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The Effects of Fieldwork on Student Achievement and Motivation in Science Education

Action Research Thesis

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ABSTRACT: Upon reaching high school, students tend to lose their motivation to learn science and their achievement suffers accordingly. In the Unites States, this trend is clear and may have economic consequences. One strategy that may improve this situation is having secondary science students engage in more fieldwork. The purpose of this study, to find out how fieldwork affects student achievement and motivation in science class, was explored in a low-income public urban charter school. The experimental action research examined 84 students using a mixed methodology through a modified time series design. Results were obtained over the course of approximately two years from an oceanography class and a physics class that engaged in fieldwork as well as traditional laboratory science instruction. An environmental science club, the Mean Green Team, engaged in extra fieldwork and was examined as a subgroup. Information was collected from state tests, classroom assignments, student surveys, and interviews. Data was graphed, averaged, and statistically analyzed using t-tests at the 95% certainty level ($p<.05$). The study found that fieldwork in oceanography improved average achievement and motivation. Fieldwork in physics had mixed results with a significant average increase in pre/posttest scores, but a drop in fieldwork turn-in rates when compared to in class assignments. Students involved in the Mean Green Team significantly outperformed their peers on every measure of achievement despite no statistical difference on pretests between them and the class averages.

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Chapter 1-Introduction

A largely ignored report in early 2001 authored by former Senators Warren Rudman and Gary Hart warned of a possible major terrorist attack on the US. That same report warned that the shortfalls within our systems of education and research should be viewed as a greater threat to the US "than any potential conventional war that we might imagine" (as cited in Lemonick, 2006, p. 2). Unfortunately, the terrorist attacks happened nine months later and the failure of science education continues today (COSEPUP, 2007). According to the last national science tests given in 2005 by the National Assessment on Educational Progress, which is administered by the Department of Education, high school science scores are dropping. This most recent round of tests showed that only 54% of high school seniors tested achieved at or above the basic level, while an even scantier 18% achieved proficient (as cited by Dillon, 2006, p. 1). According to Friedman (2005), this drop in achievement equates to a drop in competitiveness and spells trouble for the American economy. While many debate the source of the decline, Mr. Whitsett, a 36 year veteran of science teaching said that students' "overall interest in science is down" (as cited by Dillon, 2006, p. 3).

My interest in this topic stems from my profession: teaching science. I do not aim to solve the debate about the source of decline within science education, but I do seek to increase my students' achievement and motivation within my science classes. Thus, I intend to test the efficacy of one specific strategy that I find particularly interesting: fieldwork. I will examine how fieldwork affects my students' achievement and motivation.

My initial interest in fieldwork was inspired by nature. As a youth, I would almost always rather be outside observing, exercising, photographing, experimenting, or simply just pondering the infinite intricacies of the natural world. This interest in "the field" eventually led me to want to teach science and to this exploration of fieldwork. When I began teaching I perceived that many of my students lacked in the areas of achievement and motivation. Through my credentialing program, master's program, and professional development I researched best practices in the teaching of science. Those practices included constructivism, inquiry, authentic tasks, and project based learning. The results from this research led me to the decision to perform action research on my own students to find out if those practices from the classroom could be combined with the fieldwork that inspired me to get into science to inspire higher achievement and increased motivation.

Many high school science teachers integrate research proven methods such as experiments, labs, authentic assessments, project based-learning, the scientific method, and other constructivist activities all while teaching students about the nature of science and engaging them in inquiry (Ahlgren & Rutherford, 1990; Baker & White, 2003; Barnet, Chavez, Deni, et. al., 2006; Bednarz, 2000; Blumenfield, Krajcik, & Tal, 2006; Czerniak, Haney, Lumpe, 2003; Donohue, Kenney, & Militana, 2003; Dexter, 1958; Feynman, 1995; Gurian, 2001; Lehrer & Schauble, 1999; Orion & Holfstein, 1994; Tobias, 1990). But what about integrating those key elements of science education along with a field study component? Braund and Reiss (2006) found that teachers too often ignore the influence that experiences beyond the classroom have on students' knowledge, understanding, and motivation despite the fact that students consistently rate field trips as the most enjoyable to learn. Could this integration increase achievement and/or motivation in the science classroom? Could this method increase awareness of the nature of science? Research on the topic of fieldwork dates back to the pre-nuclear era (Stevenson, 1940); in fact, positive literature promoting fieldwork by high school students dates back to before the moon landing (Dexter, 1958). Fieldtrips and fieldwork are nothing new to science education, perhaps as McComas (2008) suggests, it is time to go back to the past for a better future.

Purpose

The purpose of this study is to examine the effects of integrating science classroom practices with fieldwork in relation to student achievement and motivation in the secondary science classroom.

The research questions are…

1. Does fieldwork increase student achievement in the secondary science classroom?
2. Does fieldwork increase student motivation to learn in the science classroom?

Importance of the Study

This information will be of value to me in developing future curricula and in maximizing learning, achievement, and motivation in all future science classes I teach. It will be of value to my students in helping them get the most out of my courses. It will also provide secondary science teachers with a blueprint for improving curricula involving projects, constructivist activities, labs, or inquiry that involve a field component.

Definition of Terms

- Achievement-A quantification of student performance on assignments, tests, labs, homework, projects, fieldwork, and state examinations provided by a numerical score.

- Authentic learning tasks-Activities presented in real world contexts that lead to real world results.
- Constructivism-Learning philosophy that includes students actively building meaning and understanding of reality through experiences and relations.
- CST-California Standards Test. This test is given near the end of every school year to all high school students except seniors by the state of California. The test is based on the curriculum standards.
- Fieldwork- Learning through an assignment, activity, investigation, or experience that takes place outside of the physical classroom or student's home.
- Inquiry-Activities that involve the exploration of a single question or questions through experiments, reading, discussion, or accessing prior knowledge.
- Labs-Hands-on activities that explore a scientific concept.
- Mean Green Team (MGT)-The environmental science/service club that I advised during the study. This group served as an experimental sub-group during the study, which received extra doses of the fieldwork treatment. Students in the Mean Green Team were also in oceanography and physics.
- Nature of Science-The creative, tentative, durable, questioning, evidential, predictive, explanatory, biased, social, and ethical characteristics of the scientific enterprise.
- Nature-study-A form of fieldwork that involves takes place outside of and away from the built environment.
- Place-Based Education-learning process that involves the local community and environs as a starter for teaching the basic subjects of English, math, science, and social studies.

This method aims to strengthen community ties, students' appreciation for the natural world, and civic engagement.

- Project Based Learning-Any authentic learner centered task that requires students to convey their learning through a product

Chapter II-Review of the Literature

Authentic science involves fieldwork (Dexter, 1958; Gurian, 2001), creativity (McComas, 1998), and inquiry (National Research Council, 2000). Research in education indicates that students learn best through active learning methods such as constructivism (Wilson, 1996) and project based learning (Blumenfield, Krajcik, & Tal, 2006). Research also points to fieldwork, and hands-on learning as possible ways to motivate students (Baker & White, 2003; Long, 2005; Slavin, 2003). Engagement in authentic science can increase knowledge of and achievement in the nature of science (Braund & Reiss, 2006), which according to Ahlgren & Rutherford (1990) "…is requisite for scientific literacy" (p. 1). Thus, the review of the literature surrounding fieldwork focused on how to conduct field trips, traditional field trips, fieldwork in natural settings, place-based education, fieldwork's related strategies, fieldwork and motivation, and roadblocks to implementing fieldwork.

The background of findings on fieldwork is extensive (Barnet, Chavez, Deni, et. al., 2006; Dexter, 1958; Holfstein & Orion, 1994; Gurian, 2001; Lehrer & Schauble, 1999; Stevenson, 1940; etc). This body of literature generally looks at field experiences as being positively correlated to student achievement and motivation. Some studies looked at the effects of fieldwork while some focused on factors that make fieldwork more successful. Some results indicated that fieldwork could be part of the solution to the following problem. "Pupils of school age are being turned off by science in their schools yet the same pupils may be entertained and engaged by science outside them" (Braund and Reiss, 2006, p. 1374). Gurian (2001) thought so. When conducting research for a chapter on the ultimate classroom high school classroom, he found that it may not be a classroom at all. He looked at hundreds of surveys from the Mead

Education Summit. They indicated that students want more of what the brain wants for good learning; more field trips, especially for science learning.

How to Conduct Fieldwork

According to Marcy (1940), “Field trips have developed extensively in recent years to take advantage of students' phenomenal memory for facts and things seen and heard in strange surroundings and under unusual conditions” (p. 204). This quote indicated the time period as a mark of the beginning of the development of the educational field trip. In his article, “How to Conduct a Field Trip”, Marcy laid out a plan of action for successful trips based on his five years of experience at Columbia.

The basic plan went something like this: contact the intended location, find out if they have what you want for your students, pay a visit, plan a date, and communicate number and age of students (see also Rudmann, 1994). Perhaps the most important task, to confirm and reconfirm, was highlighted by the quote, “It is highly embarrassing for the teacher to arrive with an eager group of students and find no one expects them” (p. 205). Once plans have been made, he cited the importance of preparing the students with background information and behavioral expectations. Orion & Holfstein (1994; see also Falk, Martin, & Balling, 1978) similarly conveyed that a student’s familiarity with the location before attendance was corollary with the amount of learning that took place. Orion & Holfstein also added that the field trip must have concrete connections to the classroom curriculum to be successful. During the trip a teacher must be prepared to deal with disparate levels of interest amongst students. Integrating social components to field trips could alleviate this issue while leading to an improved experience from the student perspective (Meredith, Fortner & Mullins, 1997). Finally, sites and assignments must be selected based on group size and relevance (Marcy, 1940).

Marcy (1940) conveyed two common mistakes often made by teachers conducting field trips. The first was giving the students so much work to do during the trip that they miss out on the experience. The second was overestimating the number of students who will show up for a non-compulsory field trip. To avoid the situation where too few students show up and you "bemoan your efforts and the students' lack of interest", teachers should develop a system that underestimates attendees since "it is hard to blame the students for choosing a game of ball or a motion picture rather than several hours of trudging…much as we would like to think the educational opportunity should prevail (p. 206). These considerations were made as the fieldwork was planned for this research.

Traditional Field Trips: Museums, Science Centers, Nature Centers

The classic science field trip in which many people at one time or another have experienced involved a museum, science center, or nature center. On these trips students tend to "display interest, enthusiasm, motivation, alertness, awareness, and a general openness and eagerness to learn, characteristics that tend to be neglected in school science" (Wellington, 1990 as cited by Ramey-Gassert, 1997, p, 435). One major difference between the classroom and this type of field experience is that students are in charge of their own learning and how they explore and experiment. Ramey-Gassert, Walberg, and Walberg (1994) thought very highly of this difference, "Museum learning has many potential advantages: nurturing curiosity, improving motivation and attitudes, engaging the audience through participation and social interaction, and enrichment. By nurturing curiosity, the desire to learn can be enhanced" (p. 351). Improving curiosity, motivation, and participation are certainly high on most science teachers lists.

An explanation for the increases in positive outcomes during traditional science field trips is that in school learning is based in symbols, reading, and abstraction while field trips involve learning tasks with real objects and an element of interaction. The latter process leads to learning with greater meaning (Ramey-Gassert, 1997). In fact, a common response from visitors collected by Semper (1990) was, “If science had been taught like this when I was in school, I would have stayed with it” (p. 4). If science had been taught like museum field trips the science might have stayed with them longer too, as Stevenson’s (1991) study found learning that takes place on field trips is retained for long periods of time. That same study displayed that students interacted with and observed exhibits more than adults did, while the experimental group of students showed greater skills in making inferences than did the control group. Braund and Reiss (2006) found that these interactions led to improved development and integration of learning, authentic work, greater access to ‘big’ science, attitudes that spur further learning and increased collaboration and responsibility for what is learned. Dierking and Falk (1994) and Falk and Dierking (2000) similarly reported that students’ understanding of concepts addressed were improved as measured by pre and posttests, while teachers’ and students’ understandings are retained in the long term (Parvin, 1999; Parvin & Stephenson, 2004 as cited in Braund and Reiss, 2006).

Fieldwork in Natural Settings

Fieldwork in natural settings is an effective strategy in the sciences and has been widely studied (see Orion & Holfstein, 1994; Barnett, Lord, Strauss, Rosca, Langfor, Chavez, and Deni, 2006; Lehrer and Schauble, 1999). This type of fieldwork involves trips to the outdoors that range from one day to several weeks and can be integrated by schools and informal educational groups alike. Many of the Mean Green Team's fieldwork experiences fall under this category.

A study conducted by the American Institutes for Research (2005), examined the effects of outdoor education on at risk youth in California. The results showed that those 255 students involved experienced an average 27 percent gain in science scores as measured by pre and posttests. The researchers found that these gains were maintained for the length of the study with no significant loss in scores after ten weeks.

In "Using the Urban Environment to Engage Youths in Urban Ecology Field Studies" authors Barnett, Lord, Strauss, Rosca, Langfor, Chavez, and Deni (2006), attempt to find out the success of the Urban Ecology Field Studies (UEFS) program in terms of engaging traditionally underrepresented groups in science. They examined a few hundred high school students in the Boston Public Schools over the course of two years. The researchers studied these students' views through mixed method survey and interview protocols before, during, and after the UEFS. The authors concluded that the program was a success as it improved student interest in science, supported the development and understanding of scientific methodologies, and improved environmental stewardship when compared with a control group of traditionally instructed science students.

Research on fieldwork by Lehrer and Schauble (1999) found that, "Fifth graders have been performing like twelfth graders on math and science tests after learning through a new, hands-on technique…" (p.7). One teacher involved in this study observed that students seemed to learn more quickly by getting into the field and getting their hands dirty.

Another study in Israel that investigated the factors that led to efficacy of field trips. The authors attempted to find out what variables affected students' ability to learn on a field trip in a natural environment. The authors researched 296 high school students on a one-day geological field trip. They used qualitative and quantitative research methods to collect data from students, teachers, and outside observers in three stages (before, after, and during the field trip). Using observations and questionnaires they investigated student learning and student attitudes before and after the field trip. They found that the efficacy of the field trip was controlled by the concrete relation of the field trip to the curriculum and the degree to which the students were familiar with the area of the field trip. The higher the concrete relationship to the curriculum and the more familiar the students were with the area, the more effective the fieldwork (Orion & Holfstein, 1994).

A reason that nature based fieldwork may increase student achievement is that students observe the real world where the sciences are not artificially divided. Students learn at a young age that there are different sciences. This organizational structure provides students with a conceptual structure for learning and organizing information. However, it inherently creates the disadvantage of a false separation of scientific disciplines that do not match up with the way the world actually works. In nature, physics overlaps with chemistry, geology, and astronomy, while chemistry overlies biology and psychology (Ahlgren & Rutherford, 1990). Field labs can help students gain a deeper understanding for this true nature of science (Braund & Reiss, 2006).

McComas (2008), found outdoor field study so important to science education that he ended his recent article by saying, "So, perhaps a reconsideration of an instruction orientation of the past [nature-study] may be our best hope in defining a more effective future for science teaching, whether in schools at the equator or those in the middle of America" (p. 28). This idea of including fieldwork and field trips is also recommended by the *National Science Education Standards* (1996). They state that teachers should give, "...Adequate blocks of time for students to set up scientific equipment and carry out experiments, to go on field trips, or reflect upon and share with each other" (p.44) and that they should bring science "…Beyond the walls of school to the resources of the community" (p.45).

Place Based Education Fieldwork

While Marcy (1940) advocated for formal field trips, others (Ramey-Gassert, 1997; Frazier & Sarkar, 2008; Sobel, 2005) advocate for more informal fieldwork experiences. Place based education is a more informal brand of fieldwork and was defined by Sobel (2005) as the learning process that involves the local community and environs as a starter for teaching the basic subjects of English, math, science, and social studies. This method, grounded in hands on authentic learning, strengthens community ties, students' appreciation for the natural world, and civic engagement. This method starts with two fundamental questions often asked in science "where am I?" and "what is the nature of this place?" (p. iii). In his book *Place Based Education: Connecting Classrooms and Communities*, Sobel highlights many positive effects of place-based education related to achievement and motivation in the sciences.

A basic premise of the book is that, "Good place based education leads to increased academic achievement" (p. 22). Lieberman and Hoody (1998) found that using the school's local environment as an integrating context (EIC) resulted in many positive effects on learning. In their forty school study, standardized test scores and GPAs increased as a result of place-based programs while achievement in the sciences improved. Teachers also reported increased problem solving, critical thinking, enthusiasm, and engagement. Discipline problems were reduced as the number of referrals dropped from 560 to 50 over the course of two years after the EIC program was introduced (as cited by Sobel, 2005, p.25). One student commented that his motivation to join the EIC program stemmed from his belief that it would be easier. However, his attitude changed as it turned out to be more difficult. He added that his learning from the EIC program stuck with him as opposed to the traditional classroom where "I studied really hard for the test, did the test, probably got an A, and then I forgot everything" (as cited by Sobel, 2005, p. 26)

Sobel goes on to highlight many studies with similar findings. The National Environment Education and Training Foundation (NEETF) study in 2000 found that place-based education improved students' standardized test scores in reading, math, science, and social studies. Students in the study showed an increase in skills involved in "doing science" (as cited by Sobel, 2005, p. 28). Science scores in Tompkinsville, Kentucky have risen 25 percent over the four years the school has enacted place based learning according to the Kentucky Instructional Results Information System assessment. Zibart (2002), found that achievement in the largely Hispanic population at Edcouch-Elsa High School in Texas increased with the implementation of place-based learning. The school has a population of which 90 percent of students come from households with incomes under $10,000 and 91 percent of parents are not high school graduates. However, they have sent 45 students to elite institutions of higher education and 65 percent of students to college in the past 10 years (as cited by Sobel, 2005, p31.

Finally, two non-traditional measuring tools of achievement and motivation found similar positive results. Grahn (1997 as cited by Sobel, 2005, p35) found that students involved in outdoor learning experienced 80 percent fewer infectious diseases compared to children in conventional indoor classrooms. This connects to other studies findings of lower rates of absenteeism in place-based education programs. Another non-traditional measure of achievement found by Sobel was that place based education programs make a difference in their communities by reducing waste, saving schools money, improving local habitat, and collecting important scientific data on environmental quality. This new measure of achievement prompted one school director to say, "The projects our students have completed take up much more space in our local newspapers than the results of our standardized test scores…the state standardized test scores, by the way, have improved…" (North Coast Rural Challenge Network, 2000, as cited by Sobel, 2005, p. 93).

What Good Fieldwork Includes: Authentic Assessment, Inquiry, Nature of Science, Project Based Learning, and Constructivism

Good fieldwork inherently includes many research proven best practices of science education (see Braund and Reiss, 2006; McCommas, 1998) such as authentic assessment and constructivism, and can include more such as project-based learning (Barnet, Chavez, and Deni, 2006). This section focuses on those elements that fieldwork inherently includes and what other elements it can include when done properly.

As required by the A-G requirements in California, 20 percent of class time must be spent by students actively investigating concepts. The Investigation and Experimentation Framework section of the *Science Framework for California Public Schools* (2004), authored by the California Department of Education, emphasizes both authentic assessment and the importance of labs. "Investigations and experiments engage scientists, catalyzing their highest levels of creativity and producing their most satisfying rewards" (p.278). Whether or not teachers are meeting this expectation is in question according to Singer, Hilton, and Schwiengruber (2005a as cited in Long, 2005). This seemed to indicate that there was a gap between standards of authentic experiences and actual execution of authentic experiences. The National Research

Council (2005) had similar findings. They qualified the status quo of current student laboratory exercise experiences as poor. Perhaps this is due to the fact that science as it is traditionally presented in a classroom has little resemblance to the world where science and technology are omnipresent (Wellington, 1990 as cited by Ramey-Gassert, 1997).

The same study recommended following a few design principles to help laboratory experiences improve student learning. Those principles included clear learning outcomes, thoughtful sequencing into the flow of instruction, integration of content and processes, and incorporation of continuing student reflection coupled with discussion. All of these principles could also be exercised in authentic tasks in the form of fieldwork. According to Braund and Reiss (2006), "Fieldwork provides the ideal example of authentic practical work, mainly because it provides an opportunity to challenge the myths propagated about practical science in a school laboratory" (p. 1378).

Inquiry is also fundamental in the sciences. "Those who study scientists at work have shown that no research method is applied universally" (Carey, 1994; Gibbs and Lawson, 1992; Chalmers, 1990 and Gjertsen 1989, as cited in McComas, 1998, p.58). However, McComas instead said that scientists rely heavily on asking questions, exercising imagination, harnessing creativity, engaging prior knowledge, and employing perseverance. Ahlgren & Rutherford (1990) came to similar conclusions when they said inquiry is a distinctive characteristic of science.

When students use inquiry to ask questions and conduct investigations they engage in active learning. According to the National Research Council (2000), this is an example of metacognitive learning; it focuses on sense-making and reflection. This means essentially looking at natural phenomenon, asking questions, testing hypothesis, gathering data and observations, and reflecting on the validity of your thoughts. These researched practices prove to increase transfer of student learning to new situations (Palincsar & Brown, 1984, Scardamalia et al., 1984; Shoenfeld, 1983, 1985, 1991, as cited by the National Research Council, 2000, p.12). This mode of inquiry by asking questions, investigating phenomenon, using the scientific method and sense-making and reflection is implicit in students' fieldwork (Barnet, et. al. 2006; Manzanal, Barreiro, Jimenez, 1999).

Science involves creativity. Scientists use creativity to solve problems, to make connections, to conduct experiments, and to come up with hypothesis and theories. Einstein agreed that imagination was paramount for extending the current understanding of science (National Research Council, 2005). McComas (1998) wrote somewhat extensively on this topic and conveyed that, "Only the creativity of the individual scientist permits the discovery of laws and the invention of theories" (p. 60). Unfortunately, many in class laboratory exercises that attempt to engage students in the benefits of hands-on learning are simply limited by resources and a controlled environment. Thus, they act as verification exercises that can sap creativity and turn students off to the true nature of science. In actuality, these students never truly experienced the creative nature of science. Tobias (1990) argued that many competent and intelligent students rebuff possible science careers because they do not find science class to be exciting or creative. Fieldwork should engage students in meaningful inquiry that requires them to ask creative questions and come up with creative ways to solve them (Sarkar & Frazier, 2008).

Another myth surrounding the nature of science that students often believe, according to McComas (1998), is that experiments are the principal route to scientific knowledge. While experiments provide a wonderful means for exploring science, observation and qualitative methods have similarly led to great advancements in science. One only need examine the works of astronomers or the likes of Darwin and Copernicus as evidence. This type of learning is so important that Howard Gardner, inventor of the famous multiple intelligences, even added the intelligence of naturalist. He felt that the skill of putting order to the chaos of the natural world exists in many young Darwin's today (2006). The sheer volume of variables in the field makes it a difficult place for the laboratory to duplicate. Without this experience of an uncontrolled environment, science students cannot gain a true taste of observation, creativity, and reasoning science while learning how to learn (McComas, 2008). As noted by Feynman (1995), these are three crucial pieces make up the quintessence of the scientific method. The field is the only place for students to truly experience and utilize the nature of science.

Another common strategy that can be integrated into fieldwork is projects. In their online Project Based Learning Handbook, The Buck Institute of Education defines Project Based Learning (PBL) as "a systematic teaching method that engages students in learning knowledge and skills through an extended inquiry process structured around complex, authentic questions and carefully designed products and tasks" (2007). Blumenfield, Krajcik, and Tal (2006), found that 755 students experienced significant gains as demonstrated by pre and post-tests when fieldwork was combined with PBL during a unit on water quality. On another project based learning assignment researchers Donohue, Kenney, and Militana (2003) found teachers to be impressed with student results following a fieldwork based project:

> Teachers commented on gains in student knowledge that they observed in the classroom. Students were able to retain information, that they learned outside and use it in the classroom. According to the teachers, the lessons tapped into the different learning styles that students have and also required the students to use higher level thinking skills (p. 5).

Barnet, Chavez, and Deni (2006) reported that after students participated in an outdoor project based learning environment they scored higher than the control group in three of the four areas tested. Those three areas were desire to be a scientist, ecological awareness, and knowledge of scientific methodology. They also found that teachers observed that students' self-confidence inside the science classroom increased as a result of their participation in outdoor project based learning. This indicates that fieldwork could be a desired component of PBL projects.

Constructivism is the final inherent partner of fieldwork and focuses on several important facets of education including providing experience with the knowledge; it can be defined as a process that includes students actively building meaning and understanding of reality through experiences and relations (Slavin, 2003). There are seven specific design goals for successful constructivist teachings according to Honebein (1996): to provide experience with the process of making knowledge, to provide experiences that provide multiple perspectives, to infuse learning in authentic contexts, to promote ownership of the learning, to suffuse social interaction, to exercise multiple modalities, and to encourage metacognition. Madden (1985) saw all of these constructivist elements in out of school learning such as fieldwork. Braund and Reiss (2006) stated that, “the greater importance that needs to be accorded in science education to out-of-school learning sit alongside the emphasis that is increasingly given in school science courses to a shift from ‘Transmission learning’ to ‘Constructivist learning’” (p. 1381).

In their study on constructivism, Czerniak, Haney, and Lumpe (2003) examined the views of a small group of science teachers, students, administrators, and parents respectively. Using the Beliefs About Learning Environment Instrument, they found that school administrators and science teachers hold the constructivism in high regard as a teaching philosophy for science courses. Therefore, it is an important element to integrate into fieldwork. The fieldwork experiences of this study were planned with the aforementioned elements of good fieldwork in mind.

Fieldwork and Motivation

According to educational psychologist Slavin (2003), “much of what must be learned in school is not inherently interesting or useful to most students in the short run” (p. 348). This may be an issue many teachers, including myself, have faced on a daily basis. However, according to Slavin there are some methods that can help. By offering rewards for learning activities teachers can hurt intrinsic motivation. Instead he recommends enhancing intrinsic motivation by arousing interest, presenting demonstrations that lead to cognitive dissonance, providing hands-on experience, varying presentation modes, and helping students set their own goals. According to McComas (2008) fieldwork creates these firsthand experiences, encourages questions, and inspires curiosity because it demands the application of science process skills. He also says that students like nature and find study in more natural areas, such as in the field, more compelling. Ramey-Gassert (1997) found the same connection in relation to motivation and field study. She reported that, “learners in an informal setting are intrinsically motivated to gain personal meaning from their learning, which has greater value than memorizing facts or doing well on a test” (p. 435). Braund and Reiss added that, “The science and the ways in which it is communicated, in places outside schools (science museums, hands-on centres, zoos, botanical gardens, etc.), is often seen as exciting, challenging, and uplifting” (p. 1374). Motivation, excitement, challenging, curiosity, and intrinsic are all words qualities teachers love to see from our students in the sciences.

The *Committee on Secondary School Studies* (1893), found that students who were exposed to nature at a young age were more motivated to learn the sciences while those whose “…studies begin later in the courses, after the habit of depending on authority-teacher and books-has been formed, the results are less satisfactory" (p.139). This idea of field study increasing student motivation has been confirmed by many modern studies over one hundred years later (Frazier and Sarkar, 2008, Marzano and Pickering, 2001, Sobel, 2004).

Sarkar and Frazier (2008) found that combining inquiry based practices with fieldwork made the learning more meaningful while increasing the active engagement of students. This is the opposite of traditional in class exercises which, "Sometimes remain disconnected in the student's mind and fail to nurture a deeper understanding of methods of science and the role these methods play in scientific inquiry" (p. 29).

These studies show great promise for using fieldwork as a means to motivate students in a world where students' attitudes towards school science declines the further they go in school (Braund and Reiss, 2006). After all, "It is not science that they are rejecting but the pale imitation of it that is all too often served up in school science laboratories" (p. 1382).

Why is Fieldwork Not Commonly Used?

Despite all of the previously noted findings most teachers seldom use fieldwork. There are several possible reasons that this research proven strategy is not commonly employed. Ramey-Gassert (1997) found that common reasons from the teacher's perspective included either because they are unaware how to integrate fieldwork into their curriculum or are unfamiliar with local resources. Sarkar and Frazier (2008) found a longer list of reasons from a broader perspective: not enough time, inability to manage diverse group outside of the classroom, school does not allow field trips, scheduling difficulties, and a renewed test focus because of No Child Left Behind. Another common reason that field trips do not occur more often is because of the financial cost of the trips (Ramey-Gassert, 1997).

Sarkar and Frazier (2008) gave a list of strategies for overcoming the aforementioned challenges of engaging students in fieldwork. Those approaches included narrowing the scope of the fieldwork by participating in locally based projects or those of shorter length, establishing fieldwork guidelines, soliciting help from parents as chaperones, starting with a field trip on your school campus, dividing long projects into manageable daily chunks, and having students make concept maps to connect their field and classroom learning.

Research that cited the negative aspects of fieldwork conveyed that science learning outside of school was infrequently substantial, misconceptions were fostered, and student motivation was due to entertainment (Braund & Reiss, 2006). The issue of misconceptions happens every day in science classrooms and there are significant findings (see above sections) that show that learning from fieldwork is substantial. Finally, Shortland (1987) suggested that the entertaining and motivating aspect of fieldwork did not align with the goals of student mastery of concepts and laws. However, other research (Falk, Coulson, and Moussouri, 1998 as cited in Braund & Reiss, 2006) found that combining motivations for learning with entertainment resulted in the highest gains.

Conclusion

Fieldwork involves many components of research based science education practices as defined by the aforementioned findings. It has been proven effective through the means of one day field trips, traditional field trips, natural field study, place-based education, and by integrating more commonly used methods. However, there are certain criterion that need to be met and certain challenges to overcome in order to improve or take full advantage of its efficacy. By meeting these criteria fieldwork can increase student interest, achievement, motivation, and retention within the sciences. The aforementioned criteria for fieldwork heavily influenced the trips taken in this study. Fieldwork ranged from constructivist natural field study at the beach to science museum fieldtrips to place-based lab style investigations. All trips were planned with the aforementioned literature review in mind and made strong connections to the curricula. Some barriers, such as financial costs of trips, were overcome thanks to the partnerships of local community-based and non-profit organizations. Particular beneficiaries of these partnerships were the members of the Mean Green Team who they partook in a weeklong fieldwork camping trip at minimal cost to them or the school.

Chapter III-Methodology

Participants

This study took place in a public charter school in a large downtown business district. The school is managed by a non-profit charter management organization and is sponsored by the Los Angeles Unified School District. The majority of the students are Latino (90+ percent) and of low-socioeconomic status. They all come from the metro Los Angeles area and commute to school without transportation assistance from the school or district. The majority of students arrived to school via the Metro transit system. Similarly, much of the transportation to fieldwork locations happened aboard the Metro.

There were 84 high school science students involved in this study. I began collecting data with my 70 oceanography students during the 2006-2007 school year and concluded the study with my 66 physics students during the 2007-2008 school year. Among the 70 oceanography students studied, 63 were juniors and 7 were seniors. Among the 66 physics students studied, 11 were juniors and 55 were seniors. Most of the juniors studied during the 2006-2007 school year were also studied as seniors during the 2007-2008 school year. A subgroup that I studied was the Mean Green Team (MGT), members our school's environmental science club, which I advise. These students were in the club, oceanography, and physics. The MGT students were exposed to a ten extra fieldwork experiences during the first year of the study and 20 extra during the second year of the study. This group included self-selected students. However, achievement was controlled as their original pretest scores were *not* significantly different than the class average (see Figure 5).

	Class	# Students	#FW Experiences	# Students in MGT	# Extra FW
2006-2007	Oceanography	70	6	10	10

2007-2008	Physics	66	7	13	20

Figure 1-Participants in the study. The majority of students in oceanography were also in physics. The majority of the students in the Mean Green Team were members for both years of the study.

The classroom setting was a non-lab classroom. The space was large enough to house each of the four sections of the course, which ranged from 15-24 students per section. The school resides in the financial district of downtown on the third and fourth floors of an office building. The attendance of the school at the time of study was 300-320 students. The communities the students resided in were mostly in the inner-city of Los Angeles.

Materials

The materials used in this research included the oceanography curriculum I developed alongside coworker and fellow oceanography teacher, Brigid Morales. A collection of excerpts and activities from texts were taken from two introductory college texts, *Introductory Oceanography* and *An Introduction to the World's Oceans*, and two high school geology texts, *Geology: Earth, the Environment*, and *Modern Earth* Science. The fieldwork locations for Oceanography included local beaches, Malibu Lagoon, Malibu Creek State Park, Pt Dume, Zuma Beach, and Santa Monica State Beach. Sites were so chosen based on relevance to curriculum, proximity, and cost. The website-www.stephensteach.com-includes all curriculum materials, documents, lesson plans, and fieldwork assignments. Topics of study for the class were based on the California State Standards for earth science, chemistry, and physics. Fieldwork included assignments similar to those done in the classroom: investigations with lab reports, observational assignments, data collection, and worksheets (see appendices B.01, B.02, and B.03).

Materials used in the physics curriculum I developed can also be found at www.stephensteach.com and included excerpts and activities from several sources: *Conceptual Physics*-a high school textbook written for introductory algebra-based physics, *Holt Physics*-a high school textbook written for introductory algebra/trigonometry-based physics, *Hands on Physics Activities with Real Life Applications*-a book of physics-based activities and labs, and the Glenbrook South Physics site-an online physics tutorial located at http://www.glenbrook.k12.il.us/gbssci/Phys/phys.html. Topics of study for the class were based on the California State Standards for physics. The fieldwork destinations for Physics included Wired Nextfest, the California Science Center, the Natural History Museum of Los Angeles County, Eaton Canyon Natural Area, Santa Monica state beach, Puente Hills Landfill and Material Recoveries Facility, San Jose Creek Water Reclamation Plant, Metro Gold Line, Metro Red Line, and two local city parks.

The Mean Green Team subgroup's fieldwork included various science topics including air and water quality in and around Los Angeles during the 2006-2007 school year. This group tested local streams, rivers, and beaches for water quality parameters that included nitrites, nitrates, dissolved carbon dioxide, pH, dissolved iron, temperature, and turbidity. They tested indoor and outdoor air quality as well. Field locations included Eaton Canyon, Playa Del Rey, Rio De Los Angeles State Park, the Glendale Narrows of the Los Angeles River, and the Los Angeles River Youth Conference. Destinations for the 2007-2008 fieldwork of the Mean Green Team included Washington DC, Powershift07 (a youth conference on global warming), California Green Schools Summit, Mono Lake, Arroyo Seco, Dockweiler State Beach, Topanga Canyon, Generation Earth Teen Forum, the San Gabriel Mountains, and Yosemite National Park. Topics of study included environmental science, chemistry, physics, geology, data collection, and experimental design. Community service was a major component of the fieldwork as well as investigation for the Mean Green Team. The work of the Mean Green Team can also be found at www.stephensteach.com.

To investigate the first research question on fieldwork's effect on student achievement, I used several methods of data collection. Those methods included the comparison of fieldwork assignment scores to traditional classroom assignments (see Figure 4 and Figure 10), pretest/posttest scores from the California Standards Test (CST) (see Figure 5), pretest/posttest scores from the Nature of Science (NOS) Assessment (see Figure 12 and Appendix B.05), and student surveys on achievement (see Figure 6, Figure 11, and Appendix A). Both objective tests and student surveys were included to examine achievement from both the perspectives of monism and dualism. The surveys also served as a means to determine the effect that fieldwork had on achievement versus classroom learning

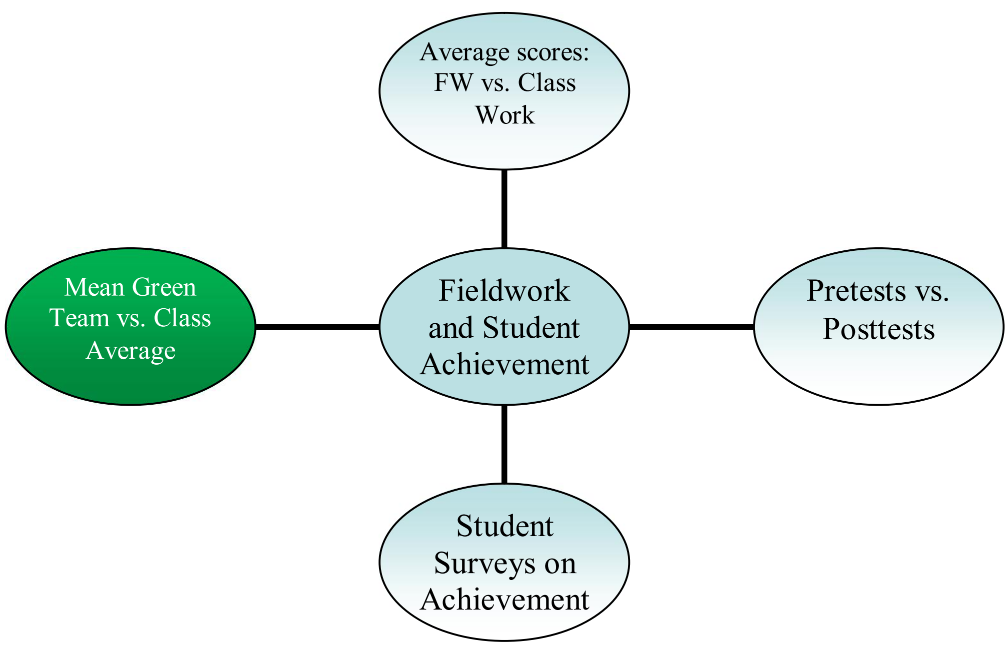


Figure 2-Triangulation of data for the first research question pertaining to the effect of fieldwork on student achievement.

The second research question examined fieldwork's effect on student motivation. This question was examined using two student surveys. One survey asked the students to rank fieldwork among other science learning activities in terms of motivation (see Figure 8, Figure 15, Figure 16, and Figure 17). The second survey asked the students to respond to questions regarding fieldwork and class work on a Likert Scale (see Figure 9 and Figure 14). Motivation was also examined by comparing average turn-in rates of fieldwork assignments to average turn-in rates of all assignments (see Figure 7 and Figure 13). Again, the Mean Green Team's turn-in rates were compared to the class average. Finally, interviews sought to determine the motivational effect of fieldwork (see Figure 18 and Appendix C).

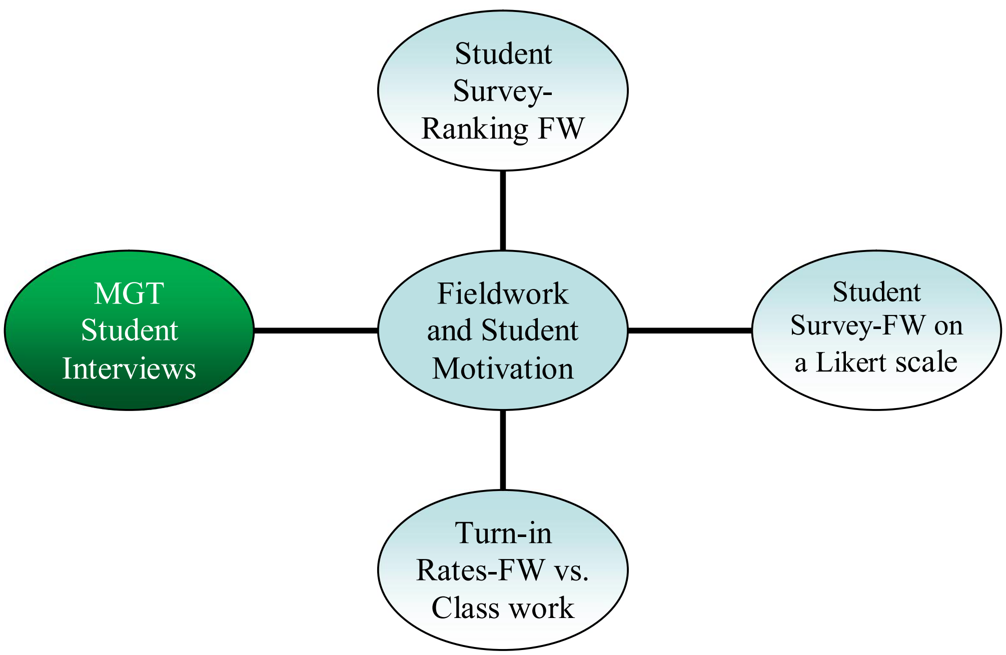


Figure 3-Triangulation of data for second research question pertaining to fieldwork's effect on motivation.

Grade data for all semesters of physics and oceanography were organized in Powergrade. Surveys were given on paper and collected or given online and collected electronically. Interviews were recorded and transcribed.

<u>Procedures</u>

The methods used for study qualify as equivalent time-sample design using two experimental groups and pretests and posttests. This is essentially an experimental design used in action research where pretest and posttests are used in conjunction with a treatment that is presented at irregular intervals (Johnson, 2008). However, the observational data was collected at regular intervals. In the case of this study the format is modified to include two treatment groups. One group, the majority of oceanography and physics students, received some of the treatment, and the other, Mean Green Team members, received more of the treatment.

The overall study lasted two years with six fieldwork experiences in oceanography, seven fieldwork experiences in physics, and 30 extra fieldwork experiences for the Mean Green Team (see Figure 1). CST pretests were taken in the spring of the 2004-2005 school year for oceanography students and CST posttests given in the Spring of 2006-2007 school year. Surveys were given at the end of each semester for oceanography. Nature of Science (NOS) pretests were taken at the beginning of the 2007-2008 fall semester for physics students with the NOS posttests taken at the end of the semester. Surveys were given to physics students at the beginning and end of the same semester. Grade data was collected almost daily for non-fieldwork; fieldwork grade data was collected for every fieldwork assignment. Finally, interviews were conducted near the conclusion of the study in 2008.

<u>Analysis</u>

Quantitative data, including assignment scores, test scores, and turn-in rates, was organized into spreadsheets, averaged, graphed and compared for analysis (see Figure 4-18 in findings section). All quantitative data was compared for statistical significance at the 95% level of significance ($p<0.05$). Qualitative data included survey answers and interview questions. Answers from the student surveys were calculated as a group by taking the average, mode, median, and standard deviation. Data from the ranking surveys were also put into a histogram plotting frequency of rankings (see Figure 17). Open ended responses regarding fieldwork were coded as positive or negative and put into pie graphs (see Appendix A.07 and A.10).

Chapter IV-Findings

The purpose of conducting this study was to find out if fieldwork increases student achievement in the secondary science classroom, and if fieldwork increases student motivation to learn in the science classroom. The data described below will answer the two research questions using the data collected from my oceanography class, physics class, and the Mean Green Team (treatment group with extra fieldwork). The data below is described in chronological order and divided into four sections: oceanography-fieldwork and achievement, oceanography-fieldwork and motivation, physics-fieldwork and achievement, and physics-fieldwork and motivation.

Oceanography-Fieldwork and Achievement

In oceanography class, data was collected from assignment scores, surveys, and the California Standards Test (CST) to examine the effects of fieldwork on achievement. Data was compiled into a spreadsheet and graphed using Microsoft Excel 2007. Six fieldwork assignments were given to each student throughout the year. Their scores were converted to percentages and averaged for each assignment. The average scores for all fieldwork were compared to student scores on the more traditional assignment categories of laboratory reports, homework, and in class work (see Figure 4). This data shows that all students, on average, achieved the highest in class work, followed by fieldwork, labs, and then homework. Mean Green Team members, with more fieldwork experiences, had greater achievement in all categories that was statistically significant (see caption below Figure 4 for p-values). This data was collected from 71 students with a total of 106 assignments over the course of one school year. Since the fieldwork experiences related very closely to labs (see Appendix B) in terms of investigating scientific topics and the product produced, it is important to note the 6.4% greater scores on fieldwork on average by all students (p-value=0.006).

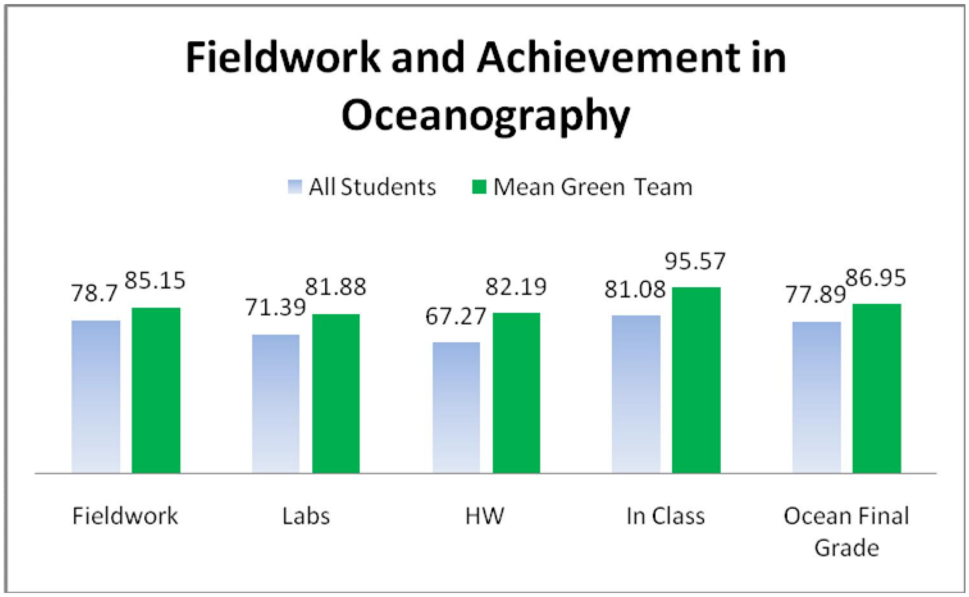
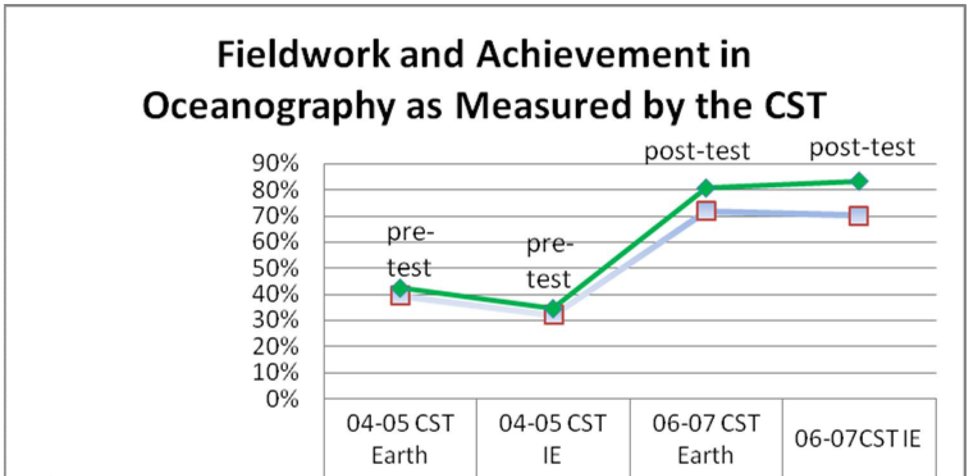


Figure 4-Bar graph of student achievement in oceanography by assignment category. All students n=68, MGT n=9. p-value=0.004 for fieldwork-all students vs. MGT; p-value=0.008 for labs-all students vs. MGT, p-value=0.001 for HW-all students vs. MGT, p-value=0.00000000005 for in class work-all students vs. MGT; p-value=0.008 for final grades-all students vs. MGT; P-value=0.007 for fieldwork vs. labs for all students. See Appendix B for sample assessments and student samples.

The CST served as a type of standardized pre and posttest for oceanography. It was an excellent indicator of achievement since students take the test every school year and it always includes a section on the Investigation and Experimentation (IE) standards. The student scores on this section also showed that Mean Green Team members had very slight differences in scores (two to three percent) that proved statistically insignificant. This shows no difference in achievement prior to joining the fieldwork based group (as seen in Figure 5). The data from the IE and Earth Science sections of the CST were chosen because oceanography is an Earth science and the fieldwork focused on investigating and experimenting on oceanography concepts. In Figure 5, the scores from the 2004-2005 school year serves as the pre-test scores and the scores from 2006-2007 serve as posttest scores. The dramatic improvement by the Mean Green Team and all other students proved statistically significant (see p-values in Figure 5).



	04-05 CST Earth	04-05 CST IE	06-07 CST Earth	06-07CST IE
All Students	40%	32%	72%	70%
Mean Green Team	42%	35%	81%	83%

Figure 5-Line graph of student achievement in oceanography as measured by the CST. All students-n=55, MGT-n=8. All students were exposed to 6 fieldwork experiences, while MGT students were exposed to 10 extra fieldwork experiences. P-value=.64 for 04-05 CST Earth-MGT vs. all students; p-value=.67 for 04-05 CST IE-MGT vs. all students; p-value=.042 for 06-07 CST Earth-MGT vs. all students; p-value=.147 for 06-07 CST IE-MGT vs. all students. P-value=4.79x10^{-5} for MGT-Earth pretest vs. Earth posttest; p-value=9.95x10^{-5} for MGT-IE pretest vs. IE posttest; p-value=2.03x10^{-18} for all students-04-05 Earth vs. 06-07 Earth; p-value=6.58x10^{-17} for all students-04-05 IE vs. 06-07 IE. See Appendix B.04 for more information.

Student surveys were also collected during the 2006-2007 school year to determine whether or not fieldwork helped student achievement. The surveys (see Appendix A) were distributed at the end of the school year and asked students about how different varieties of assignments influenced their achievement (see Figure 6). Answers ranged from one to five with one meaning he/she strongly disagreed and a five meaning he/she strongly agreed. A three represented neither agreement nor disagreement. The displayed scores are mostly near four, which indicated that students agreed with the statement in question. Students felt more strongly about class work increasing their grade and achievement, but fieldwork was ranked very closely. Students also felt more positively about fieldwork helping them to understand the nature of science than class work. This data closely relates and supports that shown by the fieldwork achievement data (see Figure 5). Finally, the strongest agreement came with the statement that all science classes should incorporate more fieldwork, while students on average neither agreed nor disagreed that science classes should incorporate more class work.

Question	Average	Median
Fieldwork has helped to increase my grade in this class.	4.1	4
Class work has helped to increase my grade in this class.	4.2	4
Fieldwork has helped my achievement in this class.	3.9	4
Class work has helped my achievement in this class	4.1	4
I better understood the nature of science by doing fieldwork (how science and scientists work).	4.2	4
I better understood the nature of science by doing class work (how science and scientists work).	3.8	4
All science classes should incorporate more fieldwork.	4.5	5
All science classes should incorporate more in class work.	3.2	3

Figure 6-Survey results on fieldwork and achievement in oceanography, n=59. Answers on a Likert Scale 1-Strongly Disagree, 2-Disagree, 3-Neither Disagree nor Agree, 4-Agree, 5-Strongly Agree. See Appendix A for full survey and responses.

Oceanography-Fieldwork and Motivation

The effects of fieldwork on student motivation in oceanography were examined using turn-in rates of fieldwork versus class work and two surveys (see Appendix A). The six fieldwork assignments had significantly higher turn-in rates, as seen in Figure 7. This graph also shows that members of the Mean Green Team were more motivated to turn in both fieldwork and class work than the general student population. The fieldwork turn in rate was taken from the average number of fieldwork assignments turned in out six by the 71 students. The oceanography turn in rate was taken from the average number of assignments turned in out of 106 by 71 students during the entire 2005-2006 school year. This rate included homework, tests, projects, labs, and other in class assignments. This data shows that fieldwork clearly had a positive motivational effect on the average student in oceanography.

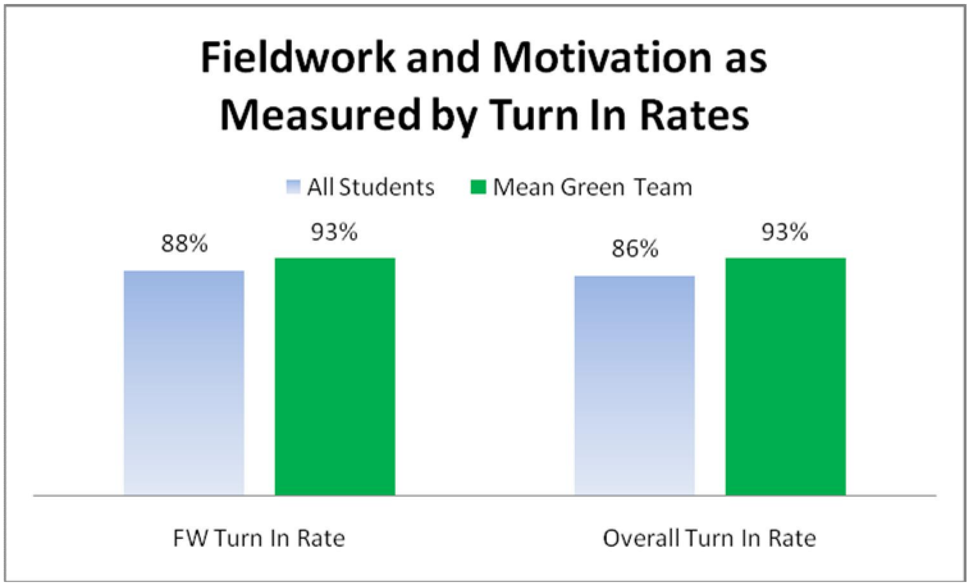


Figure 7-Bar graph of turn in rates in oceanography. All students n=68, MGT n=9. All students completed six fieldwork experiences, while the MGT completed 10 extra fieldwork experiences. P-value=0.38 for FW turn in rates-all students vs. MGT; p-value=0.003 for overall turn in rate-all students vs. MGT. See Appendix B for sample assessments and a student sample.

Two surveys were used to assess the relationship between fieldwork and motivation. The first survey simply asked students to put a list of fourteen learning activities in order from the one that motivates them to learn the most to the one that motivates them the least. The data reveals that fieldwork was ranked, on average, as the fourth greatest motivational strategy just behind labs and lab reports (see Figure 8). Rankings were formed based on the each individual students ranking. A ranking of number 1 earned 14 points while a ranking of 14 earned one point. The survey was given to 25 randomly selected students.

Overall Rank	Category	Points	Ave Points	Ave Rank	St. Dev.
1	Video	250	10	5.0	3.5
2	Visual Aids	243	9.72	5.3	3.5
3	Labs and Lab Reports	222	8.88	6.1	4.4
4	Fieldwork	219	8.76	6.3	3.4

5	PowerPoint	211	8.44	6.6	3.9
6	Models	200	8	7.0	3.6
7	Demonstrations	188	7.52	7.5	4.4
8	Discussion	178	7.12	7.9	3.7
9	Projects	150	6	9.0	3.7
10	Lecture	147	5.88	9.1	4.8
11	Computer Assignments	120	4.8	10.2	3.6
12	Student Presentations	103	4.12	10.9	3.5
13	Readings	102	4.08	10.9	2.8
14	Homework	97	3.88	11.1	3

Figure 8-Table of results from survey asking about motivational capability of learning strategies in oceanography, n=25. See Appendix A.01 for full survey.

The second survey asked about fieldwork, class work, and motivation by giving statements with students responding on a Likert scale (see Appendix A.05). Average answers indicated that students felt slightly stronger about fieldwork's ability to motivate than that of class work (see Figure 9). With an average answer of 4.4, they felt the strongest about liking science when they did fieldwork. This average response represented a statement between agreeing and strongly agreeing. This is in contrast to the average response to the statement about class work and motivation, which received an average answer of 3.7, somewhere between neither agreeing nor disagreeing and agreeing. It is important to note, however, how close the average answers actually were. By and large, students agreed that both fieldwork and class work helped motivate them to learn (see Appendix A.06 and A07 for full results).

Question	Average	Median
Fieldwork has increased my motivation to learn in this class.	4.3	4
Class work has increased my motivation to learn in this class.	3.7	4
I was more likely to turn in assignments when they involved fieldwork.	4.0	4
I was more likely to turn in assignments when they were assigned in class or as homework.	3.9	4
I like science when we did fieldwork.	4.4	5
I like science when we did class work.	3.7	4

Figure 9-Table with average and median answers from oceanography survey on motivation and fieldwork, n=59. Answers on a Likert Scale 1-Strongly Disagree, 2-Disagree, 3-Neither Disagree nor Agree, 4-Agree, 5-Strongly Agree.

Physics-Fieldwork and Achievement

The effects of fieldwork on student achievement in physics were examined by comparing fieldwork scores with other categories of assignments, a survey on fieldwork and achievement (see Appendix A.08), and through the use of pre and posttests on the nature of science (see Appendix B.05). CST scores could not be used for pre and posttests for physics since many students were seniors (who do not take the CST) and the study ended prior to its administration. The collected data compares student achievement in fieldwork, homework, labs, projects, in class work, and tests (see Figure 10). In contrast to the oceanography data, this physics data shows that students achieved at lower percentages on fieldwork than other assignments. However, that difference is not significant except between fieldwork and labs. In agreement with the oceanography data, this physics data shows that Mean Green Team members, who were exposed to dozens more fieldwork experiences during the study, achieved significantly higher on average (see Figure 10 for p-values). This difference is evident in the data from fieldwork, homework, labs, projects/class work, and on tests. It is important to remember that Mean Green Team members scored no better on previous science CST examinations than their peers (see Figure 5) and the only treatment they received was extra fieldwork related to science over the course of two years.

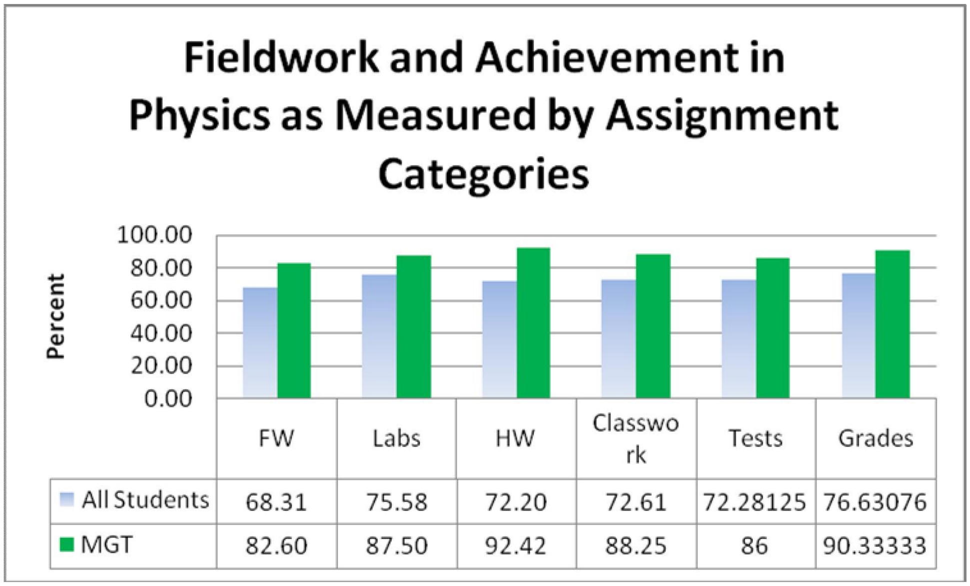


Figure 10-Bar graph of student achievement in physics by category of assignment. All students n=64, MGT n=11. All students were exposed to seven fieldwork experiences while MGT students were exposed to 20 extra fieldwork experiences. P-values for all students vs. MGT were all significant (FW=0.009, Labs=0.0004, HW=0.000001, Class work=0.003, Tests=0.0000004, Grades=0.000006). See Appendix B for sample assessments and a student sample.

To triangulate the data on fieldwork and achievement, students were given the same survey as given in oceanography. The results of this survey resemble that of the oceanography survey very closely (see Figure 11 and Figure 6). Every average answer is within two tenths except for the question on fieldwork increasing achievement. For this question, physics students felt more strongly that fieldwork helped them achieve. The trend from the surveys shows that fieldwork becomes more effective in increasing achievement over time. In summary, students felt that both class work and fieldwork were positively associated with their achievement, but had slightly stronger feelings about fieldwork.

Question	Average	Mode	Median
Fieldwork has helped to increase my grade in this class.	4.0	4	4
Class work has helped to increase my grade in this class.	4.1	4	4
Fieldwork has helped my achievement in this class.	4.2	4	4
Class work has helped my achievement in this class	4.2	4	4

I better understood the nature of science by doing fieldwork (how science and scientists work).	4.2	5	4
I better understood the nature of science by doing class work (how science and scientists work).	3.7	4	4
All science classes should incorporate more fieldwork.	4.3	5	4
All science classes should incorporate more labs.	3.4	4	4

Figure 11-Table showing results of survey on fieldwork and achievement in physics, n=61. Answers on a Likert Scale 1-Strongly Disagree, 2-Disagree, 3-Neither Disagree nor Agree, 4-Agree, 5-Strongly Agree.

The final data that examined fieldwork and its effect on achievement in physics was a nature of science (NOS) pretest and posttest. The results show that after one semester with seven fieldwork experiences the general population of students experienced a significant seven percent increase in achievement from the pretest to posttest (see Figure 12). Mean Green Team members experienced an insignificant two-tenths of one percent increase in achievement. Both MGT members and all students ended up with virtually the same scores on the NOS posttest. This was due to the timing of the pretest. It was given at the beginning of year two of the study. This was after most students had experienced one year of oceanography and fieldwork and the MGT members had experienced both oceanography and ten extra fieldwork opportunities. This fact accounts for the discrepancy between average MGT and average overall pretest scores. The insignificant difference between MGT and all students on the posttest may indicate that the positive effects of fieldwork had been maximized.

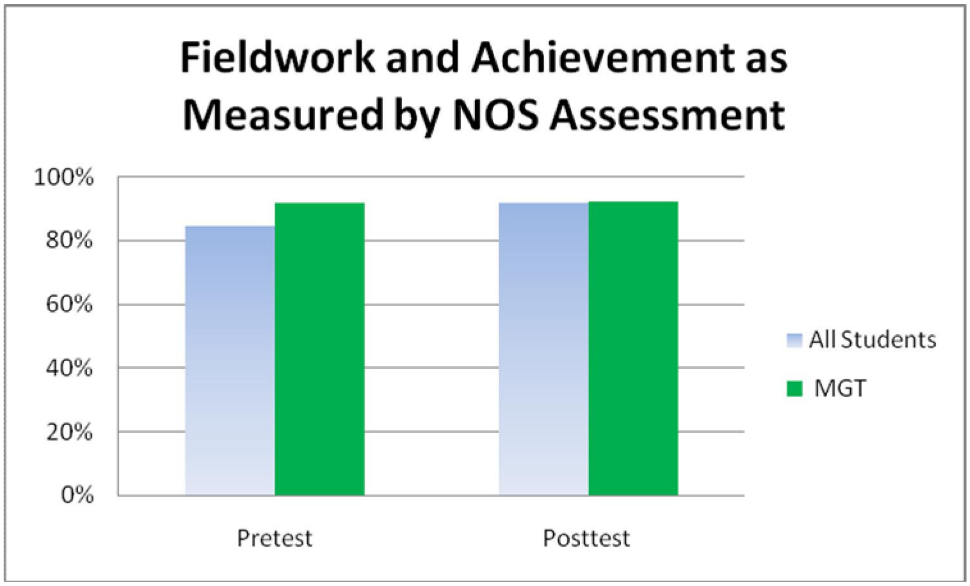


Figure 12-Bar graph of nature of science pre and posttest given to physics students. All students n=55, MGT n=10. All students were exposed to seven fieldwork experiences while MGT students were exposed to 20 extra fieldwork experiences. P-value=7.3×10^{-6} for all students-pre vs. posttest; p-value=.95 for MGT-pre vs. posttest. See Appendix B.05 for NOS Assessment.

<u>Physics-Fieldwork and Motivation</u>

The effects of fieldwork on student motivation in physics were examined by comparing fieldwork turn in rates with that of class work, two surveys on fieldwork and motivation (see Appendix A), and two student interviews (see Appendix C). The turn in rates of the 69 students for the seven fieldwork assignments were compared to the turn in rates on all assignments (see Figure 13). The turn in rates of all students for the physics fieldwork was a significant eight percent lower than that for all assignments. The Mean Green Team's turn in rate was not significantly different for fieldwork and general assignments. This data stands in stark contrast to that from oceanography which showed a much greater turn in rate on fieldwork assignments than on general assignments.

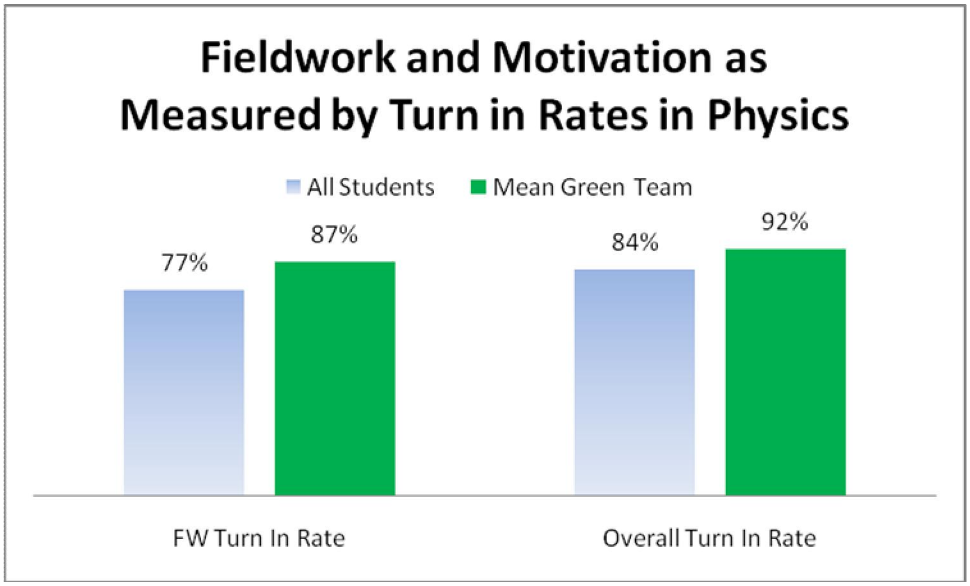


Figure 13-Bar graph of turn in rates for fieldwork and general assignments. All students n=63, MGT n=11. P-value=0.11 for FW turn in rate-all students vs. Mean Green Team; p-value=0.0026 for assignment turn in rate-all students vs. Mean Green Team, p-value=.019 for FW turn in rate vs. assignment turn in rate for all students. See Appendix B for sample assessments and a student sample.

The same ranking survey and Likert Scale survey related to fieldwork and motivation that was given to oceanography students was also given to physics students (see Appendix A). The results of the Likert Scale survey for physics (see Figure 14) are very similar to those from oceanography (see Figure 9). Every average response is within two tenths except for those related to the statement concerning likelihood of turning things in when they were assigned in class or as homework. It appears that physics student held less agreement with this statement than oceanography students (3.9 compared to 3.4). It is also interesting to note that from the average survey results one would infer that students were more likely to turn in fieldwork assignments than their non-fieldwork assignments, which was not the case according to the turn in rate data (see Figure 13). In sum, students conveyed that they, on average, agreed that fieldwork helped motivate them in science class.

Question	Average	Mode	Median
Fieldwork has increased my motivation to learn in this class.	4.2	4	4

Class work has increased my motivation to learn in this class.	3.7	4	4
I was more likely to turn in assignments when they involved fieldwork.	3.8	4	4
I was more likely to turn in assignments when they were assigned in class or as homework.	3.4	4	3
I like science when we did fieldwork.	4.4	5	5
I like science when we did class work.	3.5	4	4

Figure 14- Table with average and median answers from physics survey on motivation and fieldwork, n=61. Answers on a Likert Scale 1-Strongly Disagree, 2-Disagree, 3-Neither Disagree nor Agree, 4-Agree, 5-Strongly Agree.

Students' views of motivational capabilities of different learning strategies also varied little from oceanography (Figure 8) to physics (see Figure 15 and Figure 16). The surveys were given at the beginning of the school year and at the end of the first semester. Fieldwork was ranked as the second and third most motivating strategies respectively. However, despite fieldwork dropping in the overall rankings from the beginning of the course to the halfway point, its average ranking increased by four tenths. This pattern, along with a reduction in standard deviation, indicates that students consistently ranked it as more motivating and found such as they gained more exposure to it. The trend for students rating fieldwork increasingly more motivating was clearly displayed (see Figure 17).

Overall Rank	Category	Points	Ave Points	Ave Rank	St. Dev.
1	Visual Aids	183	10.76	4.3	2.9
2	Fieldwork	160	9.41	5.6	4.0
3	Videos	158	9.29	5.7	3.4
4	Projects	157	9.24	5.8	3.8
5	Labs and Lab Reports	155	9.12	5.9	4.0
6	Demonstrations	146	8.59	6.4	3.4
7	PowerPoint	142	8.35	6.6	4.3
8	Discussion	135	7.94	7.1	4.0
9	Models	115	6.76	8.2	3.6
10	Computer Assignments	95	5.59	9.4	3.8
11	Lecture	94	5.53	9.5	3.8
12	Readings	88	5.18	9.8	3.4
13	Students Presentations	73	4.29	10.7	2.9

14	Homework	70	4.12	10.9	3.2

Figure 15- Table of results from physics survey given at the beginning of the year asking about motivational capability of learning strategies, n=17. See Appendix A.01 for full survey.

Overall Rank	Category	Points	Ave Points	Ave Rank	St. Dev.
1	Visual Aid	593	10.40	4.6	3.2
2	Demonstrations	576	10.10	4.9	3.0
3	Fieldwork	559	9.80	5.2	3.8
4	Video	524	9.20	5.8	3.8
5	Discussion	473	8.29	6.7	3.5
6	Labs and Lab Reports	461	8.09	6.9	3.8
7	Projects	444	7.79	7.2	3.7
8	Models	438	7.69	7.3	3.2
9	PowerPoint	404	7.09	7.9	4.0
10	Lecture	392	6.88	8.1	4.9
11	Computer Assignments	329	5.78	9.2	3.2
12	Student Presentations	312	5.48	9.5	3.7
13	Readings	278	4.87	10.1	3.4
14	Homework	186	3.27	11.7	2.4

Figure 16- Table of results from physics survey given at the end of the first semester asking about motivational capability of learning strategies, n=57. See Appendix A.01 for survey.

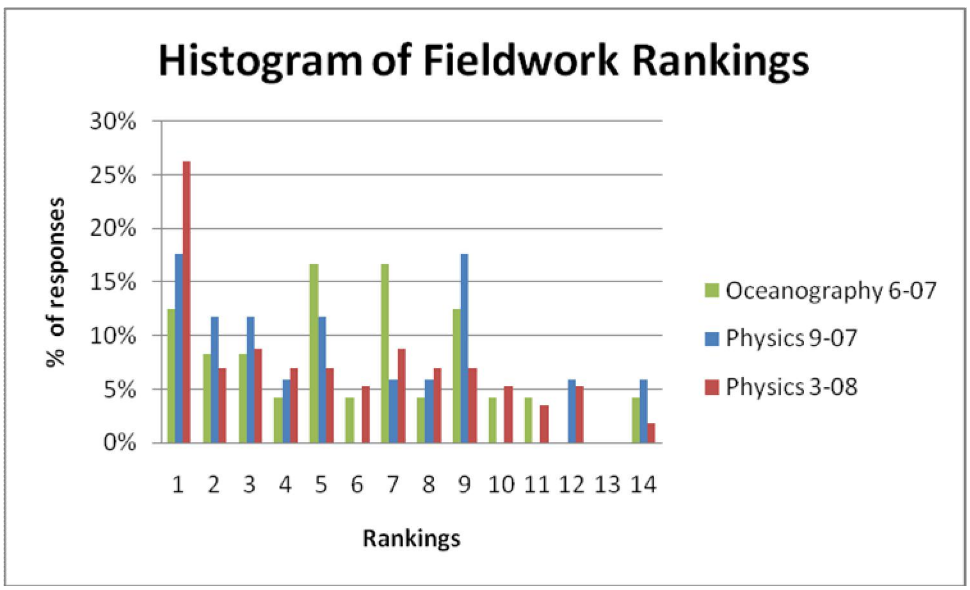


Figure 17-Histogram of fieldwork rankings according to oceanography and physics students over the course of two years. Rankings: 1-Most motivating, 14-Least motivating. See Appendix A.01 for survey.

The final piece of data collected came from two student interviews (see Appendix C).

Interviewees were selected because of their status as students who had completed oceanography, were in physics, and who had been Mean Green Team members for two years. Questions were asked about fieldwork, physics, oceanography, and the Mean Green Team. For the purposes of this study I will focus on two questions and their responses (see Figure 18). The answers support much of the previously stated findings about fieldwork improving student motivation (see Figure 9, Figure 14, Figure 15, and Figure 16). They also support the data that showed Mean Green Team members outperformed their peers in terms of motivation (see Figure 7 and Figure 13) and achievement (see Figure 4, Figure 5, Figure 10, and Figure 12) after experiencing increased fieldwork.

Has your fieldwork had any effect on your knowledge, interest, attitude, achievement related to science? How and why?	
Student 1	Student 2
"In oceanography it did. We did certain experiments with the Mean Green Team. We already knew how to go about things that we were going to do. The MGT helped motivate me for those labs." ***"I know more about science as a result of the Mean Green Team. I could learn from the Mean Green Team and then I would learn more about it in class."*** ***"Fieldwork is the most motivating, cause in class everyone is there doing it and they will try and get the same answers, but in fieldwork you will get different answers because people see things differently. In fieldwork you can observe changes and not everyone can have all the same answers all the time."***	*"Going out on the fieldwork helped me have different perspectives about what is going on in the world. When you are out in the field you have a better perspective, more broad, and you are seeing different information that you didn't see before."* *"The fieldwork has helped my achievement in science class…The fieldwork opened new doors for me about things I wouldn't have learned in the class… You are actually experiencing it, but in class we are just talking about it."* *"I would say that experiments and fieldwork are the most motivating for me in science, because talking about it and reading about it are not as motivating."*

Figure 18-A sample of answers from the student interviews related to fieldwork. See Appendix C for full interview transcription.

Chapter V-Discussion

Overview of Study

The purpose of this study, to find out how fieldwork effects student achievement and motivation in science class, was explored using a mixed methodology through experimental action research using a modified time series design. Results were obtained over the course of two years from my oceanography class, physics class, and environmental science club (MGT). These students participated in a multitude of pretests, posttests, surveys, fieldwork assignments, and regular assignments. Data was collected, graphed, averaged, and statistically analyzed using t-tests at the 95% certainty level ($p<.05$).

Summary of Findings

Findings of the study varied slightly from oceanography to physics class in terms of average achievement by all students. The findings were very similar for the extra-treatment group, the Mean Green Team, across the two year study. In oceanography, fieldwork positively affected student achievement. Students, on average, scored higher on fieldwork than lab work or homework. The average California Standards Test (CST) Earth Science pretest score rose from 40% to 72% on the posttest. The average CST-Investigation and Experimentation pretest rose from 33% to 71% on the posttest. Both increases proved statistically significant. Motivation also improved as a result of fieldwork according to turn in rates and student surveys. The average turn in rate for fieldwork was 88% vs. 86% for all class work, however this difference was not statistically significant ($p=.23$). Fieldwork also garnered the fourth highest motivational ranking among fourteen science learning activities (see Appendix A.01). Students agreed on average that fieldwork helped motivate them to learn science more than class work did, that they were more likely to turn in fieldwork assignments, that they liked science more during fieldwork, and that science classes should include more fieldwork (see Appendix A.06 and A.07).

Fieldwork in physics had somewhat less effect on improvement of achievement and motivation. Students, on average, scored lower on fieldwork than lab work, homework, and class work. However, these differences were not statistically significant ($p>.05$) for any comparison to fieldwork except for with lab work ($p=.029$). The average pretest/posttest score as measured in the Nature of Science Assessment (see Appendix B.05) rose from 85% to 92%, which proved to be statistically significant ($p<.000008$). Motivation appeared to increase with fieldwork according to student surveys; students agreed that fieldwork helped motivate them to do better, they liked science more, and they wanted to do more fieldwork. However, motivation according to turn in rates proved the opposite as there was a significantly lower turn in rate for fieldwork than for class work (77% vs. 84%, p-value=.019). The last measuring stick for motivation, ranking learning strategies according to their power of motivation, indicated that fieldwork ranked higher than previous surveys given in oceanography-26 percent of students ranked fieldwork as the greatest motivator. This was the highest response fieldwork received over the course of the two year study.

The Mean Green Team (extra-treatment group) excelled beyond the average student in all measurable categories in both physics and oceanography. The MGT average scores exceeded the overall student average for every measurable category of posttest achievement. They scored significantly higher ($p<.05$) on all assignment categories for both oceanography and physics, on the CST Earth Science, on fieldwork turn in rates for physics, overall turn in rates for physics, and overall turn in rates for oceanography. Prior to the fieldwork treatment the MGT members, on average, had no difference on scores that proved statistically significant. At the conclusion of year one, MGT students were already beginning to out-achieve the average. This trend continued until the end of the study.

Conclusions

The results showed that fieldwork can have an overall positive effect on achievement in science. These results were clear for students in oceanography, less clear for students of physics, and very clear for the Mean Green Team. The achievement results for oceanography indicated that fieldwork can help students increase their performance and achievement on both standardized tests and classroom assessments. This was evidenced by the CST pretest/posttest improvements and relatively high scores of fieldwork assignments. The achievement results for physics indicated that fieldwork had no positive effect on classroom grades, but did have a positive effect on pretests/posttests. This was most likely due to the rigor of fieldwork assignments, the procedure for turning them in, and the inability to make them up. As with lab reports, fieldwork assignments generally included inquiry, data collection, analysis, and a conclusion (see Appendix B). They were then turned in by the student posting the assignment on their webpage. This proved to be rigorous process for both types of assignments. A major difference, however, was the inability to makeup fieldwork assignments. At the end of semester one I received a flood of makeup labs from students who were recovering procrastinators or who were absent, but no makeup fieldwork assignments due to obvious logistical issues.

These results give evidence as to why Earth science teachers take their students into the field and why physics teachers tend to stay in the lab. The Earth sciences include more observational science, systems science, and big ideas that tend to lose some meaning in a reductionist laboratory. On the other hand, physics includes so many variables that need controlling to gain a true Newtonian cause and effect relationship. The nature of physics and the need for precise measurement necessitates laboratory controls to dispel the multitude of pre-conceptions that students take with them into their first physics course. Perhaps the fieldwork investigations fostered some of these conceptions as uncontrolled environments sometimes can (Braund & Reiss, 2006).

The achievement results for the Mean Green Team when compared with the achievement results of an average student indicated that if a little fieldwork was good, then a lot of fieldwork was very good. Despite having pretest CST scores that showed no significant difference from the average before the treatment, all posttest scores were dramatically above that of their peers. It is clear that the dozens of extra fieldwork experiences exposed them to the nature of science, the knowledge of science, and the processes of science. The nature in which they outgained their peers and my extensive observation of the group also indicated that they developed a tight bond, an attitude of success, and a feeling of trust in each other and in me. This comes as no surprise since we were able to participate in field events that ranged from river cleanups, to water testing, to climbing a mountain, to weeklong camping trips, to presenting at a national conference, to presenting to the school board. The extra fieldwork they did beyond their peers required tremendous understanding of a multitude of science concepts they were able to connect to the classroom and beyond.

The results related to fieldwork and motivation indicates the same thing across the board from oceanography, to physics, to the Mean Green Team: students are motivated by fieldwork and enjoy doing it. All groups consistently ranked fieldwork highly when asked about its capability to motivate. The results also indicated that students found fieldwork more motivating the more opportunities they had to engage in it. These results are not surprising as students always appeared more excited on the days of fieldwork. There was extra discussion, I received more questions, and students felt somewhat privileged as they left the school walls to pursue learning while others stayed behind.

The implications of this study are that fieldwork can continue to be a successful strategy in science education and it is well founded in its appearance in national standards. More fieldwork in science classes could spur achievement and interest in a time when it is very much needed. After all findings show that students start losing their motivation in to learn science in high school; the same time at which achievement starts to slide (Braund and Reiss, 2006).

Recommendations

The results of this study assure that fieldwork will continue to be a part of the curriculum I teach. I will continue to use it as a motivational tool for all the science classes I teach and as an achievement booster for Earth science and environmental science. The results could be used to help other classrooms use fieldwork within the class as a motivator and in clubs that involve fieldwork to help improve achievement. The review of the literature coupled with the consistent high ratings that fieldwork garnered from my students in terms of motivation indicates that fieldwork, at least in a small way, should be a part of every science classroom. Fieldwork can aid in student achievement by helping them make lucid connections to the real world, applying what they have learned, and exercising science process skills. It can also be a motivating experience for them to learn science in the field and gives incentive through exposure to Science Technology Engineering and Math (STEM) professions.

The successful fieldwork that I helped conduct could not have been possible without the generous support of community and non-profit organizations. To that end, I recommend that any teachers planning to implement many fieldwork experiences seek the support of local organizations that have a stake in educating local youth. I also recommend forming collegial partnerships and interdisciplinary assignments with grade level teachers since many can view field trips as disruptive to the curriculum in other courses.

Limitations of the Study

A few issues that may have hindered or affected my findings included the small shifting population of inner-city schools and relative attendance issues. These two factors were responsible for the small variation in n for many of the data collection tools. Also this study, with two treatment groups, lacked a true control group; the general population in oceanography and physics received a moderate amount of treatment (fieldwork), while the Mean Green Team received a large dose of treatment (fieldwork). It is worth noting again in this section that the Mean Green Team had no significant difference in achievement when compared to the class average at the beginning of the study, but they were a self-selected group. Another limiting issue with giving anonymous surveys to high school students is that you never know how honest they are. I have heard from my students in the past that they were often not sincere and did not really care about any survey they ever completed. A hindrance that may have affected the results was the subjectivity in grading and the relative amount of rigor for different assignment types. In my estimation, assignments in the homework and class work categories were somewhat easier than those in the lab work and fieldwork categories. Finally, as with any study involving education that lasts for an extended period of time, maturation and a superfluity of other factors may have helped increase achievement along with fieldwork.

In addition to the aforementioned uncertainties, there were several things that needed to be modified during the course of this study. A major change that occurred immediately before year one data collection was an unexpected change in teaching assignment from integrated science to oceanography. Another major change that occurred immediately before year two data collection was an unexpected change in teaching assignment from oceanography to physics. As a result, I taught both courses for the first time with a relatively unrefined curriculum. Other minor modifications included the changing of planned fieldwork dates, the revision of survey questions, and a basic change from students turning in paper assignments during year one of the study to turning in electronic assignments during year two of the survey.

The fundamental limitations of the applicability of this study stem from its essence founded in action research. The study examined the research questions using experimental design that manipulated the class environment. Thus, according to Johnson (2008), the applicability of the findings should be limited to examining what happened in my classroom or what is happening in very similar classrooms.

The second limitation of the applicability of this study stems from the ease at which I was able to take fieldtrips. As mentioned earlier, the high school at which the study took place resides in the center of a large metropolis with easy access to public transportation. As such, my administrators were used to teachers requesting permission to engage in fieldwork; and, my classes were able to easily access many of the fieldwork sites that were visited at relatively little cost. These factors led to students becoming well-versed in the art of the fieldtrip before entering my class as they had experienced many during their first two years of high school. This scenario is not easily replicated at many schools.

Future Research

Finally, my ideas for future research on this topic include the expansion of systematic fieldwork to other disciplines within my school and longitudinal tracking of Mean Green Team members beyond high school. The fieldwork for my classes proved at least somewhat successful both in improving student achievement and student motivation. I am curious to see if that fieldwork has a similar effect in other divisions of science and in other academic disciplines. Will similar results be produced by more biology trips to the zoo, more history trips to historical sites, more art field study at local art shows, or more mathematics trips to engineering firms? A more immediate interest is in tracking the progress of the graduating Mean Green Team members in their academic studies and professional careers. Nine of them have been accepted to four year colleges, and many will be the first in their families to attend. As of this writing, the colleges MGT members committed to included UC Davis, UC Santa Barbara, UC Santa Cruz, UC San Diego, Whittier College, California State Long Beach, Woodbury University, Seattle University, and California State University, Los Angeles. Most of them have also expressed interest in pursuing scientific or environmental degrees as a result of their experiences in this study. I am eager to see if these positive effects linger.

Final Thoughts

It has been a great pleasure to engage in extensive fieldwork experiences outside of the physical classroom with my students and colleagues. As a direct result of the activities undertaken for this study, positive relationships have been developed beyond those that come with standard classroom interactions. Another positive externality has been the development of partnerships with national and local science and non-profit organizations. While fieldwork proved to be a tremendous time commitment beyond typical lesson planning, the payoff of improved rapport, achievement, and motivation made the extra effort well worth it.

Many thanks for the success of this research are owed to my dedicated students for their full participation in innumerable assignments, surveys, activities, and adventures over the course of two years. Also, many thanks go to my colleagues at the high school for allowing me to interrupt their own lessons for many science trips. Once every chapter of the preceding project was completed I had tremendous help from classmates in my cohort and my professors in editing and ideas. Learning from and with such a dedicated and creative group has inspired me tremendously. My CSUN professors were instrumental in my development as a professional as well as in elucidating the value of action research. Other extra special thanks goes to the Mean Green Team for all of their hard work, hundreds of volunteer hours, weekends of learning, years of participation, and great adventures near and far. From Los Angeles to Mono Lake to Washington DC, it has been an amazing trip. Best of luck in college and beyond! Final thank yous go to Mom, Dad, David, and Becky for all of their support and love. And thanks to Becky for coming up with such a great idea.

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Appendix A

Student Surveys

A.01 Science Learning Activities Survey

Please order the following learning activities from most motivating to least motivating (in terms of learning science): lecture, videos, PowerPoint, visual aids, discussion, homework, reading, labs and lab reports, demonstrations, computer assignments, projects, student presentations, fieldwork, and models.

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.

A.02 Science Learning Activities Survey Results-Oceanography, n=25, randomly selected.

Overall Rank	Category	Points	Ave Points	Ave Rank	St. Dev.
1	Video	250	10	5.0	3.5
2	Visual Aids	243	9.72	5.3	3.5
3	Labs and Lab Reports	222	8.88	6.1	4.4
4	Fieldwork	219	8.76	6.3	3.4
5	PowerPoint	211	8.44	6.6	3.9
6	Models	200	8	7.0	3.6
7	Demonstrations	188	7.52	7.5	4.4
8	Discussion	178	7.12	7.9	3.7
9	Projects	150	6	9.0	3.7
10	Lecture	147	5.88	9.1	4.8
11	Computer Assignments	120	4.8	10.2	3.6
12	Student Presentations	103	4.12	10.9	3.5
13	Readings	102	4.08	10.9	2.8
14	Homework	97	3.88	11.1	3

A.03 Science Learning Activities Survey Results-Physics 1 (pre), n=17, randomly selected.

Overall Rank	Category	Points	Ave Points	Ave Rank	St. Dev.
1	Visual Aids	183	10.76	4.3	2.9
2	Fieldwork	160	9.41	5.6	4.0
3	Videos	158	9.29	5.7	3.4
4	Projects	157	9.24	5.8	3.8
5	Labs and Lab Reports	155	9.12	5.9	4.0
6	Demonstrations	146	8.59	6.4	3.4
7	PowerPoint	142	8.35	6.6	4.3
8	Discussion	135	7.94	7.1	4.0
9	Models	115	6.76	8.2	3.6
10	Computer Assignments	95	5.59	9.4	3.8
11	Lecture	94	5.53	9.5	3.8
12	Readings	88	5.18	9.8	3.4
13	Students Presentations	73	4.29	10.7	2.9
14	Homework	70	4.12	10.9	3.2

A.04 Science Learning Activities Survey Results-Physics 2 (post), n=57, randomly selected.

Overall Rank	Category	Points	Ave Points	Ave Rank	St. Dev.
1	Visual Aid	593	10.40	4.6	3.2
2	Demonstrations	576	10.10	4.9	3.0
3	Fieldwork	559	9.80	5.2	3.8
4	Video	524	9.20	5.8	3.8
5	Discussion	473	8.29	6.7	3.5
6	Labs and Lab Reports	461	8.09	6.9	3.8
7	Projects	444	7.79	7.2	3.7
8	Models	438	7.69	7.3	3.2
9	PowerPoint	404	7.09	7.9	4.0
10	Lecture	392	6.88	8.1	4.9
11	Computer Assignments	329	5.78	9.2	3.2
12	Student Presentations	312	5.48	9.5	3.7
13	Readings	278	4.87	10.1	3.4
14	Homework	186	3.27	11.7	2.4

A.05 Oceanography and Fieldwork Survey

If you would like to participate, please answer the following questions based on your experiences in Oceanography. Thank you for your participation in this anonymous survey.

Helpful Definitions:
Fieldwork-Assignments, activities, or experiment write-ups that involved a component outside of the physical classroom or student home.
Class work-Assignments, activities, or experiment write-ups that were completed inside the physical classroom or student home.

Circle the number that best fits your answer to the question.

1) Fieldwork has helped to increase my grade in this class.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

2) Class work has helped to increase my grade in this class.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

3) Fieldwork has helped my achievement in this class.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

4) Class work has helped my achievement in this class.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

5) Fieldwork has increased my motivation to learn in this class.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

6) Class work has increased my motivation to learn in this class.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

7) I was more likely to turn in assignments when they involved fieldwork.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

8) I was more likely to turn in assignments when they were assigned in class or as homework.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

9) I like science when we did field work.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

10) I like science when we did class work.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

11) I felt like a scientist when we did field work.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

12) I felt like a scientist when we did class work.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

13) I felt like a scientist when we did in class lab work.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

14) I better understood the nature of science by doing fieldwork (how science and scientists work).

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

15) I better understood the nature of science by doing class work (how science and scientists work).

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

16) I would rather learn by doing fieldwork assignments than in class assignments.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

17) I would be more inclined to choose to take a science class if it involved fieldwork.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

18) All science classes should incorporate more fieldwork.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

19) All science classes should incorporate more labs.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

20) All science classes should incorporate more in class work.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

21) All science classes should incorporate more homework.

1	2	3	4	5

Strongly Disagree   Disagree   Neither Agree Nor Disagree   Agree   Strongly Agree

22) How many times per year do you experience learning science outside of the school (family trips to the beach, boat rides, hiking, science museums, etc) Do not count class fieldwork in your answer.

1 or 2   3-4   5-6   7-8   9-10   10+

23) What grades did you receive for this class? (A, A-, B+, B, B-, C+, C, C-, D+, D, D-, F)

a. First Semester______   b. Second Semester_____

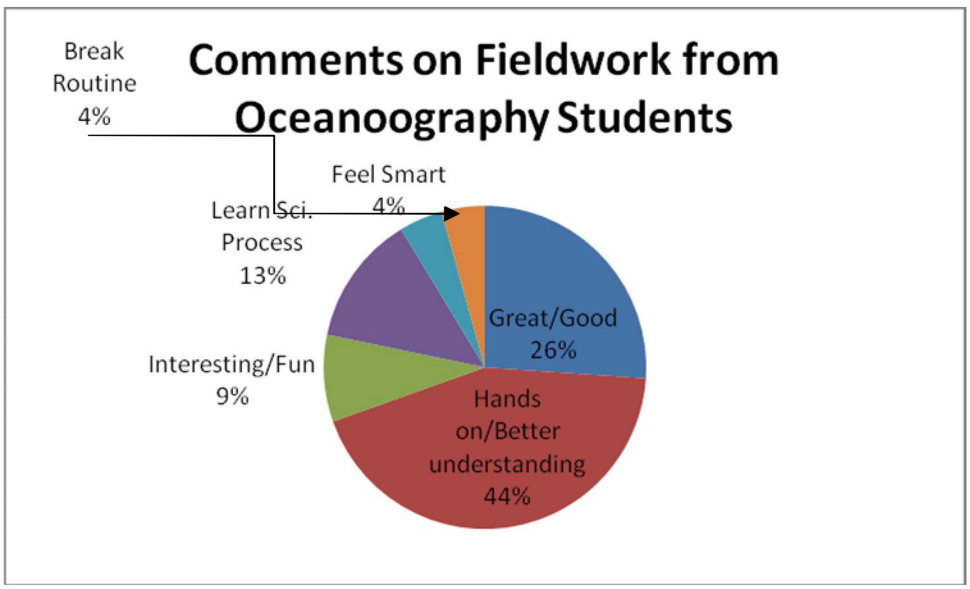
24) Please share any other thoughts you have on fieldwork in Oceanography or past/future science classes. For example, why you like or don't like fieldwork, why it helps or does not help you learn, why it engages or does not engage you, how it helps or does not help you understand the nature of science, etc. Thank you.

A.06 Oceanography and Fieldwork Survey Results

#	Question	Average	Median	Mode
1	Fieldwork has helped to increase my grade in this class.	4.05085	4	4
2	Class work has helped to increase my grade in this class.	4.16949	4	4
3	Fieldwork has helped my achievement in this class.	4.01724	4	4
4	Class work has helped my achievement in this class	4.08475	4	4
5	Fieldwork has increased my motivation to learn in this class.	4.30508	4	4
6	Class work has increased my motivation to learn in this class.	3.72881	4	4
7	I was more likely to turn in assignments when they involved fieldwork.	4.01695	4	5
8	I was more likely to turn in assignments when they were assigned in class or as homework.	3.86441	4	4
9	I like science when we did field work.	4.38983	5	5
10	I like science when we did class work.	3.72881	4	4
11	I felt like a scientist when we did field work.	3.86441	4	4
12	I felt like a scientist when we did class work.	3.45763	4	4
13	I felt like a scientist when we did in class lab work.	4.33898	4	5
14	I better understood the nature of science by doing fieldwork (how science and scientists work).	4.16949	4	5
15	I better understood the nature of science by doing class work (how science and scientists work).	3.76271	4	4
16	I would rather learn by doing fieldwork assignments than in class assignments.	4.01695	4	4

17	I would be more inclined to choose to take a science class if it involved fieldwork.	4.27586	4	4
18	All science classes should incorporate more fieldwork.	4.49153	5	5
19	All science classes should incorporate more labs.	4.37288	5	5
20	All science classes should incorporate more in class work.	3.15254	3	3
21	All science classes should incorporate more homework.	2.15254	2	1
22	How many times per year do you experience learning science outside of the school (family trips to the beach, boat rides, hiking, science museums, etc) Do not count class fieldwork in your answer.	5.5	5.5	5.5
23	What grades did you receive for this class first semester (A, A-, B+, B, B-, C+, C, C-, D+, D, D-, F)	C	C+	C
24	What grades did you receive for this class second semester (A, A-, B+, B, B-, C+, C, C-, D+, D, D-, F)	C	C+	C
25	Comments on Fieldwork	Positive=23		Negative=0

A.07 Coded comments on fieldwork from oceanography students



A.08 Physics and Fieldwork Survey

If you would like to participate, please answer the following questions based on your experiences in Physics. Thank you for your participation in this anonymous survey.

Helpful Definitions:
Fieldwork-Assignments, activities, or experiment write-ups that involved a component outside of the physical classroom or student home.
Class work-Assignments, activities, or experiment write-ups that were completed inside the physical classroom or student home.

Circle the number that best fits your answer to the question.

1) Fieldwork has helped to increase my grade in this class.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

2) Class work has helped to increase my grade in this class.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

3) Fieldwork has helped my achievement in this class.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

4) Class work has helped my achievement in this class.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

5) Fieldwork has increased my motivation to learn in this class.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

6) Class work has increased my motivation to learn in this class.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

7) I was more likely to turn in assignments when they involved fieldwork.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

8) I was more likely to turn in assignments when they were assigned in class or as homework.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

9) I like science when we did field work.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

10) I like science when we did class work.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

11) I felt like a scientist when we did field work.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

12) I felt like a scientist when we did class work.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

13) I felt like a scientist when we did in class lab work.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

14) I better understood the nature of science by doing fieldwork (how science and scientists work).

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

15) I better understood the nature of science by doing class work (how science and scientists work).

1	2	3	4	5

Strongly Disagree Disagree Neither Agree Nor Disagree Agree Strongly Agree

16) I would rather learn by doing fieldwork assignments than in class assignments.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

17) I would be more inclined to choose to take a science class if it involved fieldwork.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

18) All science classes should incorporate more fieldwork.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

19) All science classes should incorporate more labs.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

20) All science classes should incorporate more in class work.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

21) All science classes should incorporate more homework.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

22) How many times per year do you experience learning science outside of the school (family trips to the beach, boat rides, hiking, science museums, etc) Do not count class fieldwork in your answer.

1 or 2 3-4 5-6 7-8 9-10 10+

23) What grade did you receive for this class for the first semester?
A, A-, B+, B, B-, C+, C, C-, D+, D, D-, F

24) Fieldwork was more useful in Biology or Oceanography than it was in physics.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

25) Please share any other thoughts you have on fieldwork in Physics or past/future science classes. For example, why you like or don't like fieldwork, why it helps or does not help you learn, why it engages or does not engage you, how it helps or does not help you understand the nature of science, etc. Thank you.

A.09 Physics and Fieldwork Survey Results:

#	Question	Average	Mode	Median
1	Fieldwork has helped to increase my grade in this class.	4.0	4	4
2	Class work has helped to increase my grade in this class.	4.1	4	4
3	Fieldwork has helped my achievement in this class.	4.2	4	4
4	Class work has helped my achievement in this class	4.2	4	4
5	Fieldwork has increased my motivation to learn in this class.	4.2	4	4
6	Class work has increased my motivation to learn in this class.	3.7	4	4
7	I was more likely to turn in assignments when they involved fieldwork.	3.8	4	4
8	I was more likely to turn in assignments when they were assigned in class or as homework.	3.4	4	3
9	I like science when we did field work.	4.4	5	5
10	I like science when we did class work.	3.5	4	4
11	I felt like a scientist when we did field work.	4.2	5	4
12	I felt like a scientist when we did class work.	3.5	3	3

13	I felt like a scientist when we did in class lab work.	4.0	4	4
14	I better understood the nature of science by doing fieldwork (how science and scientists work).	4.2	5	4
15	I better understood the nature of science by doing class work (how science and scientists work).	3.7	4	4
16	I would rather learn by doing fieldwork assignments than in class assignments.	4.2	5	5
17	I would be more inclined to choose to take a science class if it involved fieldwork.	4.1	5	4
18	All science classes should incorporate more fieldwork.	4.3	5	4
19	All science classes should incorporate more labs.	3.4	4	4
20	All science classes should incorporate more in class work.	3.1	3	3
21	All science classes should incorporate more homework.	2.6	3	3
22	How many times per year do you experience learnint outside of the school…	5.5	3.5	5.5
23	What grade did you receive for this class…	77	75	75
24	Fieldwork was more useful in Biology or Oceanography than it was in Physics…	3	4	3
25	Comments on fieldwork	Positive=17		Negative=2

A.10 Sample comments on fieldwork from physics students.

Positive

- "I like doing fieldwork because it helps me understand physics more and is more interesting"
- "Fieldwork helps those who are active learners and need to use their senses."
- "Fieldwork is fun."
- "Every class should have fieldwork; Fieldwork more useful for younger students."
- "Fieldwork engages students to learn and makes science more interesting resulting in a better grade."
- "I liked fieldwork because I get a much better understanding and get a firsthand look at what we are learning about."

Negative

- “Fieldwork does not help me because it involves me doing things that don't help me in other areas.”
- “Sometimes we go to fieldtrips and don't do our work so it does not help.”

Appendix B

Assessments

B.01 Lab Report Format

Lab Report Format

An experiment is an investigation of a problem. We start with a question to which we want an answer. We then make an educated guess as to the answer. We use measuring devices and observations in a procedure that is planned to yield information (data) that hopefully will help us solve our problem. Then we analyze the data and express this as a result. Then we apply the results to the original question in the form of a conclusion.

This course requires a significant number of laboratory activities that will use the above scientific methods. These labs will be worth a significant percentage of your grade, so it is in your best interest to take your labs and their write-ups seriously. The requirements are as follows:

I. Prelab (title, purpose, predictions, procedure (with sketches) & data table)

The night before a lab is scheduled, your homework will involve "getting ready" for the lab. I will usually give you some written instructions, which you must read thoroughly and translate into numerical steps for yourself on paper. Draw pictures of equipment you will be using and procedures you will follow. Make a chart in which to collect data. Leave room to write your observations from the lab and any lab notes. I will stamp this paper at the beginning of the period on the day of the lab (usually 6 pts). YOU WILL NOT BE ALLOWED TO BEGIN THE LAB WITHOUT COMPLETING THE PRELAB. This includes the prediction! If you do not prelab completely before class, you will forfeit the 6 points. At that point the highest grade you can get is a "B".

1. **A Title**: Perhaps something poetic, witty, or charming. "Lab #3" is so dull.
2. **Purpose**: One or two brief sentences to identify the problem the experiment addresses.
3. **Predictions**: One or two possibilities of what might happen in the investigation. This should be regarding the science involved, not "I think this lab will be hard" or "I think the results will be accurate."
4. **Procedure**: This is a description of the steps you took. You should use sketches as well as words to indicate what equipment was used and how. This is the only reference you will have in the lab while performing your investigation, so make sure you include all the directions you need.
5. **Data Table**: The procedures describe the nature of data that you will collect. You need to design a table or a list in the prelab so that you know what data to collect during lab and where to write it down.

II. The Experiment

The day of the lab you will perform the experiment by following the procedures you have written. Collect all necessary numerical data and observations. Please consult with your lab partners and me if you have any questions. Always follow the safety guidelines as given, both written and verbal. Keep your prelab paper and your original data, as you will need to turn it in with the final draft of your lab write-up.

5. **Data** - Any measurements or observations go into your data section. When possible, data should be displayed in a table. Data is what you actually collect as you do the experiment. NO CALCULATIONS!!!!

III. The Write-up

Once you have completed the lab in class, you will begin working on the final draft of your write-up. I strongly recommend that you type this to increase the likelihood of securing maximum points for neatness (20% of the grade). On the other hand, if you have perfect printing, you may turn in a handwritten copy. The final draft should include all parts of the lab (1-7) in that order. When typing your lab, you may neatly hand draw (use a ruler!) any data charts or graphs if you are unsure how to word process these features. If you do not have a computer with word processing abilities you may use the Macs in the Library.

6. **Results** - This is the section where you analyze the data. This is where calculations, or a graph of the data, or a comparison to an accepted value, is given.

7. **Conclusions** - What conclusions can you draw from your experiment? This is the "meat" of the lab and is where you show me you understand what was going on, or at least have a reasonable idea. Please do not answer the questions posed " 1, 2, 3" in a list format. Instead, incorporate your ideas into a paragraph or two. Conclusions are mandatory not optional! Make them detailed enough to show your thoughts, but do not write a book. Relate the lab to the topics we have been covering in class! I want you to use the "**RERUN**" format.

R=Recall what you did during the lab
E=Explain why you did it, what were you trying to find out
R=Reflect on meaning, do your results support your prediction? Why did the experiment proceed as it did?
U=Uncertainty, This is the place to mention how reliable you think your results are (e.g. were there any mishaps that may have affected your results and/or were there design errors or limitations in the lab itself).
N=New questions or ideas (at least 2) that have come up because of the lab

IV. Grading

Prelab with stamp = 6 Neatness in final report = 6 Data & Results = 9 Conclusion = 9 Total = 30 pts

B.02 Sample Graded Fieldwork Report

Janice
Ashley
Christina

Wave Speed Investigation-Challenging Task 26/30 Good work

2. Purpose-The purpose of this lab is to find the speed of a wave from the pier. We will be putting our wave analyzing skills to the test!-Indeed you will, do it!

Questions:

a. What is the speed of a wave as measured from the pier?
b. What will affect the speed of the wave measured form the pier?-Do you mean what will affect your measurement or what will affect the speed? -1

3. Hypothesis (predictions)

a. I predict that the speed of a wave as measured from the pier will range from 1-3.5 meters per second.
b. I predict that the pier will get in the way and affect the speed of the wave as well as whatever is caught up in the wave, for example: sediments.

4. Materials:

- ♥ A pier (we used Santa Monica)
- ♥ Timer
- ♥ A method of measuring (measuring tape)
- ♥ At least 3 people to record data
  1. Find wavelength
  2. Time
  3. Record

5. Background:

- ♥ Wave speed can be calculated by multiplying the wavelength times the frequency. It can also be found by dividing distance and time.

6. Procedure

1. Go to the pier and measure a certain distance to find the wave speed
2. Keep a close eye on the waves we want to record speed for
3. Maybe someone might get in the water to measure for accuracy
4. Stand at one point of the pier with the measuring tape and then have another person at another point of the pier.
5. Make sure that we are able to start the timer when the wave starts and ends.

6. Find different ways to measure the wave speed if we can't do what we have planned.
7. Then calculate frequency with results we get
8. Calculate distance
9. Turn in lab

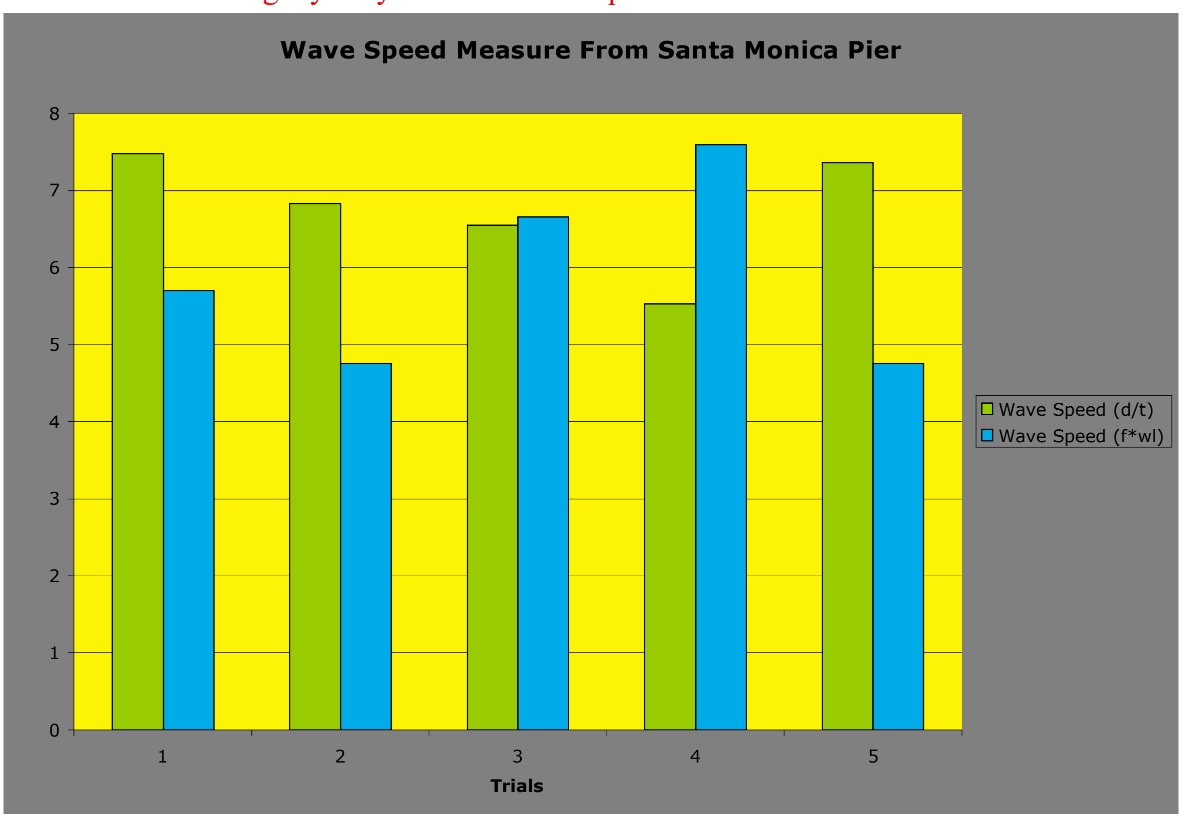
7. Data Table-Create-?

Trial	Frequency (Hz)	Period (s)	Wavelength (m)	Distance (m)	Time (s)	Wave Speed (d/t)	Wave Speed (f × λ)
1	0.6	1.67	9.5	9.5	1.27	7.48	5.7
2	0.5	2	9.5	9.5	1.39	6.83	4.75
3	0.7	1.43	9.5	9.5	1.45	6.55	6.65
4	0.8	1.25	9.5	9.5	1.72	5.52	7.6
5	0.5	2	9.5	9.5	1.29	7.36	4.75

Excellent Data Table, the only thing you are missing is the units for speed. -1

8. Observations:
- Some waves interfered with each other to create a bigger wave
- Sometimes it looked like the wave disappeared in the water
- There were a lot of littler miniature waves

9. Results:-Don't forget your y-axis label-m/s I presume. -1



10. Conclusion:

During this lab we tried to determine the speed of a wave from the Santa Monica Pier. We also tried to see if we could figure out what affects the wave speed as measured from the pier. We hypothesized that the wave speed from the pier will be between 1 and 3.5 meters per second. We also predicted that the pier would affect the wave because the wave has to travel around it and it crashes into it; also, whatever objects are caught in the wave such as sediment or other floating items. (When you use a semicolon you must have two independent clauses. -1)We had a method of measuring the wavelength that was going to be the most difficult calculation. We lowered a rope off of the side of the pier to see if it could float on top of the water from crest to crest. We would then pull the rope up and measure the wet area. Well since it was such a windy day it was really difficult to get the rope into the water. The rope also only measured the top of the wave; it did not go straight from crest to crest. That was our first uncertainty. When recording the speed of the wave it took on a much harder task. It took us a few trials to get the hang of it but we got there. Janice stood at one end of a wave and Ashley stood at the other. They were about three meters apart. Janice said start when a crest past (passed) her point and Ashley said stop as the crest past her point. This was about as accurate as we could get. When it came to our second question, it was too hard to see into the water and taking any water samples was too dangerous. We did take some risk when trying to analyze the waves but we held onto each other. The range of wave speed we calculated was 4.75-7.6 (units?). We would like to know the actual speed wave but it changes everyday due to weather and other contributing factors. Unless we could create the same conditions that seems like it would be the only possible way to compare our results to the actual wave speed. A few new questions we have are; what is the fastest ocean wave ever recorded? How fast is a tsunami? Good questions, excellent fieldwork report!

B.03 Sample Fieldwork Assignment

Name___________________
Period #________________

Physics at Eaton Canyon

Riding the Metro Section:

While on the metro fill out the following data table. Use dimensional analysis to convert mi to km and vice versa. Remember that 1 mi = 1.6 km = 1600 m. and 1 km = .62 mi. = 998 m. Use a stopwatch, cell phone, or iPod to figure out times.

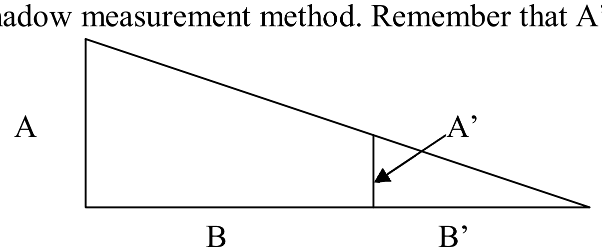
A. Union Station→ Chinatown				B. Chinatown→Lincoln Heights/Cypress Park				C. Lincoln Heights→Arroyo Station			
Mi	m	time (s)	speed (m/s)	mi	m	time (s)	speed (m/s)	mi	m	time (s)	speed (m/s)
	1240			1.43				.61			
D. Arroyo Station→ Southwest Museum				E. Southwest Museum→ Highland Park				F. Highland Park→South Pasadena			
Mi	m	time (s)	speed (m/s)	mi	m	time (s)	speed (m/s)	mi	m	time (s)	speed (m/s)

.9				1.1				2.25			
G. South Pasadena→Fillmore				H. Fillmore→Del Mar				I. Del Mar→Memorial Park			
Mi	m	time (s)	speed (m/s)	mi	m	time (s)	speed (m/s)	mi	m	time (s)	speed (m/s)
1.39				.59				.46			
J. Memorial Park→Lake				K. Lake → Allen				L. Allen to Sierra Madre Villa			
Mi	m	time (s)	speed (m/s)	mi	m	time (s)	speed (m/s)	mi	m	time (s)	speed (m/s)
1				1.14				1.98			

1. Where does metro gold line reach its top average speed?___________________
2. Assume that the metro reaches its top average speed at the halfway point of each trip. What is the metro's average acceleration from the starting station to the halfway point for each of the trips above?
   A. ____ B. ____ C.____ D.____ E.____ F.____ G.____
   H.____ I.____ J.____ K.____ L ____

<u>Eaton Canyon Section</u>:

Directions:
Measure the height of the bridge and one other object in the park by using similar triangles. Use your string and the shadow measurement method. Remember that A'/B' = A/B.



3. Object 1: Bridge A= _____ B=_____ A'= _____ B'=_____

4. Object 2:_______ A= _____ B=_____ A'= _____ B'=_____

***Directions*:**
Choose **three** more objects you would like to calculate the height of. Use your inclinometer and trigonometry functions to solve for the following problems.

5. Object 1: Bridge
   a. Distance from object______________________
   b. Angle of View___________________________
   c. Height of Object_________________________

Show your work:

6. Object 1: Waterfall
   d. Distance from object______________________
   e. Angle of View___________________________

f. Height of Object__________________________

Show your work:

7. Object 1: _____________________
   g. Distance from object______________________
   h. Angle of View____________________________
   i. Height of Object__________________________

Show your work:

Directions:
Try to estimate the height of the objects using the kinematics equation for distance.

$d=1/2at^2$ (Remember that the acceleration of gravity is approximately 10m/s/s when neglecting air resistance)

Assume that the initial vertical velocity of the water at the top of the falls is zero. Watch a drop of water from the top to the bottom and record the time it took.

8. Height of waterfall=_______________________________________

   Show your work:

Make sure that you have a partner clear the area before trying these ones! Drop a small rock from the top of the bridge and check dam and time the fall.

9. Height of bridge=____

   Show your work:

10. Height of check dam=____

    Show your work:

Conclusion: Did your bridge measurements vary? What form of measurement do you think was most accurate?

B.04 Sample California Standards Test Questions (CST)

For sample CST questions see http://www.cde.ca.gov/ta/tg/sr/css05rtq.asp.

B.05 Nature of Science Pre/Posttest

Name____________________
Date_____________________
Period___________________

Nature of Science Assessment[1]

1. Science includes aspects of…
    a. Science and Technology
    b. Technology and Math
    c. Science, Technology, and Math
    d. Just Science

2. Science can be defined as a particular way of…
    a. Observing
    b. Thinking
    c. Experimenting
    d. Validating
    e. All of the above

3. True or False-Science is a continually growing body of knowledge that builds upon and challenges past ideas.

4. True or False-Scientists believe that the universe is a single system that is understandable.

5. True or False-Scientific ideas are not subject to change.

6. True or False-Scientific knowledge is durable and based on evidence.

7. True or False-Science can provide answers to all questions.

8. True or False-All scientists follow the scientific method.

[1] Constructed from *Science for All Americans*, Chapter 1-The Nature of Science, 1989, by the American Association for the Advancement of Science.

9. True or False-Science relies on both quantitative and qualitative data.

10. True or False-Scientists rely only on machines and technical instruments to collect data and evidence.

11. True or False-Science is a collection of facts that does not involve imagination.

12. True or False-Science can explain, but not predict.

13. True or False-Scientists try to avoid bias.

14. True or False-Science is authoritarian and scientists are never wrong.

15. True or False-Science is a social activity.

16. True or False-Science is divided into different disciplines that are unrelated.

17. True or False-There are no generally accepted ethical principles in science.

18. True or False-Scientists participate in society as specialists and citizens.

Appendix C

Student Interviews

C.01 Fieldwork Interview Transcription

Pre-Bike Ride Interview

Prompt: Have you ever ridden a bicycle?	
Ashley "Yes, once every two months. Only ridden BMX bike."	***Charlie*** "Yes, twice a month. BMX bike."
Prompt: Draw the working parts of a bicycle and then explain how the bicycle works.	
Ashley (Bicycle missing several working parts. Drawing slowly). "Chain moves wheels, handlebars let you steer. Don't know what the chain is attached to. (Picture of bike is shown). Chain is attached to tires and pole thing."	***Charlie*** "Bikes have two tires, bolts, nuts, spokes. (Drawing highly accurate). The spokes resist the force that comes from your weight and attraction and the pressing down from gravity as you ride off of a curb. Gravity and motion are the main forces that pull you down. The chain helps propel the back wheel as you pedal. (Draws seat and explains that is where you sit. Seat is drawn as if it is attached above the chain.) The pedals make the bike go as you step on the pedals and move your legs in a circular motion. When you push against the pedals the chain moves and turns the back wheel just like a car (if you have a rear steering car. The front tire does not make you go, but the front tire helps you maintain your speed. The front tire moves because it is all on the same bike."
Prompt: Why do bikes have gears?	
Ashley "Never ridden a bike with gears. I have ridden an ATV with gears. You have to change gears when you are going uphill and gears help you go faster. The purpose of the gears is for different speeds."	***Charlie*** "My bike does not have gears, but they help you pedal. There are different slopes and different gears help you go up different gears. Some gears are easier and some are harder. There are 3 gears in the front or back, not sure, and there are five gears on the other side."
Prompt: Is it easier to pedal in certain gears? Why?	
Ashley "I don't know."	***Charlie*** "Yes, not sure, it's all physics." (laughs).
Prompt: Have you noticed anything different besides difficulty in pedaling? What and	

why?	
Ashley "No."	***Charlie*** "It is hard for you to have that motion in your legs because it stiffens kind of. In a lower gear, it is easier and used for uphill."
Prompt: Is it easier to balance on a bicycle when you are stopped, going slow, or going fast? Why?	
Ashley "It is easier to balance when you are going slow, because going fast I'd probably crash because I wouldn't be able to control the bike."	***Charlie*** "Going fast. It is harder when you are stopped because you do not have momentum left right forward or back. I rode down a hill top speed, and the wheel for some reason stays in one spot. I can turn a corner just by leaning. Why? There is a fast speed. What is top speed? The fastest speed that I have reached. It is not the fastest I could go, but it is the fastest I have gone. I have pedaled as fast as I can, but nothing happens because the bike is going faster than the pedals."
Prompt: Is there anything we have not talked about that you have learned about science that you can relate to the bicycle?	
Ashley "No."	***Charlie*** "No."
Prompt: How does a bicycle speedometer work?	
Ashley "Speedometer measures speed and how fast you go. There is those joggers that tell you how far you go, so maybe the speedometer is like that, maybe a motion sensor."	***Charlie*** "A speedometer tells you miles per hour." What does that measure? "It is a metric unit that tells you how fast you are going." Do you mean a 15 speed? "No..as you described. It is probably by the spinning of the tire. As you know in cars, the faster the tire runs the faster you are going. I wonder if you lifted up a car and you pressed the gas, would the speedometer still run. I will try it on the bike and I think the speedometer will still run. I think it is connected to the center of the wheel, it can't be connected to the pedal because the pedal can stop and you still go the same speed. Maybe it is a laser."

Students proceed to ride a bicycle and think about the questions that were asked. They rode, experimented, changed gears, and made general observations.

Post Bike Ride Interview

<table>
<tr><td colspan="2"><u>Prompt:</u> Why do bikes have gears?</td></tr>
<tr><td>Ashley
“Hills and flat ground.”</td><td>Charlie
“Different types of hills ground and going different speeds.”</td></tr>
<tr><td colspan="2"><u>Prompt:</u> Is it easier to pedal in certain gears? Why?</td></tr>
<tr><td>Ashley
“The 1-7 gears, when you change gears, the chain jumps and the difficulty changes.”</td><td>Charlie
“In some gears you pedal fast and you don’t really go anywhere. But the high gears are harder to pedal. Your acceleration is faster when you start pedaling in those gears, but in the lower gears your acceleration goes slowly. In the higher gears it takes more force, but it helps you when you are trying to go faster.”</td></tr>
<tr><td colspan="2"><u>Prompt:</u> Have you noticed anything different besides difficulty in pedaling? What and why?</td></tr>
<tr><td>Ashley
“In 1-3 you pedal faster, but you don’t go as far. The other gears are better because it’s flat out there.”</td><td>Charlie
“The tension in the chain changes when it is being tightened in different gears. The higher the tension the harder it is to pedal at a fast pace.”</td></tr>
<tr><td colspan="2"><u>Prompt:</u> Is it easier to balance on a bicycle when you are stopped, going slow, or going fast? Why?</td></tr>
<tr><td>Ashley
“When I said that you could balance better when you go slow, I think you can balance easier when you go fast and slow. It is hardest when you are stopped. This is because of the pressure. When you are in motion the gravity and pressure you have enables you to stay still in terms of balance.”</td><td>Charlie
“When you go faster it is harder to turn than when you are going slower. I think it is because when you are going fast you are headed that direction at a fast pace and you have to change against the fast pace. When you are going slow it is easier to turn against a slow pace.”</td></tr>
<tr><td colspan="2"><u>Prompt:</u> Is there anything we have not talked about that you have learned about science that you can relate to the bicycle?</td></tr>
<tr><td>Ashley
“No.”</td><td>Charlie
“No.”</td></tr>
<tr><td colspan="2"><u>Prompt:</u> How does a bicycle speedometer work?</td></tr>
<tr><td>Ashley
“I think it has some sort of magnet thing. Everything else I don’t know.”</td><td>Charlie
“The speedometer has a wire connected to a fork, but is not connected to the tire. There is another small piece on the tire that must transmit information from a laser or through a magnet. The tire goes in a circle and goes back and measures distance.”</td></tr>
</table>

Field Work Questions

<table>
<tr><td colspan="2"><u>Prompt:</u> Did you think there was a difference between your understanding before and after riding the bicycle…what and why?</td></tr>
<tr><td>Ashley
"Yes, the picture I drew was totally different than what I drew. Before, I didn't know that the chain jumped, I thought it just stayed in the same place when you changed gears. Getting out into the field and riding the bike helped me understand. I was able to ride it and feel it changing and hear the noise. When we were just talking about it I couldn't hear it or feel it."</td><td>Charlie
"As I was riding outside I understood the bike better and got a better understanding. This is because I am actually experiencing what is going on and observing. When you are just talking about it there are many things that could be going on that you are not focused on. It's just a bike, but there is all this physics."</td></tr>
<tr><td colspan="2"><u>Prompt:</u> Has your fieldwork (MGT/Internship) had any effect on your knowledge, interest, attitude, achievement related to science? How and why?</td></tr>
<tr><td>Ashley
"In Oceanography it did. We did certain experiments with the mean Green team. We already knew how to go about things that we were going to do. The MGT helped motivate me for those labs. I know more about science as a result of the mean green team. I could learn from the mean green team and then I would learn more about it in class.

Getting into the field for physics would help my motivation and achievement, because just learning and hearing words, it would get to me, but it won't stick. But if we get out and do something I'm like, oh okay now I understand why we are doing that. Being able to do something hands on. Like now I understand how the chain jumps when you change gears. Getting on the bike and seeing how it works helped me understand it better. Actually doing things is better. Labs in the classroom and going into the field both help me. In the classroom you are sitting there doing something, but going out you get to do different things and things around you will help you understand better.

Fieldwork is the most motivating, cause in</td><td>Charlie
"As we went out hiking, cleanups, or other activities, it helped me have the knowledge of what is actually going on in the world. Because when I was not part of the Mean green team, I was probably not even recycling, caring about cars and pollution. Going out on the fieldwork helped me have different perspectives about what is going on in the world. When you are out in the field you have a better perspective, more broad, and you are seeing different information that you didn't see before. When you keep doing your daily routine you are not really doing anything.

The fieldwork has helped my achievement in science class. In class we are just in the class learning about it, but not actually doing the I don't know how to say it. The fieldwork opened new doors for me about things I wouldn't have learned in the class. I wouldn't know about things like algae, conservation, or the growth of algae. You are actually experiencing it, but in class we are just talking about it.

I think that fieldwork in physics would help me in my physics class. As I observed how a bike actually works, I mean everything is</td></tr>
</table>

class everyone is there doing it and they will try and get the same answers, but in field work you will get different answers because people see things differently. In field work you can observe changes and not everyone can have all the same answers all the time.”	physics. I think that getting out in the field would of course help my understanding, just like experiments help me understand. I think field work and experiments are both the same. Because if you don’t go outside and you don’t do experiments you are not learning as much as what would be there in front of you. By observing with your five senses, that would just help you understand what’s going on. I would say that experiments and fieldwork are the most motivating for me in science, because talking about it and reading about it are not as motivating.”
Were you interested in these science issues before or did the fieldwork get you interested?	
Ashley “Fieldwork helped me get interested.”	***Charlie*** “I think both. I was interested in it, but as the time went on, it pulled me in more to understanding other effects that happen in the real world.”

Appendix D

Table of Figures