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Clean water in the classroom : understanding the importance of water quality

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Clean Water in the Classroom: Understanding the Importance of Water Quality

By

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A REPORT

Submitted in partial fulfillment of the requirements for the degree of

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This report, "Clean Water in the Classroom: Understanding the Importance of Water Quality", is hereby approved in partial fulfillment of the requirements for the Degree of MASTER OF SCIENCE IN APPLIED SCIENCE EDUCATION.

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ABSTRACT

Clean Water in the Classroom: Understanding the Importance of Water Quality

By

Emily Curry

This study's objective was to answer three research questions related to students' knowledge and attitudes about water quality and availability issues. It is important to understand what knowledge students have about environmental problems such as these, because today's students will become the problem solvers of the future. If environmental problems, such as those related to water quality, are ever going to be solved, students must be environmentally literate.

Several methods of data collection were used. Surveys were given to both Bolivian and Jackson High School students in order to comparison their initial knowledge and attitudes about water quality issues. To study the effects of instruction, a unit of instruction about water quality issues was then taught to the Jackson High School students to see what impact it would have on their knowledge. In addition, the learning of two different groups of Jackson High School students was compared—one group of general education students and a second group of students that were learning in an inclusion classroom and included special education students and struggling learners form the general education population. Student and teacher journals, a unit test, and post-survey responses were included in the data set.

Results suggested that when comparing Bolivian students and Jackson High School students, Jackson High School students were more knowledgeable concerning

clean water infrastructure and its importance, despite the fact that these issues were less relevant to their lives than for their Bolivian counterparts. Although overall, the data suggested that all the Jackson High students showed evidence that the instruction impacted their knowledge, the advanced Biology students appeared to show stronger gains than their peers in an inclusion classroom.

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CHAPTER 1: INTRODUCTION

Statement of the Problem

There are only a limited amount of resources available on this Earth for our use. Currently, we are not using many of the Earth's resources at a sustainable level. One example is water, with nearly one billion people lacking access to improved drinking water in the world today (WHO/UNICEF, 2010). Who is going to ensure that those individuals gain access to clean water? In addition, who is going to ensure that there is clean potable water for the future generations, not only in industrialized countries, but also in the developing world? As we think about who will need to solve the current environmental problems—including habitat destruction, pollution, and global climate change—facing the world, we need to look no further than to the students sitting in our school classrooms today.

Teachers have the greatest potential to impact students when it comes to environmental information and topics, more than the media, family, or friends (PISA, 2006). In fact, in the PISA study, fifteen year olds reported that most of their learning about the environment occurred in school. In addition to disseminating information, teachers have the opportunity to provide students with meaningful life experiences in nature, promoting stewardship of the scarce resources the Earth has to offer.

When children are exposed to nature they develop a greater appreciation for it. It instills a sense of ownership and stewardship. They also develop an understanding of the natural world. Children's life experiences in nature, in addition to their participation in formal or informal environmental education programs, contribute to their environmental literacy (Louv, 2005). Application of this environmental knowledge can then affect decisions and choices they make in their daily lives, which, in turn, may impact the natural ecosystems in which they live. These choices may be simple choices like whether to purchase bottled water or use a reusable canteen or bottle, or they may be more critical. In the future, for example, as a lawmaker or CEO of a company, a student may make tough decisions about setting emissions standards or seeking alternate methods of manufacturing using renewable or recycled resources.

As a classroom teacher I have worked with students who come from a variety of backgrounds. Some students come with extensive prior experiences with nature, while others have very limited experiences. These varying backgrounds and prior experiences affect students' decision-making and knowledge concerning the environment (Louv, 2005). Any great teacher is looking for ways to make learning relevant. Making connections between the classroom content and the students' home environments is one way to make learning relevant in the classroom and, if done well, allows teachers to teach the state curriculum at the same time.

In this study students were be exposed to an outdoor learning experience in their community as part of a unit of instruction in their science class. The goal of the teaching unit was for students to better understand water quality issues in their community and globally. In an effort to make the instruction meaningful and engaging to students, the teaching unit included various known best practice teaching strategies, such as inquiry based lessons, hands on learning, and physical experiences with the natural world.

Science Topics and Content Expectations Addressed in Study

The Michigan Merit Curriculum provided by the state of Michigan is rather vague when it comes to teaching the impact of human activities, stating, for example, that students should "Examine the negative impact of human activities" (MMC, B3.4C) (MDE, 2006a). Teaching about the importance of clean water is an excellent avenue to teach the High School Biology Content Expectation (HSCE) B3.4C as well as many of the other Biology HCSEs (MDE, 2006b). It also provides a way to connect students to the natural world and get the students outside and actively learning in their own community.

The following topics were addressed in the teaching unit that was developed for the study:

- *Where the water people use comes from*. Many individuals in our society—adults and youth—take clean water for granted. They think they turn on the faucet and it is just there, when in truth there is an entire industry and infrastructure dedicated to providing clean water. Few individuals here in the United States face life without access to an adequate supply of water.
- *Knowledge of the water quality in their community.* If the youth of today are expected to become the stewards of this planet, they need to be provided opportunities to engage in real world learning experiences in the natural world to connect them to it. They need to understand the effects the choices they make have on the ecosystem/watershed.

- *Understanding the global water crisis*. Many times clean water is taken for granted. Many of our students have never visited an impoverished country, and do not understand the importance of clean water. Contaminated water leads to disease and death in many impoverished countries. Students also are not aware of the lack of water availability worldwide.

While teaching these topics, the following Michigan High School Content Expectations (HSCE) were addressed:

- **B1.1A** Generate new questions that can be investigated in the laboratory or field.
- **B1.1B** Evaluate the uncertainties or validity of scientific conclusions using an understanding of sources of measurement error, the challenges of controlling variables, accuracy of data analysis, logic of argument, logic of experimental design, and/or the dependence on underlying assumptions.
- **B1.1C** Conduct scientific investigations using appropriate tools and techniques (e.g., selecting an instrument that measures the desired quantity—length, volume, weight, time interval, temperature—with the appropriate level of precision).
- **B1.1E** Describe a reason for a given conclusion using evidence from an investigation.
- **B1.2E** Evaluate the future career and occupational prospects of science fields.

- **B1.1C** Conduct scientific investigations using appropriate tools and techniques.
- **B1.2k** Analyze how science and society interact from a historical, political, economic, or social perspective.
- **B3.4C** Examine the negative impact of human activities.
- **B3.5g** Diagram and describe the stages of the life cycle for human disease-causing organism.
- **E4.1C** Explain how water quality in both groundwater and surface systems is impacted by land use decisions.
- **E4.1A** Compare and contrast surface water systems and groundwater in regard to their relative seize as Earth's freshwater reservoirs and the dynamics or water movement.

Research Questions

While completing a summer research internship with a Michigan Technological University International Senior Design team, I had an opportunity to teach lessons concerning water quality to students in Bolivian high school classrooms. In addition to teaching these lessons, I was able to work with undergraduate civil and biomedical engineering students while they completed fieldwork for their senior design projects.

This experience, and in particular, my opportunity to work with the Bolivian students, made me interested in whether these students had different knowledge and attitudes about water quality issues since they were raised in a very different setting than my own students in Jackson, MI. The Bolivian students were raised in a developing country with access to so little, and the Jackson High School students comparably have access to so much. Even though around 70% of the students in my school district receive free or reduced lunch, disadvantaged in the United States and disadvantaged in the developing world are two different things. The first research question focused on comparing these two groups.

Given that it has been documented that students are more likely to learn about environmental problems from school (PISA, 2006), I was also interested in how my own instruction to my Jackson classroom could affect students' knowledge and attitudes about water quality issues. My teaching assignment at Jackson High School includes work with two different learning groups, including a group of struggling students. Thus, the teacher in me wanted to know whether "best practice" teaching strategies, those I use on a regular basis, can really make a difference for struggling students. In particular, I was interested in whether such strategies could close a pre-existing gap between the general education and college prep students in my Biology (3-4) classes and the special education and struggling learners in my Biology (1-2) course. Thus, my second and third research questions focused on the overall learning that resulted from my own use of best teaching practices during a unit of instruction about water quality and differences in student learning between the two different student groups.

. In summary, the study addressed the following three research questions:

1. How do two groups of high school students, one from a developed country and one from a developing country (United States and Bolivia), initially compare regarding knowledge of water quality issues?

2. What impact does instruction that includes water quality testing and discussion of global water issues have on the US students' understanding of water quality issues?
3. To what extent does instruction that includes outdoor education experiences, inquiry-based education, and real world connections affect the achievement of general education students and special education students in an inclusive classrooms? Is achievement affected equally for these two groups?

CHAPTER 2: REVIEW OF RELATED LITERATURE

The purpose of the study was to investigate whether there were differences in two groups of students'—one group from the United States and the other from Bolivia—knowledge and attitudes about their local water quality and water availability. In addition, the study also aimed to determine how both general and special education U.S. students' knowledge and attitudes about these issues were affected by learning about their personal watershed. There are several main themes that can be found in literature that inform this study and will be reviewed in the following. First, we need to understand "best practices" for teaching and, in particular, what effects real-world, hands-on experiences have on student learning. We must also understand the importance of having students develop an understanding of environmental issues. Finally, we must understand what students currently know about the environment, and from where they get that information.

Teaching to Support Learning

Teachers have vast prior knowledge in their subject area, which makes it easy for them to make connections between materials and construct themes. Since students lack prior experience, they must participate in relevant, hands-on, experimental learning in order to make important connections in the brain (Jensen, 1998). An analysis of teacher surveys related to teaching practices and eighth graders' scores on the 1996 National Assessment of Education Progress (NAEP) shows that students whose teachers had been trained to engage them in classroom exercises and hands-on projects did better on the NAEP Science Assessment than students whose teachers did not have such training (Wenglinsky & Silverstein, 2006). The authors of the study found that students who were exposed to hands-on science activities once a week were 40 percent of a grade level further ahead in science, compared to students who were exposed to such exercises only once a month.

Humans are social beings. When teachers present one-sided lectures, it violates the principles of the brain. Brains grow and develop in social environments, and cooperative learning is highly effective when used well (Jensen, 1998). Research has shown that cooperative learning is especially important for deprived and at risk students, as they may have not had proper social skills modeled in their home environment (Taylor, 1992). Whenever cooperative learning is used in the classroom, it gives students the opportunity to improve their social skills, thus improving their academic success now and in the future. Many deprived children do not meet the same measure of academic success as students from more affluent homes because they lack basic social skills and techniques necessary for learning to take place.

Our brains are biologically wired for communication: talking, sharing, and discussing. In order for the brain to construct meaning from material, the material must be made relevant (Jensen, 1998). When material is relevant, connections are made between existing neural sites, firmly weaving information neurologically. To help students discover relevance, teachers can model their love of learning to students, give students time to link new material to prior material, use mapping and journaling, ask students to share personal experiences, and explain events in their own words. Teachers can use current events, historical events, or stories to make material more relevant for students. For example, a 2006 Finnish study showed that students' interest in their living environment could be enhanced by using out-of-school nature experiences and by engaging students in informal learning contexts such as using science kits, caring for farm animals, or building models (Uitto, Juuti, Lavonen, & Meisalo, 2006).

Teaching approaches that are consistent with constructivist learning theory, which states that humans construct knowledge from their experiences, have been shown to be successful when teaching environmental education curriculum. For example, in one study (DiEnno & Hilton, 2005), two groups of students participated in an environmental unit concerning non-native plants; both units were presented by a guest teacher. One group received traditional instruction, which focused on lecture and rote learning. The other group of students received instruction focused on a constructivist learning approach in which students constructed their own knowledge based on personal experiences. The study found that students in the constructivist learning group showed greater gains in knowledge and attitude change than students in the traditional group.

Importance of Students' Environmental Knowledge

> *"Today's children will one day be responsible for making decisions that will shape the future health of the environment. To prepare them for such responsibilities, they need a sound environmental education as a foundation upon which to make those decisions."–Deborah Mitchell (cited in Chepesiuk, 2007, p. A496).*

The global environment is currently facing many obstacles: increased levels of green house gases, an accumulation of waste, habitat destruction, and natural resource depletion. As highlighted in Mitchell's quote, it is important for today's youth to be scientifically and environmentally literate, to understand these challenges, and to help create and implement future solutions. If not dealt with, the economic impact of these environmental challenges will be devastating. Currently 2.6 billion people do not have access to improved sanitation (OECD, 2008). Today's students will be the future decision makers and problem solvers, and thus, must be environmentally and scientifically literate in order to use information about the environment to make those decisions and solve environmental problems.

There are several views concerning the importance of scientific literacy. A "macro view" has more to do with the connection between scientific literacy and the economic well-being of a nation. In this view, the more the public understands, the less likely they are to have unrealistic and unrealizable expectations for science, and the higher the levels of scientific literacy within a population, the greater support for science itself (Laugksch, 1999). The "micro view" focuses more on the direct benefits to a scientifically literate person. In this view, it would be an advantage to anyone living in a science and technology dominated society to be scientifically literate, because they are more capable of navigating through society (Laugksch, 1999).

Originally, environmental educators believed that one positive experience outdoors would correlate to environmental action: "Increasing knowledge leads to favorable attitudes ... which in turn lead to action promoting better environmental quality" (Ramsey, 1981, p. 27). In order for environmental action to take place, however, students must be scientifically and environmentally literate. This does not happen by one outdoor experience. Instead, it is important to facilitate learning that incorporates students' home environment on multiple occasions (Haluza-Delay, 2001). Students must have instruction in and modeling of problem solving and reasoning skills (Moseley, 2000). These skills must be presented to students using best practice teaching methods and made relevant to their real world environments.

Students' Knowledge of the Environment

The definition of environmental literacy was revised by the United Nations Educational, Scientific, and Cultural Organization, UNESCO, in 1989 to state:

> *Environmental literacy is a basic functional education for all people, which provides them with the elementary knowledge, skill, and motives to cope with environmental needs and contribute to sustainable development.*

Since then, a proficiency continuum has emerged with three distinct areas of environmental literacy: nominal, functional, or operational. Individuals with nominal literacy have a casual commitment to the environment and a basic understanding of issues. Functional individuals have substantive knowledge of issues and the ability to communicate environmental issues to a third party. An individual with operational environmental literacy has significant knowledge and is capable of applying analytical and logical thought processes to defend an environmental issue (Moseley, 2000).

In 2001 the National Education and Training Foundation (NEETF), in partnership with the Roper Public Affairs international survey firm, conducted a survey of American's environmental knowledge, attitudes, and behaviors. A nationwide cross section of over one thousand participants, eighteen years and older, revealed that only one third of the participants passed a simple twelve question survey concerning relevant environmental knowledge. Questions ranged from environmental topics such as the most significant cause of pollution to surface water to where most of the garbage in the U.S. ends up.

The Organization for Economic Co-operation and Development (OECD) has collected data worldwide, through their Program for International Student Assessment (PISA), about fifteen year olds' performance in Environmental Science. In their 2006 PISA release, they stated overall 80% of fifteen year olds had a basic proficiency, level D or higher, in Environmental Science, while only 19% of these students had a level A rating of high environmental proficiency. These students could handle the most complex tasks, consistently identifying, explaining, and applying knowledge to a variety of environmental topics. Highly environmentally proficient students are well equipped with a deep understanding of the environment, and are more likely to go into careers that interact with the environment in some capacity (PISA, 2006).

While it is positive that 80% of the fifteen year olds surveyed had at least a basic proficiency in environmental science, proficiency is not normally distributed. Researchers found that in some countries females were less likely to score basic proficiency, which makes it less likely for them to pursue a career that is associated with environmental science. Data also showed that, on average, students from disadvantaged socio-economic backgrounds and/or immigrant backgrounds had significantly lower proficiency (PISA, 2006). Comparing students in the United States with those in Colombia (a country similar to Bolivia), only 64.8% of students in Colombia had a basic proficiency or higher, while 84.5 % students in the United States were found to have the same level of proficiency. In Colombia the percentage of students with a level A rating of high environmental proficiency is far below the average, with only 4.6% of the students receiving the level A rating. Students in the United States were slightly below the average of 19%, with 17.1% of US students having a level A rating of high environmental proficiency.

The PISA study also reports that fifteen year olds reported their number one source for learning about the environment was school. Depending on the environmental topic surveyed, students reported between 58% and 76% of learning about the topic occurred mainly at school. The second leading source for environmental knowledge was print and electronic media: 41- 52% of students reported "mainly learning" from TV, radio, newspapers, and magazines. The Internet and books was third with 19- 27% of students, and finally family and friends was last. Family averaged between 9-20% while only 3-6% reported learning mainly about the environment from their friends.

Of the six environmental issues PISA polled students on, water shortage was the issue students felt least responsibility towards, although across the OECD countries 95% of the students polled were familiar with water shortage. Students polled showed minimum optimism for improvements in water resources, with an average of only 18% feeling optimistic about future improvements in water resources.

Summary

The economic and humanitarian impact of the current and future environmental problems has the potential to be devastating. Today's students are the future decision makers and problem solvers. One of the major environmental issues facing us today is the worldwide water shortage. In order to make improvements and consider solutions, all of our students need to be environmentally literate—not just students here in the United States, but in other countries, as well.

When students are polled concerning their acquisition of environmental knowledge, school is the number one source for students' learning about environmental knowledge (PISA, 2006). Because school is the number one source of students' environmental learning, it is important that teachers use various best teaching practices to communicate environmental information to students: inquiry/constructivist based learning, cooperative group learning, modeling, demonstrations, and making the content relevant to the students. Additionally, it is important to facilitate learning that incorporates students' home environment on multiple occasions (Haluza-Delay, 2001). Using best teaching practices to teach students about environmental issues will provide our best opportunity to help students become environmentally literate citizens who will become the stewards and decision makers of the future.

CHAPTER 3: PROCEDURES

Participants

Two different groups of students participated in the study: Bolivian students and students from the instructor's classroom at Jackson High School. All of the students were informed of their rights as human subjects; both they and their parents signed informed consent forms prior to participating in the study (MTU IRB protocol M0345; see Appendix A-1, A-2 for IRB approval form and participant consent letters).

The instructor came into contact with the Bolivian students as part of an internship through Michigan Technological University. The instructor was in Bolivia to teach in several high schools about water quality, as well as work with undergraduate civil engineering students from Michigan Technological University on their engineering projects for the city of Santa Cruz.

The instructor was able to teach at three different high schools in Bolivia: two private schools, the *Instituto Americano Walter Henry* and the *Instituto Americano Juan Wesley,* and one public school, *Unidad Educativa Bertha Cuellar*. While teaching at the *Instituto Americano Juan Wesley* and the *Unidad Educativa Bertha Cuellar*, the instructor/researcher was able to work with a Bolivian instructor who teaches at both schools. This instructor was a great aide to have in the classroom and enjoyed assisting with the project. She assisted with the dissemination of information to students in Spanish, since the instructor/reseacher had limited Spanish-speaking skills.

The Bolivian school system has a different class scheduling system than schools in the United States. For example, students in Bolivian secondary schools take biology every year. However, they only meet with their biology instructor once or twice a week, generally for only a total of sixty to ninety minutes a week. Many times, in both private and public schools, students only come to school for a half day. Because of this scheduling system, the Bolivian students were from all secondary grade levels, ninth through twelfth. Class size varied depending on the school and grade level, anywhere from eight students to forty students. *The Instituto Americano Walter Henry* had some of the smallest class sizes because the entire graduating class was in one classroom. In total, the instructor/researcher worked with approximately three hundred in the three schools combined. Although it is believed that the demographics of the students in the three schools were similar, comparisons were made among the data from the three groups of students to determine whether there were any important differences in their knowledge or attitudes about water quality issues.

The city of Santa Cruz, Bolivia is designed in a ring system, with the center or "hub" of the city in the center of the rings. Students attending the *Instituto Americano Walter Henry*, were from a more rural part of Santa Cruz, since it is located in the sixth ring. Students attending the public school and the *Instituto Americano Juan Wesley* were from a more urban setting since those schools are located within the inner rings of the city.

Biology is a 9^{th} grade course at Jackson High School. A majority of the students are between the ages of fourteen and sixteen. Three of the course sections that the instructor taught during the study were general/advanced sections of Biology titled BIO (3-4). The total number of students in each class that agreed to participate in this study were: first hour Biology (3-4), 13 students; second hour Biology (3-4), 18 students; third hour Biology (3-4), 22 students. One of the four sections was an inclusion classroom that was co-taught with a special education teacher. It is titled Biology (1-2). Approximately 58% percent of the students in this section were special education students with Individual Education Plans (IEP). Although there were 24 students in the Biology (1-2) class, only fourteen of those students agreed to participate in the study.

Jackson High School is an urban high school. It is located in the heart of downtown Jackson, Michigan. Jackson High School has approximately 1700 students: fifty-five percent Caucasian, forty percent African American, and five percent Hispanic and other minorities. Jackson High School is part of Jackson Public Schools, the largest school district in Jackson County.

Work with the Bolivian Students

The Bolivian students began by completing a pre-survey concerning their knowledge of water quality issues that was translated into Spanish by the researcher (Appendix B-1, B-2). The researcher had completed both high school and college courses in Spanish, including sixteen college credit hours. The survey was created by the researcher in English and then was translated into Spanish using the fundamental knowledge of the language learned in her coursework and the aide of an online translator.

Due to time constraints and the class scheduling of the Bolivian schools, the Bolivian students were not able to complete the post survey. However, they did participate in a number of instructional activities related to water quality issues (described in Appendix C-1). Time allotment with each group of Bolivian students was approximately one hour, with 40-55 minutes devoted to instruction. The Bolivian students participated in this study during July of 2009.

The Teaching Unit: Jackson Students

For this study, the Jackson High School students participated in a seven-day unit on water quality during May of 2009; these students also completed a survey both pre- and post-instruction. Students did not engage in any related teaching units or experiences previously in their Biology course, but typically in the fourth grade at Jackson Public Schools, students participate in a one-time, half-day presentation on the water cycle titled, "Our World of Water," given by a local nature center. It is unknown which students participated in the program, since it is up to each fourth grade teacher and the elementary principal to determine whether their students participate. In addition, not all students attended Jackson Public Schools in the fourth grade.

The unit combined lecture, demonstrations, and laboratories, both in the classroom and outdoors. The topics covered in the lessons focused on: the water cycle, watershed delineation, ground water, water-borne disease, safe water handling, sanitation, stream monitoring, the global water crisis, and the human impact on the environment. The major goals of this instruction were to educate students concerning the global water crisis, to teach students about their local watershed and what effects they have on it. The specific activities are described in the following.

Day 1: Students took the pre-survey (Appendix B-1). The teacher and students viewed a large map of all of the watersheds in the state of Michigan and discussed what a watershed is, which watershed Jackson belonged to, and the direction the water was flowing in, and also identified cities that were "down stream" from Jackson.

Day 2: The teacher provided a Powerpoint presentation, during which students took notes on the water cycle, types of pollution, and the definitions of permeability and porosity. Students were then provided with the following materials: clear tubes, gravel, coarse sand, fine sand, colored water, beakers, and stop watches. They were then asked to create a way to test permeability and porosity. Students brainstormed methods with a partner and then as a class. The class also discussed the need to collect and record data, and brainstormed methods to do it. After students were done testing, they were provided with analysis questions related to the day's objectives (Appendix C-3).

Day 3: Students participated in a demonstration from the "Sewer Science" curriculum (Appendix C-4). A waste-water sample was created by mixing potential waste substances into a tank of water. Students then hypothesized about what each substance could represent in a real waste-water sample. An example would be ammonia. Ammonia could represent human urine, or it could represent cleaning products. Students then participated in a lab in which they constructed water filtration tubes and demonstrated all the necessary steps of water reclamation: aeration, coagulation, sedimentation, filtration, and disinfection, to produce a clean water sample. (Appendix C-2). Students then completed analysis/journal questions (Appendix C-4).

Day 4: Students watched a short clip from ScienCentral.com titled, *007's Water War Based in Reality, not Fiction* (Appendix C-5). Students were instructed to watch the clip and then write a one-sentence summary of the content of the clip. The class then read an article titled, *Women Bear the Weight of Water* (Water.org), completed comprehension questions, and discussed them as a class (Appendix C-6). The instructor then presented a Powerpoint on water borne disease. Students were given the option of creating an informational brochure or poster. The students got to choose the topic—either a water borne disease or the world water crisis. Since computers were not available, the instructor provided fact sheets for students to use as they gathered additional information. The fact sheets were obtained from the World Health Organization's website (http://www.who.int/mediacentre/factsheets/en/). Each fact sheet contained information on one topic or disease, such as cholera or malaria. While students were creating their brochures they were given the opportunity to haul one gallon of water around the entire perimeter of the school campus and be timed while completing the task. After everyone had the opportunity to complete the task, and have their time recorded, the class discussed this activity, focusing on how their personal water use would be affected if they had to haul their own water daily.

Day 5: Students divided into groups to complete review stations on previously covered material. The review stations each focused on a different topic. Each station had four to five questions that related to a topic, along with informational resources on those topics (Appendix C-7). Several of the stations also had information on how to practice the chemical analysis tests, so students could become familiar how to conduct the tests. Using a timer, students rotated from one station to another, spending approximately eight minutes at each station.

Day 6: The entire class walked to the Grand River, approximately a ten to fifteen minute walk from the school. While at the river, students performed chemical analysis of the river water, collecting data about temperature, dissolved oxygen, pH, nitrates, phosphorus, and turbidity. Students also used nets to collect macroinvertebrates from the water and completed a habitat assessment. Water samples were also taken and added to bacterial test kits to check for the presence of bacteria, an indicator of *E. coli*.

Day 7: The students and teacher analyzed the data collected at the river. Students completed the post survey (Appendix B-3) and then completed a unit test (Appendix C-8).

Data Collection and Analysis

Data for the study was collected from several sources: student pre- and post-surveys, student journaling questions and student work, a teacher observation journal, and an end of unit test. Each data source and its purpose in this study are described in the following.

Student Surveys

The group of U.S. students took a pre- and post-instruction survey pertaining to their current views and knowledge of water quality and water availability (Appendix B-1, B-3). The pre-survey was designed to gather information on students' views and knowledge about water quality issues prior to the unit of instruction. The post-survey was conducted to determine if students' views and knowledge about water quality issues had been affected by the unit of instruction. The survey included both open and closed response questions. The closed-ended questions used a Likert scale; the students had to respond to a statement on a scale from one to five, with one indicating strong disagreement with a statement and 5 indicating strong agreement. The reliability of the survey was determined using Cronbach's α. Cronbach's α provides a measure of the internal consistency of the scale and the extent to which it measures the same attribute. The reliability was acceptable, but not strong (Cronbach's α= 0.630). Reliability tends to increase as the number of items on the scale increases. The scale had 17 items, which is relatively short. For a scale with 12 items or more, values around 0.7 (0.65 to .84) are acceptable (Field, 2009).

Students in Bolivia also took the pre-survey during the instructor's internship in that country (Appendix B-2). Because of the instructor's limited time with each group, there was not sufficient time to conduct the post-survey. The results of the pre-survey were used to compare the initial knowledge about water quality issues between the groups of U.S. and Bolivian students, including whether there were consistencies or differences in the way students across the globe think about water quality and supply.

Student Journal Questions

During the unit of instruction with the Jackson High School students, journaling was used to collect additional data. Journal questions and prompts were included in student's daily assignments and labs. An example question that was included in students' daily work is, "What steps can you take to protect the ground water that is available in your area? Can you give a specific example?" (Appendix C-3).

Students' responses reflected their thoughts about water quality issues and their understanding of information collected or presented during the labs and lessons. Journal entries were scored using a rubric with a numerical scale for the purposes of this study. Entries were awarded one point each for: proof of mastery of each lesson objective and evidence of a change in views or knowledge based on the day's lesson. For an example, if there were three points available, the instructor was looking for three pieces of evidence of student learning in the response. This score was used as a quantitative representation of the quality of students' journal entries. Students who mastered the lesson objectives and showed a change in their views or knowledge had higher scores than those who did not. Journal scores varied from question to question; not all questions were assigned the same number of points.

As an example, one journaling question asked, "The phrase, 'Out of sight, out of mind' is often applied to the water infrastructure and the clean water industry. How does this phrase apply?" Here, one point was awarded for interpreting what the phrase meant. Another point was awarded for applying it to the water infrastructure. A third point was awarded for mentioning something about the role of people or clean water industry. For this journal question, there were three points possible.

Teacher Journal/Observation

The teacher also kept a journal that included observations of students' participation during class and students' thoughts/views that were expressed. The teacher journal also included actions taken by the teacher and her perceived impressions of the effectiveness of the activities. The teacher journal was used in the study to identify consistencies and inconsistencies between the teacher's and students' perceptions of student learning by comparing it to student responses to journal questions and other assessment questions.

Unit Test

In addition to the post survey, students took an end-of-unit test that was similar in format to the other unit tests they had taken in class (Appendix C-8). All unit tests are made up of multiple choice, and short answer or essay questions. They include questions designed to test students' science reasoning and inquiry skills. All test questions were designed to test students' mastery of the HSCEs addressed in the unit, and to prepare students to take standardized tests given in the state of Michigan: the Michigan Merit Exam (MME) and the ACT. In the state of Michigan all instruction is guided by the Michigan Merit Curriculum, including the instruction in this study.

The unit test for this study was comprised of multiple choice and short answer questions. There were three distinct themes that the multiple-choice questions fit into: global water crisis, water testing and the water cycle, real world applications. For the purposes of this study it was helpful not only to look at individual questions, and how students performed on them, but also to group the questions based on themes in order to correlate the data to the research questions.

Student Work

Student work, including lab reports and water quality data, from the students in the Jackson High School group was also collected by the instructor. The instructor analyzed these materials, or portions of these materials, in a similar format to the journal questions. Points were awarded based on appropriate responses, with points varying for different forms of student work.

Summary

This data was collected in an effort to answer the three research questions in this study. Using the student surveys a comparison was made between the knowledge and attitudes of the Bolivian student group and the JHS student group. The data collected from the JHS unit of instruction was used to identify changes in knowledge in both the Biology (1-2) group of students and the Biology (3-4) group of students. The data was also used to assess the impact the instruction had on the JHS students' knowledge of water quality issues.

CHAPTER 4: FINDINGS

To answer the research questions, the data was analyzed in two different ways. To answer research question number one—comparing U.S. and Bolivian students' knowledge of water quality issues—the pre-test data from both the Jackson High School (JHS) test group, and the Bolivian test group were compared and analyzed. The second and third research questions specifically targeted only the JHS test group, in particular, what affect a unit of instruction had on students' attitudes and knowledge about water quality issues and how the instruction specifically affected the learning of general and special education students. Additional data, including an end of unit test, student work, and journal questions, were collected and analyzed in order to address those questions. In the following, I first discuss the comparative data and then discuss the data that documents the learning of the JHS group.

Bolivian and Jackson High School Test Groups

The instructor returned from Bolivia with over three hundred fully or partially completed surveys. For the purposes of this study, thirty fully completed surveys were randomly selected from each school, for a total of ninety Bolivian surveys. Due to time constraints in the classroom, sometimes students were not able to finish the survey before the lesson began. Typically there was only thirty to forty minutes of contact time with each group of students; in addition, some students would come to class late or were off task, socializing with friends. There were no survey questions/statements left blank more often than others, indicating that failure to complete the survey did not appear to be related to students' understanding of particular questions.

Table 1 contains pre-survey data for both the JHS and the Bolivian student groups. The student survey used a Likert scale, with responses ranging from 1: strongly disagree to 5: strongly agree. The average response for each question is presented in the table, as well as the difference in the averages between the two groups.

Table 1. *Pre-Survey Likert Results: Bolivan and JHS Test Groups*

#	Survey Questions	Average Response		
		JHS Pre	Bolivia Pre	Difference
1	My actions affect the quality of the water in my watershed.	3.25	2.72	0.53
2	My actions affect the quality of water in other watersheds.	3.12	2.7	0.42
3	Clean, fresh water must be used in moderation.	3.88	4.13	-0.25
4*	It is safe to drink the water from any faucet.	2.53	2.45	0.08
5	Water is a renewable resource.	3.58	3.16	0.42
6*	All individuals have access to clean water.	1.86	3.21	-1.35
7	Only bottled or properly disinfected water should be used for cooking, brushing teeth, and drinking.	3.42	3.56	-0.14
8	Contaminated surface water and poor sanitation contribute to the transmission of water-borne disease.	4.05	2.85	1.2
9	Impervious surfaces typically have the highest rates of runoff.	3.56	2.96	0.6
10	Boiling water can eliminate the chance of water-borne disease.	4.12	4.04	0.08
11	Water-borne disease can be eliminated by boiling water	3.88	4	-0.12
12	By treating water with chlorine and iodine water-borne disease can be eliminated	3.39	3.53	-0.14
13	Some germs and chemicals occur naturally in water.	3.77	3.227	0.5
14	Standing water creates a breeding ground for disease carrying mosquitoes.	3.93	3.1	0.83
15	The Clean Water Industry plays a vital role in my daily life.	3.95	4.09	-0.14
16	The Clean Water Industry plays a vital role in the daily lives of individuals around the world.	3.91	4.29	-0.38
17	There are many career opportunities in the Clean Water Industry.	3.42	3.62	-0.2
	**Overall Group Means	3.69	3.4	

*Denotes negative question, **Take into account reversed scores for negatively posed survey questions.

Overall, the results suggest that the JHS students performed slightly better on the Likert- scale questions of the pre-test survey, with an overall mean score of 3.69, compared with the Bolivian group overall mean of 3.4. An unpaired t-test revealed a p-value of 0.0006, which is considered to be statistically significant at a 5% significance level (see Appendix: D-1). Two survey questions, in particular, stood out as substantially different between the two groups, where the group means were separated by over one point.

First, the JHS group performed better on question number six, "All individuals have access to clean water." This question is of importance because it is a central theme of the world water crisis: people around the world do not all have access to clean water and are dying every day as a result. The responses to this question includes information from two different population of students: Bolivian students who are living in the developing world, where only 85% of the people have access to improved drinking water sources, and Jackson High School students who are living an industrialized country, where 100% of the population have access to improved drinking water sources (WHO/UNICEF, 2010).

Question number six was a negatively worded question, since all individuals do not truly have access to clean water. A more knowledgeable student should have responded to the question with a response of a 1: strongly disagree, or 2: disagree. On this question, the groups' averages were separated by 1.35 points: the JHS group had a mean of 1.86, and the Bolivian group had a mean of 3.21. On the rating scale, a score of a three represents a student feeling neutral on the subject. The results suggest that the Jackson

High School students were more knowledgeable about, or more familiar with, the lack of access to clean water for all people.

The other question that stood out between the two groups was question number eight, “Contaminated surface water and poor sanitation contribute to the transmission of water-borne disease.” Again, this is another central theme of the world water crisis: people do not have access to clean water. Many times water becomes contaminated due to poor sanitation, and then people become ill from consuming that water.

Questions number eight is a positive statement, so students who are more knowledgeable should have rated it a 4: agree or 5: strongly agree. For this question, the two groups’ means were separated by 1.2 points. The mean for the JHS group was 4.05, indicating agreement, while the mean for the Bolivian responses was only 2.85, indicating a neutral response. Again, the survey results suggest that the Jackson High School group was slightly more knowledgeable about poor sanitation contributing to the contamination of water and to the spread of disease.

In addition, on the survey there were some other interesting differences between the two test groups. The mean scores for questions number one and two indicated that both test groups were neutral in regard to their personal actions having an effect on their watershed or on the quality of the watersheds around them, suggesting that neither group related their own actions to potential problems. One potential problem with this question is that students, particularly those in Bolivia, may not have been familiar with the term *watershed*; thus, it may have been the case that since they were unfamiliar with the term, they selected the neutral response because they were unable to make a decision.

The responses to question 11 showed that both groups illustrated knowledge about boiling water to prevent disease by indicating agreement about the ability to eliminate disease by boiling water. This data suggests that both groups have knowledge concerning the elimination of water related illnesses and that were they put into a situation with a questionable water source, they could take the necessary precautions to prevent becoming ill.

The JHS group also agreed that standing water was a breeding ground for mosquitoes (mean response of 3.93 on question 14), while the Bolivian group indicated a neutral response (mean response 3.1). This is important to point out because students living in Bolivia are more likely to be exposed to many diseases that are transmitted by mosquitoes. The warm wet climate of Bolivia, make it an ideal breeding ground for mosquitoes. In 2006, there were over 70,000 reported cases of malaria, a disease caused by a parasite that is transmitted to humans via the bite of a mosquito (WHO, 2008).

Both groups' means on questions 15 and 16 indicated that both groups of students agreed that the Clean Water Industry played a vital role in their daily lives and in the lives of individuals around the world. This is important because the clean water industry is made up of the people and infrastructure needed to insure that clean water is available and that all people have access to proper sanitation.

The open-ended survey responses revealed additional differences between the two groups. One difference illustrated by the surveys was how students prepare water for cooking or drinking in their home. Pre-survey question number 19 asked, "Before you use water in your home for cooking or drinking do you do any of the following?"

(Appendix B-1, B-2). It then gave possible ways of treating the water: boiling, chemical treatment, filtering, bottled water, or no treatment. Approximately 88% of students in the JHS group indicated that they just use the water straight from the tap without any form of treatment. Some of the JHS students also checked "boil the water" but indicated in writing that they boiled water for cooking. Others marked "bottled water" and wrote "for drinking" next to it. Thus, it is possible that some of the students were confused or not knowledgeable about the difference between boiling water during cooking and boiling water to purify it, or about choosing to use bottled water out of convenience rather than out of necessity.

With the Bolivian test group, 74% percent of the students indicated that they boil the water in their home before using it for cooking or drinking in response to this survey question. Again, some students also indicated two selections. For this group 22% indicated that they practiced no method of treatment before using the water in their home for cooking or drinking. Since students in Bolivia are less likely to have access to improved sanitation and drinking ware supplies (WHO, 2010), this question is important because it suggests that the Bolivian students who are more likely to acquire water-borne diseases are more likely to additionally treat their water before use in order to protect themselves from it.

The additional open-ended questions did not show any additional differences between the two groups. These questions were intended to gauge additional prior knowledge that students had concerning how they get their water and to assess if they were at risk for acquiring water-borne disease. However, due to the design of the survey questions and the lack of students knowledge it was difficult use these questions to accurately gauge that information.

To determine whether the JHS/Bolivian comparison results were representative of all three Bolivian schools or whether there were substantial differences among the three schools that should be considered, the Bolivian survey data was additionally broken down by school. When comparing the three different Bolivian High schools, unpaired t-tests showed that there was one instance where the differences in survey results were statistically significant between two Bolivian schools—the *Instituto Americano Juan Wesley* and the *Instituto Americano Walter Henry.* Further analysis revealed that there were two survey questions, in particular, where their average survey responses differed by close to one point, number eight and number sixteen (see Appendix D-2).

Question number six was, "Contaminated surface water and poor sanitation contribute to the transmission of water-borne disease." The *Instituto Americano Juan Wesley* students had an average response of 2.43, while the *Instituto Americano Walter Henry* had an average response of 3.33. The *Juan Wesley* students were disagreeing with a correct statement, indicating they were less knowledgeable concerning standing water and poor sanitation's role in the transmission of water borne disease, where the *Walter Henry* students average response may indicate that they were unsure about the statement (see Appendix D-3). Stating that one is unsure may also indicate a lack of knowledge; however, students who responded in this way may not have had an incorrect preconceived idea about the topic. Although it is difficult to conjecture why the two groups of students may have responded as they did, one possible explanation is that students attending the *Instituto Americano Walter Henry* live in a more rural area, in an outer ring of the city and possibly have more knowledge about the issue because they have more experience being exposed to water-borne disease as a result of poor sanitation and standing water where they live.

The other question in which the two schools were separated by almost one point was question number sixteen, “The Clean Water Industry plays a vital role in the daily lives of individuals around the world.” The *Instituto Americano Juan Wesley* students had an average response of 3.6, while the *Instituto Americano Walter Henry* had an average response of 4.43. Even though the two responses are almost separated by one point, they would both round to a 4, meaning that the students generally agree with the statement. The two groups of students also both agreed with question number fifteen, “The Clean Water Industry plays a vital role in my daily life,” indicating that the differences between the two groups may be less significant than the data first suggests.

When comparisons were made between each of the *Institutos* and the *Unidad Educativa Bertha Cuellar*, the p-values indicated that the differences in survey responses were not statistically significant (see Appendix D-3). Thus, although it may be possible that the differences between the schools is attributable to their location (rural versus urban), the fact that no significant differences were found between the *Unidad Educativa Bertha Cuellar* and the *Instituto Americano Walter Henry*—the first urban and the second rural—suggests that this is not the case. Although the differences among the Bolivian schools cannot be explained based on the data available, the fact that there were some differences means that the findings should be interpreted with some caution.

Jackson High School Instruction Results

Survey Results

The JHS students completed both pre- and post-surveys, before and after the unit of instruction. Table 2 contains a summary of the survey data. This is the same survey discussed previously and it used the same Likert scale, with scores ranging from one to five. The average pre-survey and post-survey response for each question is presented in the table, as well as the change in the average response from pre- to post-survey. Paired t-tests were conducted to determine whether the change in average scores from the pre- and post-test were significant. When comparing all the JHS students, the t-test revealed a p-value of 0.0001, which is considered to be statistically significant at a 5% confidence level (see Appendix D-4 for t-test results).

When comparing the pre- and post-test results of individual classes, the first hour Biology (3-4) group had a p-value of 0.0004 (Appendix D-5) and the third hour Biology(3-4) group had a p-value of 0.0409 (Appendix D-7), both which are statistically significant at a 5% significance level. Both the second hour Biology (3-4) group and the fifth hour Biology (1-2) group had p-values that were not statistically significant at a 5% significance level: second hour 0.0745 and fifth hour 0.3289 (Appendix D-6, D-8). Since the 5^{th} hour Biology (1-2) class had a small sample size (n = 14), the results for this group should be interpreted with caution. When combining all the Biology (3-4) classes together there was a p-value of 0.0001, which is considered to be extremely statistically significant (Appendix D-9). Thus, the results suggest that the Biology (3-4) students overall showed significant differences in their pre- and post-test results, while the Biology (1-2) students did not.

Table 2. *All JHS Students Pre- and Post- Likert Survey Data*

#	Survey Questions	Average Response		
		JHS Pre	JHS Post	Difference
1	My actions affect the quality of the water in my watershed.	3.25	4.05	0.8
2	My actions affect the quality of water in other watersheds.	3.12	3.30	0.18
3	Clean, fresh water must be used in moderation.	3.88	4.07	0.19
4*	It is safe to drink the water from any faucet.	2.53	2.61	0.08
5	Water is a renewable resource.	3.58	3.51	-0.07
6*	All individuals have access to clean water.	1.86	1.42	-0.44
7	Only bottled or properly disinfected water should be used for cooking, brushing teeth, and drinking.	3.42	3.68	0.26
8	Contaminated surface water and poor sanitation contribute to the transmission of water-borne disease.	4.05	4.26	0.21
9	Impervious surfaces typically have the highest rates of runoff.	3.56	3.72	0.16
10	Boiling water can eliminate the chance of water-borne disease.	4.12	4.26	0.14
11	Water-borne disease can be eliminated by boiling water	3.88	3.93	0.05
12	By treating water with chlorine and iodine water-borne disease can be eliminated	3.39	4.07	0.68
13	Some germs and chemicals occur naturally in water.	3.77	3.81	0.04
14	Standing water creates a breeding ground for disease carrying mosquitoes.	3.93	4.28	0.35
15	The Clean Water Industry plays a vital role in my daily life.	3.95	4.28	0.33
16	The Clean Water Industry plays a vital role in the daily lives of individuals around the world.	3.91	3.91	0
17	There are many career opportunities in the Clean Water Industry.	3.42	3.47	0.05
	**Overall Group Means	3.69	3.91	0.22

***Denotes negative question, **Takes into account reversed scores for negatively posed survey questions**

Table 3 highlights the differences in the JHS pre- and post-surveys, with the data broken down by biology class. In addition, the average response to each question for all JHS students was calculated, as well as the average response for each question for only the Biology (3-4) classes.

When comparing individual questions, there was an average increase of 0.8 points from pre- to post-survey for all biology groups for question number one, “My actions affect the quality of water in my watershed.” The Biology (3-4) sections had a larger average increase than the Biology (1-2) group: Biology (3-4) with a 0.89 point increase and Biology (1-2) with a 0.46 point increase (Appendix D-8, D-9). Overall, the data suggests that students changed their attitudes about their personal actions having an effect on their local environment, specifically their watershed, during the study.

Table 3. *Differences in JHS Pre- and Post-Surveys by Class*

Survey Question	**All JHS**	**BIO(3-4) 1st**	**BIO(3-4) 2nd**	**BIO(3-4) 3rd**	**BIO(1-2) 5th**	**BIO(3-4) ALL**
1	0.8	1.5	1	0.36	0.46	0.89
2	0.18	0.58	0.58	-0.06	-0.54	0.35
3	0.19	0.67	-0.11	0.41	-0.18	0.29
4	0.08	0.67	-0.59	0.23	0.27	0.04
5	-0.07	-0.08	0.41	-0.35	-0.37	0
6	-0.44	-1.09	-0.12	-0.3	-0.45	-0.44
7	0.26	0.59	0	0.05	0.82	0.14
8	0.21	0.92	0.06	0.35	-0.55	0.39
9	-0.16	0.33	0	0.06	0.37	0.11
10	0.14	0	-0.11	0.06	0.82	-0.02
11	0.05	0.08	-0.06	0.24	-0.10	0.08
12	0.68	0.59	0.77	0.7	0.64	0.69
13	0.04	0.16	0.06	0.06	-0.19	0.09
14	0.35	0.92	-0.12	0.35	0.45	0.32
15	0.33	0.41	0.3	0.59	-0.09	0.43
16	0	0.08	-0.12	0.12	-0.09	0.02
17	0.05	0.09	0.12	0.29	-0.46	0.18

Another individual question that showed a large average increase for all groups was question number twelve, “By treating water with chlorine and iodine, water-borne disease can be eliminated.” All students showed an average increase of 0.68 points, with little difference between the two ability groups of Biology (1-2) and Biology (3-4). This suggests that students' attitudes had changed concerning using chemicals to treat water, although it is possible that they initially had a more neutral stance because they did not understand the difference between using chemicals to treat water, and potentially getting sick from ingesting those chemicals. During the unit of instruction, students created a "mock" wastewater sample, treated the sample, and discussed disinfection with small amounts of chlorine; these activities may have cleared up this potential misunderstanding.

Student Work/Journals

On day three, students participated in a demonstration from the "Sewer Science" curriculum (Appendix C-4). A wastewater sample was created by mixing potential waste substances into a tank of water. Students hypothesized about what each substance could represent in a real wastewater sample. They then constructed water filtration tubes and demonstrated all the steps of the water filtration process; after the activity students completed a set of journaling questions.

One of the journaling questions asked, "The phrase, "Out of sight, out of mind" is often applied to the water infrastructure, and the clean water industry. How does this phrase apply?" A correct response should have included that we don't see the infrastructure, so many people don't know or think about where their water comes from and all the work people do to ensure we have clean water to use and a method to eliminate the water that we have used. 86% of the students correctly interpreted the phrase by mentioning something similar to "being underground, and not thinking about it." None of the students included anything about the people working in the clean water industry. Typical student responses, such as those that follow, focused on not being able to physically see the pipes, nor where the water comes from or where the water goes after it is used.

> *"It is mostly underground, so many people just take it for granted that we can get water anytime we want. It you don't see something (the water infrastructure) you don't think about how it works."*

> *"Once the water goes down the drain, you don't have to worry about it anymore."*

Several students, 14%, misinterpreted the "out of sight" portion of the phrase. They included something in their response concerning not being able to physically see things in the water. Examples follow:

> *"Because even though you can't see that the water is dirty, it could still be dirty and could harm you."*

> *"Because many chemicals in the water are not really visible."*

On day four, students viewed a short clip from ScienCentral.com titled, *007's Water War Based in Reality, not Fiction.* Following the video, students were instructed to write a one-sentence summary of the information presented in the clip. The purpose of the clip was to highlight the world water crisis and the fact that both the amount of water available and the quality of water are in jeopardy. Student responses focused mainly on the potential for violence in the future over water, thus highlighting the scarcity or lack of clean water. All responses included something concerning the "scarcity of water," or "violence over water." Examples of student work follow:

> *"They are saying that now we fight over oil and gasoline but in the nearby future they may fight wars over water too"*

"The water is going to be a bad situation in the future if we don't start to take care of it. They think that what will fight wars with us is the water."

"Over a billion people worldwide do not have water daily, the new James Bond movie portrays a water war that is expected to happen in the future."

"They think that there will be an increase in violence or a war over the amount of water in the world."

"Water is becoming more scarce and people have already tried to control fresh water."

Only six student responses, representing 10% of the students, included something about pollution being a problem in the future. Polluted water was mentioned in the video clip, but not centrally highlighted like violence over the scarcity of water.

"There is more and more water being polluted every day. They say there is going to be a water crisis. The clean drinkable water is going to run out."

"People will try to take over someone's water source, by polluting it".

Also on day four, the class read an article titled *Women Bear the Weight of Water*. This article highlights the additional danger and sacrifices that many women face in order to obtain clean water for their family. To piggyback on that article and questions around it, students were given the opportunity to carry one gallon of water around the entire campus and have their time recorded. After students had completed the task, the class had a discussion about the activity. Students stated that the gallon was heavy, and they had to switch hands back and forth to keep their arms from getting tired. It was easier to carry the gallon if they walked with it, instead of running with the water. In the first hour class, a group of students went out with their gallons of water and decided to race each other;

one girl fell down and the others left her. We discussed what might happen if she had been left alone in a part of the world where people do have to travel long distances to get their water. Students thought a wild animal might get her, or someone could have caused harm to her.

Following the activity, students responded to the journal question, “It is estimated that every American uses 100 gallons of water a day. How would not having water readily available in your home impact that number?” All students included something in their response about using less water. Sample responses include:

> *“People wouldn’t want to go to the lake every time they needed water. So they would use it for just water they needed it for, and they would use less gallons.”*
>
> *“It would drop a lot, because the reason why that number is so high is because we have an unlimited source of water at our fingertips.”*

Unit Test

The unit test was comprised of twelve multiple-choice questions and two short written response questions (Appendix C-8). A summary of the results is given in table 4. When combining all classes of students, they averaged 12.6 points for correct responses on the unit test, or a 66%. Students in the Biology (3-4) classes performed better on both the multiple-choice questions and the written response questions than did the students in the Biology (1-2) class. On average students in the Biology (3-4) classes got 9.0 questions correct on the multiple choice section of the unit test or 75%, where students in the Biology (1-2) class only averaged 5.6 correct responses, or 47%. As seen in table 4, students in the first hour Biology (3-4) class scored the highest on average, with an average score of 9.4 correct multiple-choice responses.

Table 4. *Unit Test Scores*

Class	Multiple choice #1-12	Short response #13	Short response #14	Total
Possible points	**12**	**3**	**3**	**18**
All JHS	7.9	2.3	2.4	12.6
1st hour BIO(3-4)	9.4	2.6	2.9	14.9
2nd hour BIO(3-4)	9.1	2.6	2.5	14.2
3rd hour BIO(3-4)	8.4	2.6	2.8	13.8
5th hour BIO(1-2)	5.6	1.7	1.5	8.8
All BIO(3-4)	9.0	2.6	2.8	14.4

For the purposes of this study, the multiple-choice questions were broken down into several groupings. As seen in table 5, several of the multiple-choice questions contained were related to the global water crisis. All students participating averaged 69% correct on questions concerning the global water crisis. Again, the Biology (3-4) classes performed better on this group of questions than the Biology (1-2) students, with the Biology (3-4) group averaging 72% correct and the Biology (1-2) averaging only 55%. The second hour Biology (3-4) class performed the best, averaging 79% correct for the four questions containing content on the global water crisis.

Table 5. *Student Percentages on Multiple Choice Questions: Global Water Crisis*

	Question #9	Question #10	Question #11	Question #12	Average
All JHS	37%	72%	86%	79%	69%
1st BIO(3-4)	50%	92%	83%	75%	75%
2nd BIO(3-4)	59%	82%	88%	88%	79%
3rd BIO(3-4)	24%	65%	82%	76%	62%
5th BIO(1-2)	9%	45%	91%	73%	55%
All BIO(3-4)	43%	78%	85%	80%	72%

All students performed well below the overall average for this group of questions on question nine. As a whole, only 37% of the students in all of the Biology classes had the correct answer for this question. Question nine contained a short article about cholera and asked students what would be the least effective way of stopping a widespread cholera outbreak. For this question, all of the information was presented in the paragraph, or students could have used previously learned knowledge about cholera. Had they read and comprehended the information in the paragraph, then they should have been able to select the correct response. Surprisingly, not even half of the students were able to correctly answer this question, even though they had received instruction on it and were provided with the information on the test.

Table 6 indicates the percent of correct responses to the group of multiple-choice questions on the unit test that focused on water testing or parts of the water cycle. For this group of questions, students, on average, answered 70% correctly, with Biology (3-4) students averaging 76% correct and Biology (1-2) student averaging only 44% correct.

Question number four asked students, “Aquatic animals are sensitive to changes in which of the following water parameters?” Seventy-two percent of the students correctly answered the question, indicating that aquatic animals would be sensitive to all of the parameters listed: pH, temperature, and dissolved oxygen. All of the students in the first hour Biology (3-4) class answered this question correctly. When comparing the two different groups of students, only 27% of the Biology (1-2) students correctly answered the question, whereas 83% of the Biology (3-4) students correctly answered the question concerning water parameters and their effects on aquatic animals.

Table 6. *Student Percentages on Multiple Choice Questions: Water Testing and Water Cycle*

	#1	#2	#3	#4	#5	#6	#7	#8	Average
All JHS	91%	89%	42%	72%	77%	70%	89%	28%	70%
1st BIO(3-4)	100%	100%	33%	100%	92%	92%	92%	42%	81%
2nd BIO(3-4)	94%	88%	41%	82%	88%	82%	88%	29%	74%
3rd BIO(3-4)	88%	100%	59%	71%	76%	76%	100%	24%	74%
5th BIO(1-2)	82%	64%	27%	27%	45%	18%	73%	18%	44%
All BIO(3-4)	93%	96%	46%	83%	85%	83%	93%	30%	76%

Multiple-choice question number two asked students, “What is a watershed?” In both the first and third hour Biology (3-4) classes, all students correctly answer this question. On average, 89% of the total students could correctly identify what a watershed was on the unit test. Of the Biology (1-2) students, 64% could correctly identify what a watershed was, and 96% of the Biology (3-4) students could do so correctly. All but one of the incorrect responses to this question indicated that a watershed was a garage filled with water.

Table 7. *Student Percentages on Multiple Choice Questions: Real World Applications*

	#6	#9	#10	#11	#12	Average
All JHS BIO	70%	37%	72%	72%	86%	79%
1st BIO(3-4)	92%	50%	92%	83%	75%	78%
2nd BIO(3-4)	82%	59%	82%	88%	88%	80%
3rd BIO(3-4)	76%	24%	65%	82%	76%	64%
5th BIO(1-2)	18%	9%	45%	91%	73%	47%
All BIO(3-4)	83%	43%	78%	85%	80%	74%

As seen in Table 7, on average, 79% of the students correctly answered multiple-choice questions that focused on real world applications. Although these questions were multiple-choice, they had a case study format, where a brief description of an event or topic was given, followed by a question on the material. Students could use both previously learned knowledge and information from the brief description to answer the questions. For this group of questions, the Biology (3-4) students again outperformed the Biology (1-2) students, averaging 74% correct, compared to 47% correct for the Biology (1-2) group.

The Biology (1-2) students actually outperformed the Biology (3-4) students on question number eleven, with 91% of the Biology (1-2) students correctly answering this question. That is all but one student from that Biology (1-2) class. Question number eleven asked students, "What should travelers do to avoid getting cholera?" Then gave several options; all of the options were correct.

There were two short answer questions on the unit test, questions thirteen and fourteen. Question number thirteen contained a diagram of the water cycle, and asked, "Using Figure 36-3, trace the path of water that leaves a lake through evaporation, and describe how it might return to the lake." There were three possible points for this question number. Examples of student responses scored at each level follow:

> One point answer*: "It would return through precipitation of some sort. Rain, snow, etc."*
>
> Two Point answer*: "Condensation, Precipitation, & runoff."*
>
> Three Point answer*: "The water from the lake can runoff to the ocean and get evaporated. Then it can go through condensation, then precipitate back to the Earth into a runoff that eventually goes back to the lake."*

Students, on average, received 2.3 points for their responses to question number thirteen. Again students in the Biology (3-4) classes did better on this question, averaging

2.6 points for their response to the question, whereas the Biology (1-2) class only averaged 1.7 points for their response.

Question number fourteen was the second written response question. It stated, "Identify a point in the water cycle where a water source could become contaminated. Explain how it could happen, and what the effects would be." There were also three points available for question fourteen. Example responses, with scoring, are:

> One point answer: *"From the ground or in the lake or even the sky."*
>
> Two Point: *"The groundwater would be more contaminated because of landfills, and because of chemicals that are poured on the ground."*
>
> Three Point: *"Waste chemicals that were unproperly disposed of could seep through the soil and enter the water. The effects would be unsafe drinking water which may result in death to whoever drinks it."*

Out of the three possible points, all students averaged a score of 2.3 points. Again the Biology (3-4) classes scored higher on this question. With three points possible the Biology (3-4) classes averaged 2.8 earned points, where the Biology (1-2) class averaged 1.5 points for their responses.

In response to this question, some students gave specific examples that we had discussed in class or what they experienced during class activities. For example, we had discussed a neighboring community that had its ground water polluted by a drycleaner's improper disposal of chemicals. One student response that reflected this was:

> *"Ground water can easily become contaminated through improper waste disposal by factories and businesses. For example, a Laundromat dumped its waste behind the building for an extended amount of time. The chemicals soaked into the ground and reached ground water. This groundwater was used for wells, and when the well water was ingested the person would become ill. Also, plants soaked up the contaminated water which could kill them or contaminate them."*

During the trip to the river with the second hour Biology (3-4) class, students saw two pedestrians walking by the river, and one of them tossed a cup they were drinking out of into the river, instead of placing it in a trash can. Several students in second hour included "throwing trash" into the river as part of their response for question fourteen:

> *"It could be contaminated in the lake or ocean. People throw things in the water and it would effect our water and animals".*
>
> *"Someone could drop something in the water or on the ground and go into the water and contaminate it."*

There were also several misconceptions present in students' responses to question number 14 related where and how the water cycle could be contaminated. Two examples are:

> *"Ground water b/c it is dirty."*
>
> *"It could be contaminated through the evaporation because it could be a disease in the air".*

Summary

Overall, the instructor felt that the instructional goals were met during the unit. Students participated in several "hands on," "real-world," laboratory activities, and simulations. These activities were focused on the basic understanding of the water cycle, wastewater treatment, the global water crisis, and water quality testing of the local river.

Thus, the instructor felt that her goal of teaching the instructional unit using best practice teaching strategies was met. In the next chapter, each research question will be discussed, including how the data apply to each question and why the questions are important both instructionally and in relation to environmental issues more broadly.

CHAPTER 5: DISCUSSION AND CONCLUSION

The purpose of this study was to answer three research questions focused on students' knowledge about water quality issues and the effects of instruction on their understanding of these issues. This section will address how the findings of the study correspond to each of the research questions.

Discussion of Results

Research Question One: Comparing Student Knowledge

The first research question was, *How do two groups of high school students, one from a developed country and one from a developing country (United States and Bolivia), initially compare regarding knowledge of water quality issues?*

The World Health Organization and UNICEF have a Joint Monitoring Program (JMP) for Water Supply and Sanitation. According to the JMP, in the year 2008 86% of the Bolivian population had access to "improved" sources of drinking water (WHO/UNICEF, 2010). "Improved" sources are defined as: piped water into dwelling, piped water to yard/plot, public tap or standpipe, tubewell or borehole, protected dug well, protected spring, or rainwater. In the US, 99% of the population has access to "improved" sources of drinking water. The JMP also stated that 100% of the US population has access to "improved" sanitation, where only 25% of the Bolivian population had access to "improved" sanitation. "Improved" sanitation is defined as: flush toilet, piped sewer system, septic tank, flush/pour flush to pit latrine, ventilated improved pit latrine, pit latrine with slab, or composting toilet. That means 75% of the Bolivian population only has access to "unimproved" sanitation: flush/pour flush to elsewhere, pit latrine without slab, bucket, hanging toilet or hanging latrine, or no facilities. Bolivia is one of the least developed countries in South America, with 70% of the population living in poverty. In 2000, the World Health Organization stated that only 26% of the urban water supply was disinfected in Bolivia, and that only 25% of the collected wastewater received treatment. Clearly, many areas in Bolivia lack proper infrastructure for sanitation.

Based on these statistics, it would seem that the JHS students would be far less likely to be concerned about poor sanitation and its potential to cause disease because they have access to the appropriate infrastructure. However, the results of this study suggest that the JHS students were more knowledgeable than their Bolivian counterparts about the fact that individuals around the world do not all have access to clean water, and about the effects of contaminated surface water and poor sanitation, in particular, the ability for it to harbor disease, even though it is not a daily concern for them. The Bolivian students' pre-test score indicated that they were unsure whether everyone has access to clean water, even though 14% of the people in their own country do not have access to "improved" water sources. On top of that, 75% of the wastewater is not being treated, so that water could very well be contaminating clean water sources. Thus, although students in Bolivia are at a much higher risk for becoming ill due to poor sanitation than those living in the US, many of those students showed a lack knowledge about contaminated surface water and proper sanitation. All students in both groups, however, acknowledged that the Clean Water Industry plays an important role in the lives of people around the world.

Both groups indicated they had knowledge concerning the ability to kill water borne disease by boiling or chemically treating water. One striking difference was that only 22% of the Bolivian students indicated that they used water directly from the tap for cooking and drinking, whereas 88% of the JHS students indicated that they did so. Interestingly, Bolivian students showed knowledge concerning disinfecting the water before use, but did not consider that the water, once used, could transport disease and be dangerous to them.

Based on the results from this study, it seems the Bolivian students were less knowledgeable concerning clean water, even though the information was more applicable to their daily lives. It seems the Bolivian students may not have been looking at the big picture; they were concerned about the water they themselves were using, but were not really knowledgeable about the dangerous potential that water has to spread disease. While in Bolivia, I experienced a similar instance with trash. Students would just throw trash out the window without any concern for where that trash was going.

Although there is very little education on clean water infrastructure within classrooms in the U.S., this study indicates that students are more knowledgeable about the subject than they might think. Students who were interviewed globally, stated they were least likely to learn about the environment from "family and friends."—less likely than from school, the media, and the internet and books (PISA, 2006). However, the results of this study suggest that students may be indirectly gaining that knowledge on a daily basis, even if they don't know it. For example, in the U.S. there is a much lower tolerance for non-hygienic conditions, since the U.S. is a developed country. Many times children are warned not to put something in their mouth, or not to touch something because it is dirty. So, although they are not learning specific environmental content at home, they may be using the informal knowledge gained at home to reason about environmental situations. The JHS students may have been more knowledgeable because they had more of these experiences in their daily lives. Considering Bolivia is a developing country, some of the living conditions the Bolivian students were exposed to in their daily lives are vastly different than those in the U.S.

Research Question Two: Impact of Instruction

The second research question was, *What impact does instruction that includes water quality testing and discussion of global water issues have on the US students' understanding of water quality issues?*

Overall, the data suggests that the unit of instruction appeared to impact the scores on the student survey; specifically, an increase in the JHS student scores indicated that their overall knowledge was impacted, particularly with respect to two major water quality issues facing the world today: lack of available water and access to clean water. There were several specific survey questions that showed increases, thus supporting the assertion that there was a gain in knowledge amongst the students about the global water crisis.

Students scored almost one-half of a point lower (question is a negative question) on question number six: all individuals have access to clean water. Thus, after the unit of instruction they appeared to have a better understanding of the fact that not every person around the world has access to clean water. In addition, their responses to the journal question on day four indicated that they have knowledge about the potential for violence in the future, as clean water becomes a more scarce resource around the world.

Students had two physical experiences that may have contributed to their increase in knowledge, as shown by the data. Students physically encountered how hard it is to carry water when you don't have access to it in your own home by carrying a gallon of water around the campus, and commented on how this might affect their water-use habits in their journals. Students also went to a local river and completed quality analysis of the water. While at the river, some students actually saw someone "pollute" the water by dropping trash into the river, which they later recalled on their unit test.

On the unit test, multiple-choice question four specifically targeted water quality testing. Students were asked, "Aquatic animals are sensitive to changes in which of the following water parameters?" 72% of the students correctly answered this question, demonstrating knowledge of the fact that animals would be sensitive to pH, temperature, and dissolved oxygen.

For the group, of eight of the questions on the unit test concerned water quality testing and the water cycle, students correctly responded to 70%. Biology (3-4) responded correctly more often, correctly responding to 76% of the questions, where Biology (1-2) students responded correctly to 44% of the questions. On the unit test, students averaged 2.4 out of 3 points on a short response question where they had to identify a point in the water cycle where water could be contaminated, and the impacts that contamination could have. In addition, students correctly answered questions concerning the global water crisis 69% of the time and averaged 75% correct responses on the real world application questions. Thus, not only did students learn about the global water crisis, but also showed gains in knowledge in the other two question groups.

In conclusion, the findings suggest that students did, in fact, increase their knowledge about the global water crisis, the water cycle, water quality testing and real world applications of water quality issues as a result of the unit of instruction. Their work throughout the unit influenced their post survey scores, supporting the conclusion that there was an increase in their knowledge as a result of the instruction.

This increased knowledge is important because students need to have an understanding of the world water crisis. We are all people living on this planet together, and need to use the scarce resources accordingly. According to the PISA study (2006), students are more likely to learn about significant environmental problems at school. If they don't develop a basic understanding of the problem, then they will never be able to help provide a solution. Learning about the global water crisis in school could potentially inspire a student to pursue a career related to solving these problems and someday be part of the solution.

Understanding of water quality issues and water infrastructure is also important because it plays a vital role in students' daily lives. Currently the state of the water infrastructure in the United States is not good. Once a modern marvel that brought fresh clean water and improved sanitation to everyone, it is now in dire need of repairs. The infrastructure itself is literally crumbling under our feet, after one hundred years and few updates (Ayanian, 2008). As future community members, students need to understand the importance of this infrastructure. Everything comes at a cost; many people are unhappy to “pay for water” every month. This may be because they don’t understand the infrastructure that is necessary to allow them to have access to clean water at the tap, and to remove waste from the toilet. If this problem is ever to be solved, the students of today need to informed, either to make decisions as community members or as the engineers working to fix the problem.

Research Question Three: General and Special Education Student Achievement

The final research question was *To what extent does instruction that includes outdoor education experiences, inquiry-based education, and real world connections affect the achievement of general education students and special education students in an inclusive classrooms? Is achievement affected equally for these two groups?*

When comparing the two different groups of students, the Biology (3-4) students performed better in the unit than the Biology (1-2) students. The Biology (3-4) students had a larger increase in their pre- and post-survey scores. Biology (1-2) students only had an average increase of 0.1 point, from 3.6 to 3.7 points, where Biology (3-4) students had an overall average increase of 0.3 points, from 3.7 to 4 points. Statistical analyses showed that the Biology (3-4) gains were significant, while the Biology (1-2) gains were not. In fact, the Biology (3-4) students’ pre-survey score was the same as the Biology (1-2) students’ post-survey score. As previously stated, however, these results should be interpreted with caution because of the small sample size for the Biology (1-2) group.

On the unit test, the Biology (1-2) students averaged a 53% overall. They scored lower in both question categories: multiple choice and short answer, than all of the

Biology (3-4) classes combined. The Biology (3-4) classes averaged an 83% on the unit test. That is 30% higher on the unit test than the Biology (1-2) class.

By using the various teaching strategies in the unit of instruction, the Biology (3-4) students performed better than the Biology (1-2) students. The two groups of students did not perform equally on the post-instruction assessments. Thus, although "best practice" teaching strategies have been shown to positively affect student performance in the classroom (DiEnno & Hilton, 2005), this study suggests that they may not yield the same results for all students.

Students are placed into a Biology (1-2) classroom because they either qualify for special education services, or they do not qualify but it has been designated by their prior performance in middle school that they could benefit from the additional assistance in the classroom. Although all students made progress as a result of this unit of instruction, the Biology (1-2) students may lack necessary skills that other students possess, such as reading at grade level and basic mathematical computation skills. The unit of instruction, consisting of various "best practice" teaching strategies, did not improve the Biology (1-2) scores to the same level as the advanced Biology (3-4) level. This is probably due to the fact that Biology (1-2) students are lacking or struggling with those basic abilities.

Limitations

Translation

When working with the Bolivian students, the English to Spanish translation could be a major limitation of this work. The instructor/researcher does not speak fluent Spanish, so she often had to rely on the Bolivian instructor for translation during instruction. Even though the surveys were translated into Spanish for the students, some of the questions or specific words may not have translated well. Whenever something is translated from one language to another, the meaning can easily be misinterpreted. Online translators are unable to use the context of the word to determine the appropriate translation. As a result, the translation may not be interpreted as originally intended. This could have affected the student responses on the survey.

Survey

The survey used in this study used a Likert scale. A limitation of the Likert scale is that it measures not only participants' knowledge, but also their attitudes—how strongly they feel about a particular statement. For future purposes, if using a Likert scale, it might be more helpful to analyze the percent of respondents who felt a particular way about a statement or to combine the response categories into agree, neutral or disagree, since it is not clear why students chose, for instance, strongly agree versus agree.

In addition, the survey only had two negatively worded statements out of the seventeen. The survey should have a balance of both positive and negative questions, by phrasing the same question in both a positive and negative format. By doing this, the responses to the two versions of the question could be compared to see whether the respondent was responding consistently, thus increasing the internal validity of the instrument. Another option would be to find another method to quantify participant knowledge, such as a pre- and post-test.

The open-ended questions were intended to collect information on what prior knowledge the students have, however they failed to do so. Some students may have been unsure about what a question was asking, and marked "I don't know", while others who were not sure may have guessed, making it hard to determine what students actually knew. Thus, the wording of questions would need to carefully be considered before using this instrument in future studies.

Sample Size

During the research period, the instructor only had one class of Biology (1-2) students and many of the students in the class decided not to participate in the study, leaving an extremely small sample size of only fourteen students. Of the students who chose not to participate, many were "special education" students with Individualized Education Plans, IEPs. Unfortunately, they may have felt so stigmatized from being labeled "special education" for their entire scholastic career that they may have been afraid to "look stupid." Even though their names were never going to be used, they still were not comfortable participating in a study. Those students make up an important part of the demographics of the Biology (1-2) class, and play an important role in getting a representative sample of the students. As a result of the small sample size, in all instances when t-test were calculated with the Biology (1-2) data, the results should be interpreted with caution.

Teaching Unit

As an instructor it is very hard to teach the exact same unit to every group of students. At times students ask questions or something may occur in the classroom that may lead to a “teachable moment” that is followed up on. Even though it may be the instructor’s intention to teach the same exact unit of instruction, students may have slightly different experiences.

Future Extensions of the Unit

For future extensions of research question number one, it would be interesting to teach two exact units of instruction to both the Bolivian students and the JHS students. Then a comparison could be made between the Bolivian students’ pre- and post-instruction knowledge, and an additional comparison could be made between the Bolivian students’ and the JHS students’ post knowledge. However, the scheduling process of the Bolivian schools made that very difficult to accomplish in this study.

Relevant research shows that generally one outdoor exposure is not enough to alter students’ behavior. An additional extension would be to follow two groups of students for several years: one group being exposed to outdoor experiences and best practice teaching strategies, the other not being exposed. The increased time and exposures could provide additional insight.

Finally, following a group of students for several years could also be an extension for research question number three. Within the group of students, one could flag those who are identified as special education students or those who end up being placed in Biology (1-2) courses when they reach high school. The Biology (1-2) data could then be compared with the Biology (3-4) data to see how those two groups compare over the extended period of time.

Conclusion

In summary, there is sufficient data to answer the research questions presented in this study. For the first research question, the data collected in this study seems to provide some support to the data presented in the PISA document: on average, students from disadvantaged socio-economic backgrounds and/or immigrant backgrounds had lower proficiency related to environmental issues (PISA, 2006). The data collected for this study suggests that the JHS students were more knowledge concerning clean water and disease than the Bolivian students. Even though the Bolivian students are at a higher risk of being exposed to water-borne disease, or of not having access to clean water, they appeared to have less knowledge of these topics that play a critical role in their daily lives.

JHS student survey responses suggested they were impacted by the unit of instruction that included outdoor experiences, specifically water quality testing. Not only did students show an increase in their survey responses, but they also demonstrated knowledge of the global water crisis in their student work, by answering journaling questions and in their responses to questions on the unit test.

Finally the Biology (3-4) students showed a larger increase in achievement then the Biology (1-2) students after completing the same unit of instruction. The unit of instruction for both groups contained various teaching practices that are considered “best practices.” Even though they completed the same unit of instruction, they did not have the same increase in achievement.

The number one source reported by students for learning about the environment was school (PISA, 2006). All students must be exposed to curriculum that addresses environmental issues, both locally and globally, if they are going to be environmentally and scientifically literate in the future. The students of today are the environmental problem solvers of tomorrow. Focusing on environmental education in ways that are multi-faceted, engaging and relevant to them is the only way that they will be prepared to take on this role.

Environmental problems do not have borders. It is the responsibility of all people to help be stewards of the planet, and use the scarce resources we have at a sustainable rate. This includes not only people and students in the developed world, but all people. The results of this study suggest that those students living with the greatest risk of being affected by water issues may also be those who have less knowledge about the issues. Thus, it becomes the responsibility of those with the knowledge to pass it on or “lend a hand” to help those without the knowledge. Becoming educated about environmental issues positions our students to do just that.

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APPENDIX A: HUMAN SUBJECT FORMS

Appendix A-1: IRB Approval Letter

MichiganTech
Michigan Technological University

Office of Research Integrity
and Compliance

317 Admin. Building
1400 Townsend Drive
Houghton, MI 49931
906.487.2902

MEMO

TO: Dr. Shari Stockero, Cognitive and Learning Sciences
CC: Emily Curry, Cognitive and Learning Sciences

FROM: Joanne Polzien, Director Research Integrity and Compliance [redacted]

DATE: June 5, 2009

SUBJECT: Continue Approval M0345

Protocol #M0345
Project Title: " Understanding the Importance of Water Quality "

A continuing approval for the above project is valid for the period: July 10, 2009 through July 9, 2010

Your human subject application continuation was reviewed by the Institutional Review Board (IRB). The Committee has approved the renewal, with no changes in the protocol or consent form, and it is now on file in the Office of Research Integrity and Compliance. **Approvals are granted for up to a one year period.** You will need to request a continuation for each year of the project six weeks prior to the end date indicated above. The Research Integrity and Compliance Office will make every effort to send the Principal Investigator annual reminders. However, the Principal Investigator is responsible for submitting annual Continuation Forms in advance of the expiration date for the project. It is very important that these expiration dates are not missed. Failure to submit annual review materials on time will result in the termination of this protocol.

This approval applies only for this project, and only under the conditions and procedures described in the application; if any changes are made in the protocol or conditions set forth in the application, the principal investigator must obtain a separate approval before these changes take place. The approved project will be subject to surveillance procedures requiring periodic review. This review will consist of consulting with the principal investigator and examining the appropriate project records.

Individual identification of human subjects in any publication is an invasion of privacy. Before beginning a project involving human subjects, and only if required, the principal investigator must obtain a properly executed informed consent from each subject and/or the person legally responsible for the subject. **If a consent form has been reviewed and approved it has been attached with an official date stamp on it. Only copies of the official date stamped informed consent is to be distributed to participants relating to this project. If any changes or modifications are needed regarding this form, you must first submit the revised document for review and approval prior to use.** The principal investigator must retain informed consent forms on file for at least three years after the end of the project. If a project involves a high level of risk, copies of the signed informed consent forms must be filed with the Human Subjects Committee; if this is the case, you will be notified.

This document is on file in the Office of Research Integrity and Compliance. If you have any questions, please contact me at 487-2902 or jpolzien@mtu.edu.

Appendix A-2: Parent and Student Consent Letters

MichiganTech

July 21, 2008

Dear Parent or Guardian:

I am a high school teacher from Michigan in the United States. I am working on a research project for Michigan Technological University on students' knowledge of water quality here in Bolivia and in my own classroom in the USA. I will be teaching in your child's class about water quality in Bolivia. I request permission for your child to participate.

The study consists of the following activities

1. Taking a pre survey, and answering questions about the water in Bolivia.
2. Participation in several lessons concerning: ground water, water-borne disease, safe water handling, and sanitation.
3. Participation in laboratory activities, where students will have the opportunity to perform water quality tests, and interpret their results.
4. Taking a post survey.
5. In some instances students may be asked to volunteer to be interviewed. Students being interviewed will be asked questions about the water where they live. The interview will be videotaped, and portions of that interview may be shared with teachers and students in the United States. The Bolivian students' names will not be used to identify them to the audience.

Only Michigan Technological University students/professors and I will have access to information from your child. At the conclusion of the study, children's survey responses will be reported as group results only; individual student quotes from interviews will use pseudonyms to protect students' identities.

Participation in this study is voluntary. Your decision whether or not to allow your child to participate will not affect the services normally provided to your child by the Walter Henry School or John Wesley School. Even if you give your permission for your child to participate, your child is free to refuse to participate. If your child agrees to participate, he or she is free to end participation at any time. You and your child are not waiving any legal claims, rights, or remedies because of your child's participation in this research study.

Should you have any questions or desire further information, please contact me at your child's school or email either Dr. Shari Stockero at stockero@mtu.edu or Emily Curry at ecurry@jpsmail.org. Please keep this letter. Complete and sign the second page, and have your child return it to their biology teacher at school.

If you have any questions about your rights as a research subject, you may contact the Michigan Technological University Institutional Review Board (IRB) by mail at 1400 Townsend Drive, Houghton, MI 49931, by phone at (908) 487-2902, or by e-mail at jpolzien@mtu.edu. This study (IRB #M000) was approved by the IRB on July X, 2008

Sincerely,

Emily Curry
MTU Master's Student

Dr. Shari Stockero
Assistant Professor, Michigan Technological University

DATE OF IRB APPROVAL: 07-10-09
IRB NUMBER: M0345
PROJECT EXPIRATION DATE: 07-09-10

Parental Consent

Please indicate whether or not you wish to allow your child to participate in this project by checking one of the statements below, signing your name and having your child return this page to their science teacher at school. Keep the first page for your records.

_____ I grant permission for my child to participate in Emily Curry and Shari Stockero's study on improving students' understanding of global water quality issues.

_____ I do not grant permission for my child to participate in Emily Curry and Shari Stockero's study on improving students' understanding of global water quality issues.

______________________________ ______________________________

Signature of Parent/Guardian | Printed Parent/Guardian Name

______________________________ ______________________________

Printed Name of Child | Date

Student Assent to Participate in Water Quality Research

I have read and understand the Student Assent to Participate form for Mrs. Curry and Dr. Stockero's water quality research project. If I have questions I understand that I can ask them at any time during the classroom unit or contact Mrs. Curry by emailing her at ecurry@jpsmail.org

Please check one of the following, and return this page to your science teacher. Sign and keep the Student Assent to Participate form for your records.

______I do agree to participate in Mrs. Curry and Dr. Stockero's water quality research project. I have read and understand the Student Assent to Participate form, and agree to its terms.

______ I do not agree to participate in Mrs. Curry and Dr. Stockero's water quality research project. I have read and understand the Student Assent to Participate form and I do not wish for my class work or scores to be used.

____

Signature of Subject

______________________________ ______________________________

Printed Name of Subject | Date

APPENDIX B: SURVEYS

Appendix B-1: Pre-Survey Given to U.S. Students

Rate each statement on a scale from 1-5. For example if you feel strongly that a statement is correct circle 5, strongly agree.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. My actions affect the quality of the water in my watershed.	1	2	3	4	5
2. My actions affect the quality of water in other watersheds.	1	2	3	4	5
3. Clean, fresh water must be used in moderation.	1	2	3	4	5
4. It is safe to drink the water from any faucet.	1	2	3	4	5
5. Water is a renewable resource.	1	2	3	4	5
6. All individuals have access to clean water.	1	2	3	4	5
7. Only bottled or properly disinfected water should be used for cooking, brushing teeth, and drinking.	1	2	3	4	5
8. Contaminated surface water and poor sanitation contribute to the transmission of water-borne disease.	1	2	3	4	5
9. Impervious surfaces typically have the highest rates of runoff.	1	2	3	4	5
10. Boiling water can eliminate the chance of water-borne disease.	1	2	3	4	5
11. Water-borne disease can be eliminated by boiling water	1	2	3	4	5
12. By treating water with chlorine and iodine, water-borne disease can be eliminated.	1	2	3	4	5
13. Some germs and chemicals occur naturally in water.	1	2	3	4	5
14. Standing water creates a breeding ground for disease carrying mosquitoes.	1	2	3	4	5
15. The Clean Water Industry plays a vital role in my daily life.	1	2	3	4	5
16. The Clean Water Industry plays a vital role in the daily lives of individuals around the world.	1	2	3	4	5
17. There are many career opportunities in the Clean Water Industry.	1	2	3	4	5

18. Do you have running water in your home? _____Yes _____No

If no, where do you get water from_________________________________

If yes, mark all of the following ways you use this running water.

_____Cooking _____Drinking _____Bathing _____Brushing your Teeth

_____Laundry _____Dish Washing

19. Before you use water in your home for cooking or drinking do you do any of the following?

_____Boil the water _____Treat with chemicals _____Filter water using a water filter
_____No, we just use our water _____No, we used bottled water

20. Do you know the source of the water in your home (where it comes from)? Mark all that apply.

_____City Water, pumped through water lines to home _____ Private Well/Ground Water
_____ Collected from River or other water source _____ Bottled Water
_____ I don't know _____ Other: Please Explain_________________________

21. Are there any bodies of water within 60 meters (200 ft) of your home? Mark all that apply

_____ Lakes _____Rivers/Streams _____Swamps
_____Landscape Ponds
_____Rain Buckets/Collection Containers
_____Large areas that flood and hold water for 2 weeks of longer
_____Drainage Canals/Ditches that hold water for 2 weeks or longer

22. Which of the following types of toilet do you have in or near your home?

_____Flush Toilet with water tank _____Squat Toilet/ Latrine _____ No Toilet
_____I don't know _____ Other. Please Explain__________________________

23. Do you know where "grey water " (waste water from you sinks, toilets, and washing machines) goes?

_____Septic Tank _____Drainage Ditch/Canal ____ Yard _____Sewer System
_____I don't know _____Other. Please Explain_____________________

Appendix B-2: Bolivian Pre-Survey in Spanish, Las Preguntas del Examen

Nombre ________________Cuántos años tiene?___Género________ Clasifique cada declaración sobre una escala a partir de la 1-5. Por ejemplo si usted se siente fuertemente que una declaración es el círculo correcto 5, convenga fuertemente.	discrepan fuertemente	discrepan	hilo neutro	convienen	convienen fuertemente
1. Mis acciones afectan la calidad del agua en mi línea divisoria de las aguas.	1	2	3	4	5
2. Mis acciones afectan la calidad del agua en otras líneas divisoria de las aguas.	1	2	3	4	5
3. El agua limpia, dulce se debe utilizar en la moderación.	1	2	3	4	5
4. Es seguro beber el agua de cualquier grifo.	1	2	3	4	5
5. El agua es un recurso reanudable.	1	2	3	4	5
6. Todos los individuos tienen acceso al agua limpia.	1	2	3	4	5
7. Solamente el agua en botella o correctamente desinfectada se debe utilizar para cocinar, los dientes que cepillan, y beber.	1	2	3	4	5
8. El agua superficial contaminada y el saneamiento pobre contribuyen a la transmisión de la enfermedad flotante.	1	2	3	4	5
9. Las superficies impermeables tienen típicamente los índices más altos de la salida.	1	2	3	4	5
10. El agua hirvienda puede eliminar la ocasión de la enfermedad flotante.	1	2	3	4	5
11. La enfermedad flotante se puede eliminar por el agua hirviendo	1	2	3	4	5
12. Tratando el agua con clorina y yodo, la enfermedad flotante puede ser eliminada.	1	2	3	4	5
13. Algunos gérmenes y productos químicos ocurren naturalmente en agua.	1	2	3	4	5
14. El agua derecha crea una tierra de crianza para los mosquitos que llevan de la enfermedad.	1	2	3	4	5
15. La industria de agua limpia desempeña un papel vital en mi vida de cada día.	1	2	3	4	5
16. La industria de agua limpia desempeña un papel vital en las vidas diarias de individuos alrededor del mundo.	1	2	3	4	5
17. Hay muchas oportunidades de la carrera en la industria de agua limpia.	1	2	3	4	5

18. ¿Usted tiene agua corriente en su hogar? _____Sí _____No

¿Si no, donde usted consiguieron el agua de?______________________________

Si sí, marque todas las maneras de siguiente que usted utiliza esta agua corriente.

_____ cocinando _____ que bebe _____ bañarse _____ para cepillar sus dientes

_____ lavando sus ropas _____ sirva lavarse

19. ¿Antes de que usted utilice el agua en su hogar para cocinar o beber usted hace el siguiente un de los?

_____ Hierva el agua _____ Trátela con los productos químicos _____Filtre el agua usando un filtro del agua

_____ No, apenas utilizamos nuestra agua sin ninguna forma de tratamiento _____ No, utilizamos el agua en botella

20. ¿Usted sabe cuáles es la fuente del agua en su hogar? ¿De dónde viene? Marque todos que se apliquen.

_____ Agua de la ciudad, se bombea a través de líneas de agua a mi hogar. _____ Pozo privado o el agua subterránea

_____ Recogemos el agua del río o de la otra fuente de agua. _____ Agua en botella

_____ No sé _____ Otro: Explique por favor__________

21. ¿Hay aguas de superficie a 60 metros (200 pies) de su hogar? Marque todos que se apliquen.

_____ Lagos _____ Ríos o corrientes _____ Pantanos _____ Las charcas artificiales

_____ llueven las áreas de los cubos o de los envases de la colección

_____ del agua de la tierra que inundan y sostienen el agua por 2 semanas o más de largo.

_____ Canales o zanjas del drenaje que sostienen el agua por 2 semanas o más de largo.

22. ¿Qué tipo de tocador usted tiene adentro o acercó su hogar?

_____un tocador rasante con un tanque de agua tocador _____ un tocador agazapado o una letrina _____ No tenemos un tocador

_____ No sé _____ Otro: Explique por favor _____________________

23. ¿Usted sabe adónde va el agua gris de usted hogar? El agua gris es el agua inútil de los fregaderos, de los tocadores, y de la lavadora en su hogar.

_____ un tanque séptico _____ una zanja o un canal de drenaje _____ su yarda _____ el sistema de alcantarilla de la ciudad

_____ No sé _____ Otro: Explique por favor ___________________________

Appendix B-3: Post-Survey Given to U.S. Students

Rate each statement on a scale from 1-5. For example if you feel strongly that a statement is correct circle 5, strongly agree.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. My actions affect the quality of the water in my watershed.	1	2	3	4	5
2. My actions affect the quality of water in other watersheds.	1	2	3	4	5
3. Clean, fresh water must be used in moderation.	1	2	3	4	5
4. It is safe to drink the water from any faucet.	1	2	3	4	5
5. Water is a renewable resource.	1	2	3	4	5
6. All individuals have access to clean water.	1	2	3	4	5
7. Only bottled or properly disinfected water should be used for cooking, brushing teeth, and drinking.	1	2	3	4	5
8. Contaminated surface water and poor sanitation contribute to the transmission of water-borne disease.	1	2	3	4	5
9. Impervious surfaces typically have the highest rates of runoff.	1	2	3	4	5
10. Boiling water can eliminate the chance of water-borne disease.	1	2	3	4	5
11. Water-borne disease can be eliminated by boiling water	1	2	3	4	5
12. By treating water with chlorine and iodine water-borne disease can be eliminated	1	2	3	4	5
13. Some germs and chemicals occur naturally in water.	1	2	3	4	5
14. Standing water creates a breeding ground for disease carrying mosquitoes.	1	2	3	4	5
15. The Clean Water Industry plays a vital role in my daily life.	1	2	3	4	5
16. The Clean Water Industry plays a vital role in the daily lives of individuals around the world.	1	2	3	4	5
17. There are many career opportunities in the Clean Water Industry.	1	2	3	4	5

18. Describe your daily use of water. How and when do you use water?

19. There are two major problems facing the world's water supply: Water Quality and Amount of Water Supply. Can you identify things you can do in your daily life to combat these problems? Explain.

20. How do your actions affect the watershed you live in?

APPENDIX C: INSTRUCTIONAL ACTIVITIES

Appendix C-1: The Teaching Unit: Bolivian Students

The Bolivian students took the survey, and then participated in labs and demonstrations. First they tested the permeability and porosity of gravel, coarse sand, and fine sand. Three student volunteers poured colored water through clear cylinder tubes filled with each substrate. Their classmates watched to see which filled the fastest, and also observed how much water was remaining in the cup they poured from, thus reflecting the porosity and permeability of the substrates.

To further illustrate the concept, students stood up and pretended to be the different soil substrates. First students pretended to be gravel; they were all spaced out so that they could not touch each other. Two students were selected to be molecules of water and were instructed to pass through the gravel. They reported, and the students observed, that it was very easy to do so. Next the “substrate” students modeled sand. To become sand, students had to stand with their fists on their hips and elbows pointing out. Students were spaced so that they could just barely graze the elbows of the other students around them. Again the water molecules passed through. Finally the “substrate” students modeled the permeability and porosity of clay. Students did this by clumping very closely together. The two water molecules were then instructed to pass through the clay. Finally, the instructor took out a sample of real clay and poured water on it. Students observed how the water pooled on top of the clay and could not be seen on the underside of the container.

Students then participated in a discussion with the instructor about where their water comes from in Santa Cruz. Students described that it came from a "*purifica*" or a water treatment facility. The instructor and students depicted the water cycle on the chalkboard, and discussed from where the water treatment facility got the water. The class confirmed that this water came from the ground water, and that the ground water was part of the water cycle. Students then conducted a water filtration lab, where they demonstrated the main steps of the water filtration process: aeration, coagulation, sedimentation, filtration (Appendix C-1).

Finally, students observed as the instructor demonstrated a ground water model. Using gravel, sand, and clay, a model was made of the ground that contained both a confined and unconfined aquifer. Plastic tubes were inserted to represent wells at varying depths. By using different colored waters, the instructor could model various types of contamination, such as contamination caused by surface runoff seeping into the water supply of the unconfined aquifer or how contamination of one deep well could affect a neighboring well. To summarize the lesson, the class discussed how the water pools on top of the ground during the rainy season in Santa Cruz. They hypothesized about what types of soil substrates were most likely in the soil there, and discussed how easily contaminants in that water could eventually seep down into the ground water.

Appendix C-2: Filtration Lab in English and Spanish

Lab Activity 3: How do we get impurities out of our drinking water?

Water in lakes, rivers, and swamps often contains impurities that make it look and smell bad. This water may also contain bacteria and other microscopic organisms that can cause disease. Consequently, water from surface sources must be "cleaned" before it can be consumed by people. Water treatment plants typically clean water by taking it through an aeration, coagulation, sedimentation, and filtration process.

Procedure

1. Obtain from your teacher a cup containing 150mL of soiled water which simulates polluted water. Describe the appearance, color and smell of the water.
2. **Aeration** is the addition of air to water. It allows gases trapped in the water to escape and adds oxygen to the water. To aerate your sample, slowly pour your sample into another cup then back and forth between the two cups several times. Observe and describe and changes noticeable in the water.
3. **Coagulation** is the process by which dirt and other suspended solid particles are chemically stuck together into large particles or floc, so they can be removed from water. Add 2 grams of alum crystals to your contaminated water to coagulate the solid matter. Slowly stir the mixture for about 5 minutes. Observe and describe any changes in the water that take place during this process.
4. **Sedimentation** is the process that occurs when gravity pulls the particles of floc to the bottom of the water collection site. Allow the water mixture to stand undisturbed. Observe the water at 5 minute intervals for a total of 20 minutes. Record your observations with respect to changes in appearance of the water.
5. While waiting and making observations you will construct a filter apparatus

- Attach a piece of muslin cloth to one end of the tube with a rubber band.
- Slowly pour about an inch of gravel into the tube.
- Slowly pour about an inch of coarse sand on top of the gravel.
- Finally, slowly pour an inch of fine sand on top of the coarse sand
- Clean the filer by slowly pouring half or a liter of clean water through it.

6. **Filtration** through sand and pebbles removes most of the impurities remaining in water after coagulation and sedimentation have taken place. After a large amount of sediment has settled on the bottom of the bottle of the contaminated water mixture, carefully without disturbing the sediment, pour the top two thirds of the soiled water through the filter. Collect the filtered water in a clean cup. Compare the treated untreated water. Note whether treatment has changed the physical characteristics and smell of the water. You may repeat the filtration step to further clarify and purify the water.
7. The final step at a water treatment facility plant is to add disinfectants to purify the water and to kill any harmful organisms. The water that we just filtered is unsafe to drink since it has not yet been chemically treated.

Actividad 3 del laboratorio: ¿Cómo conseguimos impurezas de nuestra agua potable?

Riegue en los lagos, ríos, y los pantanos contienen a menudo las impurezas que le hacen mirada y huelen malo. Esta agua puede también contener las bacterias y otros organismos microscópicos que pueden causar enfermedad. Por lo tanto, el agua de las fuentes superficiales debe “ser limpiada” antes de que pueda ser consumida por la gente. Las plantas de tratamiento de aguas limpian típicamente el agua tomándola con una aireación, una coagulación, una sedimentación, y un proceso de la filtración.

Procedimiento

1. Obtenga de su profesor a la taza que contiene 150mL del agua manchada que simula el agua contaminada. Describa el aspecto, el color y el olor del agua.
2. **La aireación** es la adición del aire a regar. Permite los gases atrapados en el agua para escaparse y agrega el oxígeno al agua. Para airear su muestra, vierta lentamente su muestra en otra taza entonces hacia adelante y hacia atrás entre las dos tazas varias veces. Observe y describa y los cambios sensibles en el agua.
3. **La coagulación** es el proceso por el cual la suciedad y otras partículas sólidas suspendidas químicamente son pegadas juntas en partículas o flóculo grandes, así que pueden ser quitadas del agua. Agregue 2 gramos de cristales del alumbre a su agua contaminada para coagular la materia sólida. Revuelva lentamente la mezcla por cerca de 5 minutos. Observe y describa cualquier cambio en el agua que ocurra durante este proceso.
4. **La sedimentación** es el proceso que ocurre cuando la gravedad tira de las partículas del flóculo al fondo del sitio de la colección del agua. Permita que la mezcla del agua esté parada imperturbada. Observe el agua en 5 intervalos minuciosos para un total de 20 minutos. Registre sus observaciones con respecto a cambios en el aspecto del agua.
5. Mientras que esperarle y la fabricación las observaciones construirán un aparato del filtro.

- Una un pedazo del paño de la muselina a un extremo del tubo con una goma.
- Vierta lentamente alrededor de una pulgada de grava en el tubo.
- Vierta lentamente alrededor de una pulgada de la arena gruesa encima de la grava.
- Finalmente, vierta lentamente una pulgada de la arena fina encima de la arena gruesa.
- Limpie el limador por mitad lentamente que vierte o un litro de agua limpia con él.

6. **La filtración** a través de la arena y de los guijarros quita la mayor parte de las impurezas restantes en agua después de que hayan ocurrido la coagulación y la sedimentación. Después de que una cantidad grande de sedimento haya colocado en el fondo de la botella de la mezcla contaminada del agua, cuidadosamente sin disturbar el sedimento, vierta el dos tercios superior del agua manchada a través del filtro. Recoja el agua filtrada en una taza limpia. Compare el agua untreated tratada. Nota si el tratamiento ha cambiado las características físicas y el olor del agua. Usted puede repetir el paso de la filtración para clarificar y para purificar más lejos el agua.

El paso final en una planta de la facilidad del tratamiento de aguas es agregar desinfectantes para purificar el agua y para matar a cualquier organismo dañoso. El agua que acabamos de filtrar es insegura beber puesto que todavía químicamente no se ha tratado.

Appendix C-3: Water Cycle Analysis

Name______________________
Date______________Hour_____

Create a diagram of the hydrologic/ water Cycle. Be sure to include all of the appropriate labels.

Analysis:

1. How is water stored in an aquifer?

2. How can groundwater become contaminated?

3. What effect does this contamination have on the water we drink?

4. Describe the porosity and permeability of various soil types.

5. Can you identify any relationship between the porosity of a soil and the permeability of that soil?

6. What steps can you take to protect the ground water that is available in your area? Can you give a specific example?

Appendix C-4: Sewer Science Activity

Name_____________________________
Date____________________Hour______

Making Wastewater

Waste Substance	Recommended Amount	Amount Used	What types of waste might this represent in REAL wastewater?
1. Dried used coffee grounds			
2. Ground-up breakfast cereal			
3. Ground- up pet food			
4. Cut up plastic			
5. Baking Soda			
6. Torn-up toilet paper pieces			
7. Ammonia			
8. Vegetable Oil			

I predict that after 20 minutes, ______________________________________will float ____will settle to the bottom, and

____ will stay mixed.

The phrase, "Out of Sight, out of mind" is often applied to the water infrastructure, and clean water industry. How does this phrase apply?

Why is water an essential component of life?

If water <u>was not</u> readily available in your home, how would you get water you need for your daily tasks?

It is estimated that every American uses 100 gallons a day. How would not having water readily available in your home impact that number?

Appendix C-5: 007's Water War Based in Reality, not Fiction.

Link to ScienCentral.com to view clip.

http://www.sciencentral.com/video/2008/11/17/007s-water-war-based-in-reality-not-fiction/

Appendix C-6: Women Bear the Weight of Water

Women Bear the Weight of Water

In the developed world, humans do not have to carry the water we use on a daily basis. If we did, it's safe to assume we'd use a lot less than we do. The average American used 100 to 176 gallons of water at home each day. The weight of that water is 836 to 1400 pounds. Imagine if your family had to work together every day to transport over 800 pounds of water into your home!

For people living in many third world countries, distance from a clean water source is a critical factor. In particular, it affects the lives of women. Collecting water in third world countries is rarely a family activity. It is a task largely designated to women and young girls. Because women are also responsible for the care of young infants and children, girls begin carrying a small version of a water jug as early as 2 years old.

In some places in sub-Saharan Africa, for instance, women can spend between 15 and 17 hours each week collecting water. In times of drought, it can sometimes take even longer. Adequate water supply and good health are tightly linked, and the need to carry water long distances limits the amount women can bring to their families.

The dangers are not over even once water has been brought back home to the family. Water is often contaminated with microorganisms that cause diarrhea, typhoid, and cholera. There diseases are responsible for approximately 80 percent of all illnesses and deaths in the developing world, many of them children. In fact, one child dies every eight seconds from a waterborne disease; approximately 15 million children a year.

Women and female children who have to travel to collect water pay a high cost. Less time is available for caring for children, preparing food, or pursuing income-generating activities. In some regions women and girls must travel through unsafe areas and are vulnerable to attack. Families, in many cases, must forego sending their daughters to school. perpetuating the vicious cycle of illiteracy and poverty.

Sources (http://www.amnh.org/exhibitions/water)
(http://news.nationalgeographic.com)

"Women Bear the Weight of Water"
Reading for Comprehension Questions

1:: Why do people in developed countries not have to worry about collecting their own ware for daily use?

2:: Approximately how much water does the average North American family use per day?

3:: What is the most important explanation for why women and girls in third world settings are disproportionately burdened with the task of finding and collecting water for their families?

4:: In what ways are adequate water supply and good health likely to be linked?

5:: What are the "costs" associated with women and girls collecting water as a daily ritual?

Appendix C-7: Water Test Objectives

Name________________
Date_______Hour________

Water Test Objectives

1. Identify how water is stored in an aquifer
2. Differentiate between Porosity and Permeability: Identify if there is a connection between the two.
3. Diagram and interpret steps in the water cycle.
4. Distinguish steps in the water cycle where water can become contaminated
5. Describe key steps in the procedures municipal water plants use to purify drinking water.
6. Identify two key concerns about the "global water crisis."
7. Explain who is most at risk for water related problems, death, and disease
8. Identify water related diseases, and risk factors for becoming infected
9. Describe what a watershed is, and identify the watershed you live in
10. Summarize the following water parameters: Temperature, pH, Dissolved Oxygen, and Turbidity

Appendix C-8: Unit Test

Multiple Choice

Identify the choice that best completes the statement or answers the question.

____ 1.Where is water stored underground?

a. Most groundwater is found in large underground pools.
b. Water is not stored underground.
c. Water is stored between the pore spaces and crevices between rock and soil particles.
d. All water is stored in huge underground tanks.

____ 2.What is a watershed?

a. It is a garage filled with water.
b. It is the total area of land that drains into a body of water.
c. It is all the water under the ground in the state of Michigan.
d. It is all the water being bottled in the country.

____ 3.Which would be the most effective in purifying polluted water?

a. An aquifer composed of fine sand.
b. An aquifer composed of coarse sand.
c. An aquifer composed of gravel.
d. All of the above would be equally effective.

____ 4.Aquatic animals are sensitive to changes in which of the following water parameters?

a. pH
b. Temperature
c. Dissolved Oxygen
d. They would be sensitive to changes in all of the above.
e. They would not be sensitive to changes in any of the above.

____ 5.Which impermeable substrate layer would you find below the uncontained aquifer and above the contained aquifer?

a. clay
b. sand
c. medium sand
d. Gravel

____ 6.An algae bloom is the rise of an algae population in an aquatic environment. Algae blooms can occur when large amounts of fertilizer runoff enter a lake.

• As algae blooms grow, some die, and bacteria reproduce rapidly as they consume the dead matter.
• This causes a massive increase in bacteria populations in the lake.

Which of the following is a damaging effect of algae blooms?

a. The algae will release massive quantities of carbon dioxide, which will have an adverse effect on the ozone.
b. The algae will create competition for sunlight among plants on the land next to the lake.
c. The increase of bacteria will cause competition for oxygen in the lake, decreasing oxygen vital to other aquatic species.
d. The increase of bacteria will release small amounts of heat into the atmosphere, which will warm up the land around the lake.

____ 7. The repeated movement of water between Earth's surface and the atmosphere is called

a. the water cycle.
b. the condensation cycle.
c. precipitation.
d. evaporation.

____ 8. Matter can be recycled through the biosphere because

a. matter is passed out of the body as waste.
b. matter moves in one direction through ecosystems.
c. chemicals can be used again and again.
d. biological systems use only carbon, oxygen, hydrogen, and nitrogen.

9. **Use the following reading to answer questions**

Cholera

Cholera (also called Asiatic cholera) is a severe, infectious disease of the small intestine. It is marked by heavy diarrhea, vomiting, and muscle cramps and can result in coma and death. For centuries, it was confined to India, but in the early 19th century it began to spread to other parts of Asia, Europe, and the Americas. In the 1970s and 1980s, cholera epidemics occurred in the Middle East and Africa, and there was a localized outbreak of the disease in Naples, Italy. In the early 1990s, an epidemic that began in Peru spread to several other countries in Latin America.

The disease is contracted by ingesting food or drink—usually water—that is contaminated with a bacterium found in feces. After cholera bacteria are swallowed, they multiply in the small intestine, where they set off an infection that interferes with normal intestinal functions. Frequent diarrhea results. This can cause a great deal of fluid loss—water and essential salts—in a short period of time. In some cases, three to four gallons of fluid loss has been reported in a 24-hour period. In addition, vomiting and other symptoms often develop. Sometimes, however, an infected cholera victim will develop only mild diarrhea and can get rid of the disease through excretion. With prompt treatment, recovery is almost certain. Treatment consists of replenishing the body's fluids until the diarrhea stops. Sometimes antibiotics, such as tetracycline, are administered. Unfortunately, about 50 percent of all those who contract cholera are not treated and die of the disease.

Cholera remains common in impoverished tropical and semitropical developing nations. A vaccine can provide partial protection for a limited time, but the vaccine cannot prevent the spread of infection on a large scale.

Which of the following would be the least effective way to stop a widespread cholera outbreak?

a. Vaccines
b. Clean food and water sources
c. Improved sanitation
d. All of the above a very effective ways to stop the spread of cholera on a large scale.

____ 10. Why is prompt attention needed, if you show symptoms of cholera?

a. Diarrhea and vomiting will quickly lead to dehydration.
b. Vaccinations can be administered.
c. Family members need to be notified.
d. None of the above are correct.

____ 11. What should travelers do to avoid getting cholera?

a. Drink only water that you have boiled or treated with chlorine or iodine.
b. Eat only foods that have been thoroughly cooked and are still hot, or fruit that you have peeled yourself.
c. Make sure all vegetables are cooked avoid salads

d. All of the above are correct answers.

12. The table lists some characteristics of West Nile virus.

West Nile Virus

- West Nile virus causes a disease that can be fatal.
- Mosquitoes transmit the virus from wild birds to humans and horses.
- Horses can be vaccinated against the virus, but no vaccine exists for humans.

Which strategy is *most* likely to be successful in controlling the spread of West Nile virus to humans?

a. Eliminate all breeding grounds for birds that may harbor the virus.
b. Destroy any mosquito that has been exposed to the virus.
c. Vaccinate all horses to protect them from the virus.
d. Take steps to prevent being bitten by mosquitoes that may carry the virus.

Short Answer

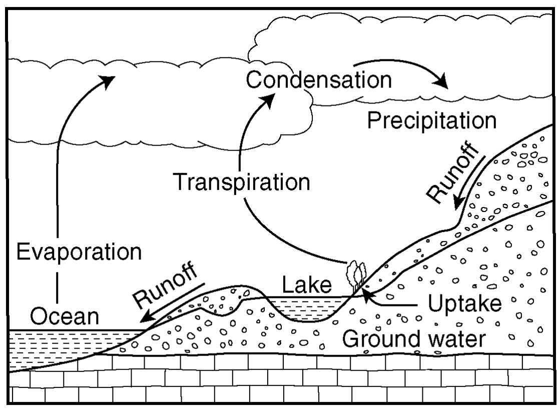

Figure 36-3

13. Using Figure 36-3, trace the path of water that leaves a lake through evaporation, and describe how it might return to the lake.

14. Identify a point in the water cycle where a water source could become contaminated. Explain how it could happen, and what the effects would be.

APPENDIX D: DATA

Appendix D-1: Pre-Survey Results for Bolivian and JHS Test Groups

#	Survey Questions	Average Response		
		JHS Pre	Bolivia Pre	Diff.
1	My actions affect the quality of the water in my watershed.	3.25	2.72	0.53
2	My actions affect the quality of water in other watersheds.	3.12	2.7	0.42
3	Clean, fresh water must be used in moderation.	3.88	4.13	-0.25
4*	It is safe to drink the water from any faucet.	2.53	2.45	0.08
5	Water is a renewable resource.	3.58	3.16	0.42
6*	All individuals have access to clean water.	1.86	3.21	-1.35
7	Only bottled or properly disinfected water should be used for cooking, brushing teeth, and drinking.	3.42	3.56	-0.14
8	Contaminated surface water and poor sanitation contribute to the transmission of water-borne disease.	4.05	2.85	1.2
9	Impervious surfaces typically have the highest rates of runoff.	3.56	2.96	0.6
10	Boiling water can eliminate the chance of water-borne disease.	4.12	4.04	0.08
11	Water-borne disease can be eliminated by boiling water	3.88	4	-0.12
12	By treating water with chlorine and iodine water-borne disease can be eliminated	3.39	3.53	-0.14
13	Some germs and chemicals occur naturally in water.	3.77	3.227	0.5
14	Standing water creates a breeding ground for disease carrying mosquitoes.	3.93	3.1	0.83
15	The Clean Water Industry plays a vital role in my daily life.	3.95	4.09	-0.14
16	The Clean Water Industry plays a vital role in the daily lives of individuals around the world.	3.91	4.29	-0.38
17	There are many career opportunities in the Clean Water Industry.	3.42	3.62	-0.2
	**Overall Group Means	3.69	3.4	

*Denotes negative question

**Take into account reversed scores for negatively posed survey questions.

Unpaired *t* test results: US and Bolivian Groups

P value and statistical significance:

The two-tailed P value equals 0.0006

By conventional criteria, this difference is considered to be statistically significant.

Group	US Groups	Bolivian Group
Mean	3.69656	3.43288
SD	0.36598	0.48460
N	57	89

Appendix D-2: Pre-Survey Results for Bolivian Schools

#	Survey Questions	Average Response			
		JW	WH	BC	ALL
1	My actions affect the quality of the water in my watershed.	2.67	2.97	2.43	2.72
2	My actions affect the quality of water in other watersheds.	2.60	3.10	2.30	2.7
3	Clean, fresh water must be used in moderation.	4.07	4.10	4.10	4.13
4*	It is safe to drink the water from any faucet.	2.97	1.87	2.47	2.45
5	Water is a renewable resource.	3.10	3.07	3.20	3.16
6*	All individuals have access to clean water.	3.45	3.27	2.93	3.21
7	Only bottled or properly disinfected water should be used for cooking, brushing teeth, and drinking.	3.50	3.47	3.60	3.56
8	Contaminated surface water and poor sanitation contribute to the transmission of water-borne disease.	2.43	3.33	2.70	2.85
9	Impervious surfaces typically have the highest rates of runoff.	2.93	3.03	2.80	2.96
10	Boiling water can eliminate the chance of water-borne disease.	3.70	4.03	4.27	4.04
11	Water-borne disease can be eliminated by boiling water	3.63	4.00	4.23	4
12	By treating water with chlorine and iodine water-borne disease can be eliminated	3.13	3.60	3.73	3.53
13	Some germs and chemicals occur naturally in water.	2.97	3.47	3.27	3.227
14	Standing water creates a breeding ground for disease carrying mosquitoes.	3.07	3.63	2.50	3.1
15	The Clean Water Industry plays a vital role in my daily life.	3.70	3.87	4.57	4.09
16	The Clean Water Industry plays a vital role in the daily lives of individuals around the world.	3.60	4.43	4.70	4.29
17	There are many career opportunities in the Clean Water Industry.	3.53	3.57	3.63	3.62
	**Overall Group Means	3.17	3.55	3.46	3.4

*Denotes negative question
**Take into account reversed scores for negatively posed survey questions.

Bolivian Private Missionary Schools

JW: *Instituto Americano Juan Wesley*

WH: *Instituto Americano Walter Henry*

Bolivian Public School

BC*: Unidad Educativa Bertha Cuellar*

Appendix D-3: t-test Results for Comparison of Bolivian Schools

Juan Wesley/ Walter Henry Unpaired *t* test results

P value and statistical significance:
The two-tailed P value equals 0.0252
By conventional criteria, this difference is considered to be statistically significant.

Juan Wesley/ Bertha Cuellar Unpaired *t* test results

P value and statistical significance:
The two-tailed P value equals 0.2080
By conventional criteria, this difference is considered to be not statistically significant.

Walter Henry/ Bertha Cuellar Unpaired *t* test results

P value and statistical significance:
The two-tailed P value equals 0.7121
By conventional criteria, this difference is considered to be not statistically significant.

Appendix D-4: All JHS Students Pre- and Post-Survey Data

#	Survey Questions	Average Response		
		JHS Pre	JHS Post	Diff.
1	My actions affect the quality of the water in my watershed.	3.25	4.05	0.8
2	My actions affect the quality of water in other watersheds.	3.12	3.30	0.18
3	Clean, fresh water must be used in moderation.	3.88	4.07	0.19
4*	It is safe to drink the water from any faucet.	2.53	2.61	0.08
5	Water is a renewable resource.	3.58	3.51	-0.07
6*	All individuals have access to clean water.	1.86	1.42	-0.44
7	Only bottled or properly disinfected water should be used for cooking, brushing teeth, and drinking.	3.42	3.68	0.26
8	Contaminated surface water and poor sanitation contribute to the transmission of water-borne disease.	4.05	4.26	0.21
9	Impervious surfaces typically have the highest rates of runoff.	3.56	3.72	0.16
10	Boiling water can eliminate the chance of water-borne disease.	4.12	4.26	0.14
11	Water-borne disease can be eliminated by boiling water	3.88	3.93	0.05
12	By treating water with chlorine and iodine water-borne disease can be eliminated	3.39	4.07	0.68
13	Some germs and chemicals occur naturally in water.	3.77	3.81	0.04
14	Standing water creates a breeding ground for disease carrying mosquitoes.	3.93	4.28	0.35
15	The Clean Water Industry plays a vital role in my daily life.	3.95	4.28	0.33
16	The Clean Water Industry plays a vital role in the daily lives of individuals around the world.	3.91	3.91	0
17	There are many career opportunities in the Clean Water Industry.	3.42	3.47	0.05

*Denotes a negative question

Paired t test results: All Classes JHS Biology

P value and statistical significance:

The two-tailed P value equals 0.0001

By conventional criteria, this difference is considered to be statistically significant.

Group	Pre All	Post All
Mean	3.69656	3.91640
SD	0.36598	0.42738
N	57	57

Appendix D-5: 1st hour Biology(3-4) JHS Student Pre- and Post-Survey Data

#	Survey Questions	Average Response		
		1st Pre	1st Post	Diff.
1	My actions affect the quality of the water in my watershed.	2.83	4.33	1.5
2	My actions affect the quality of water in other watersheds.	3.00	3.58	0.58
3	Clean, fresh water must be used in moderation.	3.58	4.25	0.67
4*	It is safe to drink the water from any faucet.	2.08	2.75	0.67
5	Water is a renewable resource.	4.00	3.92	-0.08
6*	All individuals have access to clean water.	2.17	1.08	-1.09
7	Only bottled or properly disinfected water should be used for cooking, brushing teeth, and drinking.	3.33	3.92	0.59
8	Contaminated surface water and poor sanitation contribute to the transmission of water-borne disease.	3.75	4.67	0.92
9	Impervious surfaces typically have the highest rates of runoff.	3.17	3.50	0.33
10	Boiling water can eliminate the chance of water-borne disease.	4.42	4.42	0
11	Water-borne disease can be eliminated by boiling water	4.00	4.08	0.08
12	By treating water with chlorine and iodine water-borne disease can be eliminated	3.83	4.42	0.59
13	Some germs and chemicals occur naturally in water.	3.92	4.08	0.16
14	Standing water creates a breeding ground for disease carrying mosquitoes.	3.75	4.67	0.92
15	The Clean Water Industry plays a vital role in my daily life.	4.17	4.58	0.41
16	The Clean Water Industry plays a vital role in the daily lives of individuals around the world.	4.00	4.08	0.08
17	There are many career opportunities in the Clean Water Industry.	3.33	3.42	0.09

*Denotes a negative question

Paired *t* test results: JHS 1st hour Biology (3-4)

P value and statistical significance:

The two-tailed P value equals 0.0004

By conventional criteria, this difference is considered to be statistically significant.

Group	**Pre 1st**	**Post 1st**
Mean	3.69583	4.12259
SD	0.34374	0.26722
N	12	12

Appendix D-6: 2nd hour Biology(3-4) JHS Student Pre- and Post-Survey Data

#	Survey Questions	Average Response		
		2nd Pre	2nd Post	Diff.
1	My actions affect the quality of the water in my watershed.	3.00	4.00	1
2	My actions affect the quality of water in other watersheds.	2.71	3.29	0.58
3	Clean, fresh water must be used in moderation.	3.82	3.71	-0.11
4*	It is safe to drink the water from any faucet.	3.06	2.47	-0.59
5	Water is a renewable resource.	3.06	3.47	0.41
6*	All individuals have access to clean water.	1.47	1.35	-0.12
7	Only bottled or properly disinfected water should be used for cooking, brushing teeth, and drinking.	3.18	3.18	0
8	Contaminated surface water and poor sanitation contribute to the transmission of water-borne disease.	4.18	4.24	0.06
9	Impervious surfaces typically have the highest rates of runoff.	3.94	3.94	0
10	Boiling water can eliminate the chance of water-borne disease.	4.35	4.24	-0.11
11	Water-borne disease can be eliminated by boiling water	3.94	3.88	-0.06
12	By treating water with chlorine and iodine water-borne disease can be eliminated	3.41	4.18	0.77
13	Some germs and chemicals occur naturally in water.	3.94	4.00	0.06
14	Standing water creates a breeding ground for disease carrying mosquitoes.	4.12	4.00	-0.12
15	The Clean Water Industry plays a vital role in my daily life.	3.88	4.18	0.3
16	The Clean Water Industry plays a vital role in the daily lives of individuals around the world.	4.06	3.94	-0.12
17	There are many career opportunities in the Clean Water Industry.	3.35	3.47	0.12

*Denotes a negative question

Paired t-test results: JHS 2nd hour Biology (3-4)

P value and statistical significance:

The two-tailed P value equals 0.0745

By conventional criteria, this difference is considered to be not quite statistically significant.

Group	**Pre 2nd**	**Post 2nd**
Mean	3.67129	3.87547
SD	0.32771	0.43462
N	17	17

Appendix D-7: 3rd hour Biology(3-4) JHS Student Pre- and Post-Survey Data

#	Survey Questions	Average Response		
		3rd Pre	3rd Post	Diff.
1	My actions affect the quality of the water in my watershed.	3.82	4.18	0.36
2	My actions affect the quality of water in other watersheds.	3.65	3.59	-0.06
3	Clean, fresh water must be used in moderation.	3.88	4.29	0.41
4*	It is safe to drink the water from any faucet.	2.59	2.82	0.23
5	Water is a renewable resource.	3.76	3.41	-0.35
6*	All individuals have access to clean water.	1.71	1.41	-0.3
7	Only bottled or properly disinfected water should be used for cooking, brushing teeth, and drinking.	3.76	3.71	0.05
8	Contaminated surface water and poor sanitation contribute to the transmission of water-borne disease.	4.24	4.59	0.35
9	Impervious surfaces typically have the highest rates of runoff.	3.65	3.71	0.06
10	Boiling water can eliminate the chance of water-borne disease.	4.29	4.35	0.06
11	Water-borne disease can be eliminated by boiling water	3.94	4.18	0.24
12	By treating water with chlorine and iodine water-borne disease can be eliminated	3.24	3.94	0.7
13	Some germs and chemicals occur naturally in water.	3.59	3.65	0.06
14	Standing water creates a breeding ground for disease carrying mosquitoes.	4.00	4.35	0.35
15	The Clean Water Industry plays a vital role in my daily life.	3.88	4.47	0.59
16	The Clean Water Industry plays a vital role in the daily lives of individuals around the world.	3.88	4.00	0.12
17	There are many career opportunities in the Clean Water Industry.	3.24	3.53	0.29

*Denotes a negative question

Paired t Test Results: 3rd Hour Biology (3-4)

P value and statistical significance:

The two-tailed P value equals 0.0409

By conventional criteria, this difference is considered to be statistically significant.

Group	**Pre 3rd**	**Post 3rd**
Mean	3.79594	3.98271
SD	0.43279	0.50594
N	17	17

Appendix D-8: 5th hour Biology(1-2) JHS Student Pre- and Post-Survey Data

#	Survey Questions	Average Response		
		5th Pre	5th Post	Difference
1	My actions affect the quality of the water in my watershed.	3.18	3.64	0.46
2	My actions affect the quality of water in other watersheds.	3.09	2.55	-0.54
3	Clean, fresh water must be used in moderation.	4.27	4.09	-0.18
4*	It is safe to drink the water from any faucet.	2.09	2.36	0.27
5	Water is a renewable resource.	3.64	3.27	-0.37
6*	All individuals have access to clean water.	2.36	1.91	-0.45
7	Only bottled or properly disinfected water should be used for cooking, brushing teeth, and drinking.	3.36	4.18	0.82
8	Contaminated surface water and poor sanitation contribute to the transmission of water-borne disease.	3.91	3.36	-0.55
9	Impervious surfaces typically have the highest rates of runoff.	3.27	3.64	0.37
10	Boiling water can eliminate the chance of water-borne disease.	3.18	4.00	0.82
11	Water-borne disease can be eliminated by boiling water	3.55	3.45	-0.10
12	By treating water with chlorine and iodine water-borne disease can be eliminated	3.09	3.73	0.64
13	Some germs and chemicals occur naturally in water.	3.64	3.45	-0.19
14	Standing water creates a breeding ground for disease carrying mosquitoes.	3.73	4.18	0.45
15	The Clean Water Industry plays a vital role in my daily life.	3.91	3.82	-0.09
16	The Clean Water Industry plays a vital role in the daily lives of individuals around the world.	3.64	3.55	-0.09
17	There are many career opportunities in the Clean Water Industry.	3.91	3.45	-0.46

*Denotes a negative question

Paired *t* test results: JHS 5th Biology (1-2)

P value and statistical significance:
The two-tailed P value equals 0.03289
By conventional criteria, this difference is considered to be not statistically significant.

Group	**Pre 5th**	**Post 5th**
Mean	3.58282	3.65227
SD	0.34131	0.30730
N	11	11

Appendix D-9: All Biology (3-4) JHS Student Pre- and Post-Survey Data

#	Survey Questions	Average Response		
		(3-4) Pre	(3-4) Post	Difference
1	My actions affect the quality of the water in my watershed.	3.26	4.15	0.89
2	My actions affect the quality of water in other watersheds.	3.13	3.48	0.35
3	Clean, fresh water must be used in moderation.	3.78	4.07	0.29
4*	It is safe to drink the water from any faucet.	2.63	2.67	0.04
5	Water is a renewable resource.	3.57	3.57	0
6*	All individuals have access to clean water.	1.74	1.30	-0.44
7	Only bottled or properly disinfected water should be used for cooking, brushing teeth, and drinking.	3.43	3.57	0.14
8	Contaminated surface water and poor sanitation contribute to the transmission of water-borne disease.	4.09	4.48	0.39
9	Impervious surfaces typically have the highest rates of runoff.	3.63	3.74	0.11
10	Boiling water can eliminate the chance of water-borne disease.	4.35	4.33	-0.02
11	Water-borne disease can be eliminated by boiling water	3.96	4.04	0.08
12	By treating water with chlorine and iodine water-borne disease can be eliminated	3.46	4.15	0.69
13	Some germs and chemicals occur naturally in water.	3.80	3.89	0.09
14	Standing water creates a breeding ground for disease carrying mosquitoes.	3.98	4.30	0.32
15	The Clean Water Industry plays a vital role in my daily life.	3.96	4.39	0.43
16	The Clean Water Industry plays a vital role in the daily lives of individuals around the world.	3.98	4.00	0.02
17	There are many career opportunities in the Clean Water Industry.	3.30	3.48	0.18

*Denotes a negative question

Paired *t* test results: JHS Biology All (3-4)

P value and statistical significance:

The two-tailed P value is less than 0.0001

By conventional criteria, this difference is considered to be statistically significant.

Group	**Pre (3-4)**	**Post (3-4)**
Mean	0.72376	3.97957
SD	0.36997	0.43033
N	46	46