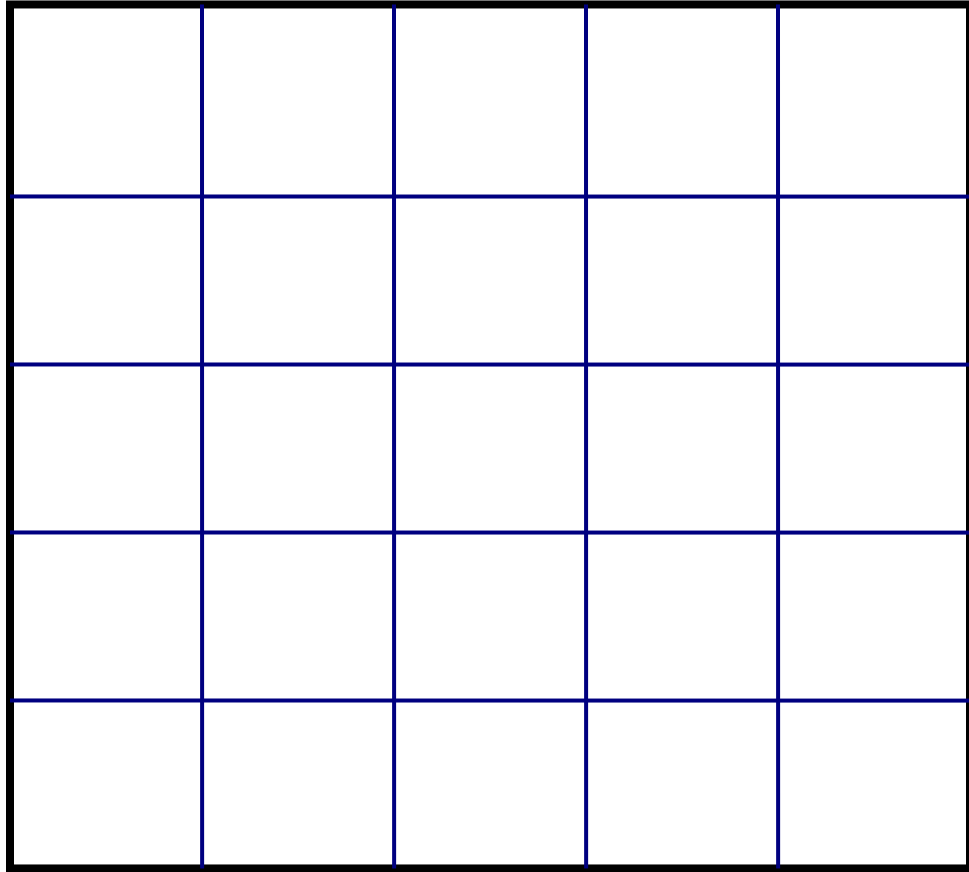


Photo #s and camera name _____ (Fill in photo log sheet!)

(Add identifying characteristics that will help you identify the photo later)

Appendix E

GCI/GCI-MLS Matched to NSES and Montana, Wyoming, and Idaho Standards

Table E1

GCI/GCI-MLS Matched to NSES

NSES pg #	Level Descriptions	Standards	GCI questions match	GCI-MLS questions match
134	ES K-4; 3 Properties of Earth Materials	<ul style="list-style-type: none"> Fossils provide evidence about the plants and animals that lived long ago and the nature of the environment at that time. 	14	3, 10, 12, 14
134	ES K-4; 1 Changes in Earth and Sky	<ul style="list-style-type: none"> The surface of the earth changes. Some changes are due to slow processes, such as erosion and weathering, and some changes are due to rapid processes, such as landslides, volcanic eruptions, and earthquakes. 	20, 22,	17
159	ES 5-8; 1 Structure of the Earth System	<ul style="list-style-type: none"> The solid earth is layered with a lithosphere; hot, convecting mantle; and dense, metallic core. 	3	5, 6
160	ES 5-8; 2 Structure of the Earth System	<ul style="list-style-type: none"> Lithospheric plates on the scales of continents and oceans constantly move at rates of centimeters per year in response to movements in the mantle. Major geological events, such as earthquakes, volcanic eruptions, and mountain building, result from these plate motions. 	3, 6, 7, 11, 17, 23, 25	4, 6, 7
160	ES 5-8; 3 Structure of the Earth System	<ul style="list-style-type: none"> Land forms are the result of a combination of constructive and destructive forces. Constructive forces include crustal deformation, volcanic eruption, and deposition of sediment, while destructive forces include weathering and erosion. 	2, 5, 10, 16	9, 13, 17, 19

Table E1 (Continued)

NSES pg #	Level Descriptions	Standards	GCI questions match	GCI-MLS questions match
160	ES 5-8; 6 Structure of the Earth System	<ul style="list-style-type: none"> Water, which covers the majority of the earth's surface, circulates through the crust, oceans, and atmosphere in what is known as the "water cycle." Water evaporates from the earth's surface, rises and cools as it moves to higher elevations, condenses as rain or snow, and falls to the surface where it collects in lakes, oceans, soil, and in rocks underground. 	15, 18, 24	8, 11,18
160	ES 5-8; 7 Structure of the Earth System	<ul style="list-style-type: none"> Water is a solvent. As it passes through the water cycle it dissolves minerals and gases and carries them to the oceans 		8
160	ES 5-8; 11 Structure of the Earth System	<ul style="list-style-type: none"> Living organisms have played many roles in the earth system, including affecting the composition of the atmosphere, producing some types of rocks, and contributing to the weathering of rocks. 		8
160	ES 5-8; 2 Earth's History	<ul style="list-style-type: none"> Fossils provide important evidence of how life and environmental conditions have changed. 	14	12
190	ES 9-12; 1 & 4 Origin and Evolution of the Universe	<ul style="list-style-type: none"> The sun, the earth, and the rest of the solar system formed from a nebular cloud of dust and gas 4.6 billion years ago. The early earth was very different from the planet we live on today. Evidence for one-celled forms of life—the bacteria—extends back more than 3.5 billion years. The evolution of life caused dramatic changes in the composition of the earth's atmosphere, which did not originally contain oxygen. 	4, 8, 9, 12, 13, 21, 25,	1, 2, 3, 16,

Table E2

GCI/GCI-MLS matched to Montana, Wyoming, and Idaho State Benchmarks

State	Level	Benchmarks	GCI questions match	GCI-MLS questions match
MT	4 & 8	<ul style="list-style-type: none"> 1-4th) Describe and give examples of Earth's changing features 	2, 3, 5, 6, 11, 23, 25	4, 5, 6, (7-gr 12), 17
		<ul style="list-style-type: none"> 1-8th) Model and explain the internal structure of the earth and describe the formation and composition of Earth's external features in terms of rock cycle, plate tectonics (including the movement of plates over time), and constructive and destructive forces (such as erosion) 	2, 3, 5, 6, 7, 10, 11, 16, 20, 22, 23, 25	4, 5, 6, 7 (grade 12 BM), 17
		<ul style="list-style-type: none"> 2-8th) Rocks – formation and classification 	7, 10	9, 11, 13, 19
		<ul style="list-style-type: none"> 3-4th) Fossils – used to make inferences about past life 4-4th) Water cycle 	14 15, 18, 24	10, 12, 14 18
WY	5-8 Earth and Space Systems	<ul style="list-style-type: none"> SC8.1.88) <u>The Structure of the Earth System</u>: Students examine the structure of the Earth, identifying layers of the Earth, considering plate movement and its effect, and recognizing landforms resulting from constructive and destructive forces 	2, 3, 5, 6, 7, 10, 11, 16, 20, 22, 23, 25	4, 5, 6, 7, 11, 18
		<ul style="list-style-type: none"> SC8.1.9 <u>The Earth's History</u>: Students systematize the Earth's history in terms of geologic evidence, comparing past & present Earth processes and identifying catastrophic events & fossil evidence. 	8, 12, 14, 19, 21, 25	1, 2, 9, 10, 12, 14, 17

Table E2 (continued)

State	Level	Benchmarks	GCI questions match	GCI-MLS questions match
ID	5 & 8-9 Earth and Space Systems	a) earth system interactions 5.S.4.1.1 Describe the interactions among the solid earth, oceans and atmosphere (erosion, climate, tectonics and continental drift) (609.01.a) 8-9.ES.4.1.2 Identify methods used to estimate geologic time. (654.01b)	2, 5, 6, 7, 10, 11, 12, 16, 17, 20, 22, 23, 25	4, 5, 6, 7, 9, 11 3, 15, 16
	Scientific theories of origin and subsequent changes in the universe and Earth's system	b) comparing conditions necessary for life g) geologic time and fossil use 8-9.ES.4.1.3 Show how interactions among the solid earth, oceans, atmosphere, and organisms have changed the earth system over time (654.01c)	14	9, 10 12, 14
	Geochemical cycles and energy in the Earth's System	b) plate tectonics 8-9.ES.4.2.1 Explain the internal and external energy sources of the earth (654.02a)	3, 5, 11, 16, 17, 22, 23	5, 6, 7

Appendix F

GCI/GCI-MLS Subsection Breakdown

Table F-1

GCI-MLS TT and Subsections

Problem #	Topic or Concepts	# of points	GK	EY	STaRRS
1	Prehistoric earth – characteristics	1		1	
2	Types of life encountered	1		1	
3	Characteristics of first types of life look like	1			1
4	Continent movement	1		1	
5	Tectonic plates - descriptions	2	2		
6	Why do tectonic plates move?	1	1		
7	Relationship of volcanoes, earthquakes, and tectonic plates	1	1		
8	Why does YNP have hot springs?	4		4	
9	Age of rocks	1	1		
10	How are fossils made?	2	2		
11	Oceanic rock formation	3	3		
12	Reason for studying fossils	2	2		
13	Rocks and minerals, characteristics	1	1		
14	Fossils – what can become fossils?	4	4		
15	Extra-terrestrial/early earth life forms	1			1
16	Key ingredient for life	1			1
17	Erosion	2	2		
18	Ground water	1	1		

Table F-1 (Continued)

Problem #	Topic or Concepts	# of points	GK	EY	STaRRS
19	Rocks and minerals characteristics	1	1		
20	Powers of ten	5			5
21	Hot Springs Facies Model	4			4
22	Use of scientific models	2			2
Subtotals		42	21	7	14

Appendix G
IRB Approval Letter

UNIVERSITY OF ILLINOIS
AT URBANA - CHAMPAIGN

Office of the Vice Chancellor for Research
Institutional Review Board
528 East Green Street
Suite 203
Champaign, IL 61820



June 4, 2008

Lizanne Destefano
Educational Psychology
110 Education Bldg
M/C 708

RE: *Expedition: Yellowstone! Students Teachers and Research Scientists - Investigating Earth Science at Mammoth (hereafter referred to as E:Y! STaRS)*
IRB Protocol Number: 08654

Dear Lizanne:

Thank you for submitting the completed IRB Application for Exemption form for your project entitled *Expedition: Yellowstone! Students Teachers and Research Scientists - Investigating Earth Science at Mammoth (hereafter referred to as E:Y! STaRS)*. Your project was assigned Institutional Review Board (IRB) Protocol Number 08654 and reviewed. The research activities involving human subjects are exempt from Title 45 – Public Welfare, Part 46 – Protection of Human Subjects, Subpart A – Federal Policy for the Protection of Human Subjects per the following category:

45 CFR 46.101(b)(1): This exemption applies since this study involves the creation and evaluation of a collaborative educational program between UIUC researchers (SSP Students and Scientist Partnership) and the Yellowstone EY program in Yellowstone National Park. The study uses quantitative measures (pre-post assessments) and qualitative techniques (observation, journaling, interviews) to collect data on affective and cognitive change of participants. The study includes teacher professional development and the implementation of an educational curriculum involving the scientific method, geology education, environmental education, etc. The study is being conducted on accepted educational settings and attempts to determine the effectiveness of an instructional curriculum, therefore the category 1 exemption is applicable.

This determination of exemption only applies to the research study as submitted. **Exempt protocols are approved for a maximum of three years.** Please note that additional modifications to your project need to be submitted to the IRB for review and exemption determination or approval before the modifications are initiated. To submit modifications to your protocol, please complete the IRB Research Amendment Form (see <http://www.irb.uiuc.edu/?q=forms-and-instructions/research-amendments.html>).

We appreciate your conscientious adherence to the requirements of human subject research. If you have any questions about the IRB process, or if you need assistance at any time, please feel free to contact me or the IRB Office.

Sincerely,

A handwritten signature in black ink, appearing to read 'Sue Keehn', written over a horizontal line.

Sue Keehn, Director, Institutional Review Board

c: Bruce W Fouke
Ana K Houseal
Anne Robertson

telephone 217-333-2670 • fax 217-333-0405 • email IRB@uiuc.edu