Preparing California Public Middle School Students

For Scientific Inquiry into Environmental Issues

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Abstract

Skilled scientists in all fields of study are critically needed to begin resolving ecological problems resulting from human impact. Time is an essential element in creating a proper conceptual foundation and training should begin early in a student's education. As of 2010, the California State Standards for Science for grades six through eight do not sufficiently address the importance of inquiry-based studies, limiting the scope of possibilities in public education. Studies show that middle school students build a deeper understanding of conceptual science and its application if they have opportunities to apply their knowledge through empirical activities. Multiple benefits, both academic and social, arise when lab activities reinforce scientific principles. A student survey in a Marin County, California public middle school revealed that students learn science concepts best, and prefer experiential activities, to other teaching methods.

Chapter 1 Introduction

Now there is one outstandingly important fact regarding Spaceship Earth, and that is that no instruction book came with it. – R. Buckminster Fuller, Operating Manual for Spaceship Earth

The chilly air could not dampen the enthusiasm of the animated group of 12-year olds as they struggled to pull three-meter strands of *Carpobrotus chilensis* from the ground. Planting their feet firmly, they pulled the weeds with all their might. One long strand unexpectedly snapped, sending its captor heavily to the ground with an audible thump. Laughing, two other students rushed to her aid, their battered leather gloves slipping from their fingers. They grabbed the rest of the piece still anchored firmly in the ground. “One…two…three!” They tugged in unison, and the strand finally released its stranglehold and flew skyward. Other students ran over until a dozen excited hands were giving each other high-fives in a frantic melee of activity. Then they quickly turned back to their work. They laughed. They tripped in the sand. They had contests to see who could make the tallest pile of the dreaded, invasive ice plant. They refused to stop for lunch. It was a long day. On the ride back home, some fell asleep against the rattling bus windows. What on Earth could have motivated those middle school students to restore that small patch of seaside dirt?

Statement of Problem

The stability of the Earth's ecosystems seems to be undermined by human activity more than any other naturally-occurring factor. Due to negligence and population growth, irreversible damage to Earth's fragile ecosystems is possible (Nelson, 1995). Evidence is mounting that destruction of vital habitat has reached the point where damage to the environment must cease if Earth is to remain an inhabitable planet for humans. Scientists and engineers from all fields and other highly trained support people are working on solutions. The problems are so complex, though, that they require the massive cooperative effort of people with skill sets that are at once known and yet to be determined.

For scientists, proper management of our natural resources requires overall skill in observation, critical thinking, experimental design, data collection and analysis, and communication. Skills in science build slowly and are best learned through years of hands-on experience. A major problem in California public middle schools is that the state standards for science do not emphasize investigative science activities, particularly those focused on environmental education and stewardship. Time needs to be devoted consistently to hands-on activities throughout grades six, seven, and eight, so students can adequately understand the application of scientific principles, especially those directed toward environmental stability.

Purpose Statement

Conceptual understanding of science must being early in a student's education since time is a critical factor for thorough comprehension. Teaching scientific methodology through hands-on environmental awareness activities can increase the depth of understanding of scientific principles, preparing students for the next level in their science studies. Although the State of California does not require environmental education investigative activities, there is an immediate need to broaden the depth of understanding of California's natural environment for middle school students. The purpose of this paper is to show the long-term benefits of investigative experiences as middle school students learn scientific concepts relating to their natural environment.

Research Question

What are the benefits of using experiential laboratory activities to help students develop a deep understanding of scientific concepts?

Theoretical Rationale

Educational reform in the United States was greatly influenced by John Dewey, who proposed that education should not be reserved just for the wealthy. In 1899, he discussed the role of public education in the classic paper *The School and Society*. Even as this new era of public education was taking root, Dewey proposed that social conditions were changing, requiring radical alterations in the approach to education. Over one hundred years later, the topic of public education is still strongly debated.

Warning against passive classrooms dependent solely upon students' listening skills, Dewey advocated interaction between students and their surroundings. He believed that the best possible learning situations stemmed from experience-based learning integrated with academic subjects (Dewey, 1899; Senechal, 2010). Organizing education with two dimensions fulfilled knowledge requirements and social requirements.

Dewey recognized that societies are built through social interaction, not isolation. He believed that various levels of organized society - governments, businesses, and educational systems - worked in the same manner, and all were dependent upon social connection. In 1906, in *The Educational Situation*, he wrote that students acquired knowledge through both social and physical interactions with their environments. The integration of experiences when combining academic topics with hands-on reinforcement activities provided students with important overlapping learning opportunities. Such cooperative activities served dual purposes: they developed knowledge and social skills simultaneously. Because they promoted communication and cooperation among people, they lead to the betterment of society as a whole (Dewey, 1906).

Dewey's efforts led to others examining the way people learn. Over time, constructivist models emerged. According to these theories, knowledge is built over time, with information from each new situation nesting within previous information already in place. Learning experiences build upon each other as a scaffold, awaiting new ideas.

Through his work published after his death in 1934, Vygotsky emphasized that childhood experiences play a major role in forming foundations of learning. Imagination and creativity motivate children to understand events that occur around them. When exposed to novel situations, a child creatively reworks knowledge already in place, recombining it with the new knowledge to form a more intricate level of understanding (Clabaugh et al., 2010). This model can be extended into science classes, where concepts build as students mature and modify their instructional scaffolding (Reif, 1983). Cakir (2008) describes how conceptual learning can be drawn from a student's original scaffolding framework, applied to future novel situations, and built upon year after year.

Another pioneer in the field of constructivist theory, Jean Piaget described the learning process as one where existing information is blended with new ideas upon exposure to novel experiences (Lipton, Wellman & Humbard, 2007). This implies that for cognitive development to occur, meaningful interaction with the environment is required. Describing the acquisition of new ideas as a knowledge conflict, Driver et al. believe that students learn best through empirical, interactive experiences. Current understanding becomes challenged through interactive experiences, and students reorganize their knowledge constructs to include new ideas acquired during the process (Driver et al., 1994).

Science is best learned through combinations of experiences that depend upon different modalities of learning. People may recall their own feelings of inadequacy when learning science as a child in school; perhaps at the time, they didn't consider themselves smart enough. Yet according to Howard Gardner, determining true intelligence is a complex matter since it exists in many forms. His theory of multiple intelligences measures intellect in eight distinct areas that depend upon and interact with each other. Each area is specific, and strength in one area does not necessarily indicate strength or even weakness in another. The original seven intelligences he identified are linguistic, spatial, logical-mathematical, interpersonal, intrapersonal, bodily-kinesthetic, and musical (Smith, 2008). Yet, he knew there was a gap; something was missing. In 1997, Gardner added an eighth category: naturalist.

The naturalist category recognized the heightened ability of some people to relate to the environment in ways others could not. Once largely ignored, Sherman writes that scientists in varied fields such as evolutionary science, geology, ecology, and animal behavior require highly developed naturalist intelligence in addition to Gardner's other intelligences. The works of Charles Darwin, John Muir, Rachel Carson, and Jane Goodall demonstrate highly developed naturalist intelligence acquired through experience and interaction with the environment (Sherman, 2006).

During classroom lab activities, all intelligences described by Gardner can be developed, many simultaneously. The sequential acts of observation, analysis of the problem, developing a hypothesis, designing an experiment, collecting and analyzing data, and communicating results strengthen skills in most of Gardner's categories. Interpersonal and intrapersonal intelligences develop as students map out their experiments and physically work together. Spatial and bodily-kinesthetic skills help with the physical design of an experiment. Manipulating a variable requires logical-mathematical skills, which are again needed to analyze data. Linguistic skills are clearly needed during the experiment and to convey the results. An additional benefit arises as students use newly acquired vocabulary (Gardner, 1988). When the elements in the student's natural environment are used in a study, all eight of the separate intelligences combine in unique ways as students learn new concepts and develop a deeper understanding of scientific methodology.

Once students have a clear understanding of concepts, they are able to apply them to new situations (Gardner, 1993). That is, newly acquired knowledge from experiential processes can be transferred to novel situations both inside and outside the classroom as the student's knowledge base, or scaffold, builds. For example, concepts about invasive species and other knowledge acquired when pulling ice plant along the seashore could be applied at a different time and site, and even brought back into the classroom where they are expressed to other students.

Without hands-on activities, students learn facts about science but lack chances to apply the knowledge to new situations. Sitting passively in classrooms completing work books, worksheets and watching occasional videos greatly narrows the scope of scientific possibilities. Results are that students retain information long enough to complete paperwork, but the knowledge remains in discrete units of isolated facts, disconnected from each other as unrelated and irrelevant. Knowledge is blocked into a simple elementary grid of facts instead of being stored in an expandable collection of well understood, related concepts. Facts can be recited but the depth of understanding necessary to apply the knowledge to new situations is not given a chance to develop. This limitation prevents them from being applied to future novel situation; essentially, the information is useless (Mansilla & Gardner, 2008). Students need deep comprehension of concepts rather than superficial memorization of bits of factoid information. From there, they can construct a mental architectural blueprint to which they can refer and continue to build in the future. Students begin the process of thinking like scientists, developing vital critical thinking skills that will serve them throughout their lives.

The concepts behind scientific thought cannot be acquired quickly. Conceptual development requires experience, and therefore time, to build. Steps cannot be omitted or a learning deficit is created. For example, although science is rooted in fact, scientists must be open and flexible when investigating the unexplained. Bias should have no part in a scientific study. Yet the opportunity to examine bias must be available during a student's education, so it can be recognized and avoided later.

To facilitate conceptual learning in the classroom, Mansilla and Gardner (2008) suggest that a few vital concepts should be identified by the teacher, and time should be spent using various approaches to foster their conceptual understanding. Teachers should develop lesson plans that involve multiple intelligences simultaneously. To include empirical manipulations would engage most of Gardner's intelligence categories. Today's complex world requires that youth develop the ability to think critically sooner than was necessary in the past (Kay, 2009). Teaching students how to think, rather than what to think, should occupy the time in a classroom (Mansilla & Gardner, 2008).

Assumptions

Teaching students how to think is critical. One step is to teach them how to organize their knowledge for practical application. This is especially important in today's ecologically threatened world, since human activity has undermined the stability of Earth's ecosystems more than any other naturally-occurring factor. The fear is that negligence and population growth can irreversibly damage the Earth (Nelson, 1995).

Globally, scientists and laypersons are working on solutions to slow or reverse the effects of human activity. While they are aware of countless problems, unseen issues will certainly be unveiled. Today's middle school students will be tomorrow's scientists. The State Standards for Science in California do not emphasize environmental studies in grades six through eight, losing three valuable years of science education and the empirical opportunities that would accompany them. Many of the standards could be easily revised to be environmentally-based without compromising the intent of the standards.

While it seems apparent that California is trying to make significant changes to include environmental studies in the standards, full enactment is still many years away. Because of the steps involved in bringing approved text books and materials to the classroom, the process can take several years. Current economic difficulties will slow progress even further. Developing science concepts is a process that requires time to formulate, but it is a vital first step in solving the environmental problems facing all nations today. Students will have the framework to help manage natural resources and resolve ecological problems provided they are given adequate time and practice. Emphasizing application of scientific skills now, without waiting years for California to mandate changes, prepares students for the future challenges and complexities facing an impacted planet.

Background and Need

Although humans have had a devastating effect on its flora, fauna, and water quality, California was once an ecological paradise. When gold was discovered in California in 1850, the Gold Rush was on. In the following 12 years, it is estimated that statewide the population grew from 15,000 to 380,000 people. One-fourth of California's population was living in the San Francisco Bay area during the Gold Rush era (Bay Institute, 2003).

Until then, California's natural bounty was extraordinary. It may have had the largest population of beaver in the United States. It was home to huge herds of several species of elk, and its waterways were filled with river and sea otters. Lynx, bobcat and mountain lion were common, as were grizzly bear, pronghorn antelope and mink. Marine mammals were plentiful, including fur seals that swam the coastal waters. Fish and shellfish were bountiful (Bay Institute, 2003).

Flocks of birds blackened the skies as they passed overhead. Hunters flung nets to catch them for food for the burgeoning population in nearby San Francisco. Their eggs were also gathered as a high-protein food source. In just six years, the Farallon Egg Company collected between three and four million seabird eggs from the Farallon Islands. But the hunger of a ravenous city could not be quenched as San Francisco continued to grow. While the land provided, it also suffered as animal populations declined.

California's pristine waters began to suffer, too. It was common practice in the latter half of the 1800s to discharge untreated sewage into nearby rivers and streams. For his 1870 Biennial Report of the State Board of Fish Commissioners, Lockington wrote about decline of the coast's fish and shellfish beds, blaming the "…fouling of the waters and consequent destruction of life by the foetid impourings of our sewers…"(Bay Institute, 2008, p. 3-28). The huge populations of salmon in the Bay had already been over fished, prompting one naturalist in 1877 to estimate that only one-twentieth of the population remained compared to the previous 20 years. To this date, populations have not recovered and stand on the brink of collapse. Other species were exploited, including larger species like sharks and sturgeon, and smaller ones like smelt, anchovies, herring, bay shrimp, clams, mussels, and oysters (Bay Institute, 2003).

Today, it is known that harmful man-made chemicals concentrate in the bodies of fish and shellfish, often rendering them unsafe as a food source. Once-plentiful abalones require a special license for collection due to scarcity. When Californians spot an otter, it can make the local news. Marine mammals regularly beach themselves, too ill to return to the water. Pronghorn antelope no longer roam California's hills and plains, and the last known grizzly bear in the state was shot in 1922 (Bay Institute, 2003).

The middle school stewards of the patch of seaside sand, so cheerfully eradicating ice plant, were unaware of this sad part of California's history. They never saw the vast flocks of birds, witnessed salmon struggle upstream, or heard elephant seals on the beach. They only know what they see, touch, and hear today. But they know things used to be different in California. They are eager to learn and to preserve what is left of our natural resources.

As the planet spins toward ecological disaster, scientists around the world are seeking ways to slow or reverse the kinds of damage experienced in the state of California. To be successful, people from all walks of science are needed to work cooperatively toward a common goal. California's global influence to help solve ecological problems can be important. It can choose to educate its students by providing them with vital knowledge and skills, or it can continue as status quo and hope for the best.

Chapter 2 Review of the Literature

Introduction

Chapter Two places this report within a historical context through a search of the literature. Statistical information is presented supporting the need for additional concentration on science study in schools in the United States. Evidence from California's Board of Education and the federal government is cited, and facts published by respected national organizations and agencies help back this paper's premises. Opinions from colleagues, personal observations, student surveys, and comments from a well-respected marine scientist finalize this chapter.

Historical Context

It is in mankind's nature to have a natural curiosity about the world. Explorers of the past accepted the fact that knowledge would be acquired at the risk of life and limb. Today, because of technological breakthroughs, modern explorers can minimize risks and information is gathered at far greater speed and in greater depth. The result is that in the past few decades we have witnessed an explosion of information. Reports of newly discovered ecological wonders make headlines regularly. Researchers can venture deep into uncharted rainforests, documenting new animal species and miracle-promising plants. Polar explorers drill for ice core samples and determine volcanic activity and weather conditions from ages past. Marine biologists can sink cameras miles below the ocean's surface to an eternally dark world rich in exotic life forms.

Unfortunately, with the good news comes the bad. As we proceed to discover what we have missed, we are missing what we have left behind. The complexities of human activity on the planet have reached every corner of the world. We can no longer ignore the fact that pollution and depletion of natural resources has increased exponentially with population growth. It is time to address those critical issues before irreparable damage occurs. This is a daunting task, since we are experiencing new problems of staggering magnitude and, as R. Buckminster Fuller noted, there is no instruction book to call upon.

Several decades ago, we were largely unaware of grave ecological concerns. Today, we confront issues such as global warming. National leaders and scientists have been aware of the problems created by greenhouse gases and other forms of pollution for many years but only relatively recently has the public become aware of the magnitude of the problems. Since then, the problems have escalated quickly.

Concern for the planet has a history in the United States dating back at least to the 1970s. At that time, pollution problems seemed to have simple answers. Participation in America's first Earth Day, celebrated in 1970, highlighted concern over human impact upon our planet (Williams, 2000). Twenty million people responded by showing their concern for the environment in many ways, locally and nationally. Some scavenged beaches for litter; some planted trees. The idealistic shift was not lost on teachers. Around the world, they began showing students how to care for the Earth (Wei, 2009; Al-Naki, 2004; Louv, 2005). Interest in classroom science began moving from traditional lessons to more hands-on, environmentally-based ones – the type Dewey said were the most effective in the early 1900s (Dewey, 2001).

A poll conducted in 1995 indicated that when students were given a choice of community service options, environmentally-based service rated very high (Wirthin Group, 1995). A report published two years later stated that American parents clearly desire environmental education for their children (National Environmental Education Foundation, 2008). By the year 2000, Americans were concerned about their children gaining an understanding of the environment and wanted it as part of their public school curriculum (NEEF, 2008). The first Earth Day was not missed by politicians. Between 1970 and 1995, over 40 major federal laws protecting the environment were enacted (Nelson, 1995).

Leaders world-wide were also seriously examining environmental responsibility. In 1994, The United Nations Framework Convention on Climate Change (UNFCCC) was formed by a majority of the world's countries. Together, these countries outlined the responsibilities and efforts needed by all governments, particularly those of industrialized nations, to assume responsibility for their part in climate change and to act accordingly (United Nations Framework Convention on Climate Change, Convention, 2009).

Three years later, in 1997, the UNFCCC adopted the Kyoto Protocol during a summit in Kyoto, Japan. The goal of the protocol was to reduce global greenhouse gas emissions, relying on the 37-nation membership to determine the best way their country could accomplish that target (UNFCCC, Kyoto Protocol, 2009). More than thirteen years later, the protocol is still not ratified by all UNFCCC member countries.

Back in the United States, the No Child Left Behind Act was written to reauthorize the Elementary and Secondary Education Act of 1965. The act was intended to act as a guide toward accountability of each school, with the goal of providing all children equal access to a high quality education. Expectations were that each child would reach minimum proficiency levels as assessed by standardized testing (United States Department of Education, 2004). In 2007, the House of Representatives considered amending it with the No Child Left Inside Act. In part, this act was designed to supplement states' environmental education through new grant programs (Hoff, 2008). In the proceedings, reports discussed the essential nature of environmental education as it enhanced student learning. It recognized that adding environmentally-focused changes missing from the No Child Left Behind Act would help create responsible students who were engaged in their communities. The bill acknowledged national security concerns, such as human health issues and biological diversity challenges that would be addressed at the same time (No Child Left Inside Act of 2008). Unfortunately, the bill supporting the act expired before Congress could enact it into law as the Congressional Session ended (Congressional Research Service Summary, 2008).

By that time, interest in classroom science practices had secured a position in the forefront. In a statement released by Education Secretary Arne Duncan, he stated that current science standards are not progressive and that major improvements in teaching methods are required if America is to keep pace with the rest of the world. He stressed that current public school policies do not prepare students to join a workforce that is becoming more diversified and globally connected daily. He announced that teachers need to teach beyond simple facts and impart critical thinking skills earlier in students' educations. Calling for the development of new science curricula, he believes effective teachers must well versed in constructivist theories of learning and also have a deep understanding of science (Bohrer, 2009; Ramirez & Clark, 2009; United States Department of Education, 2009).

Imparting concepts requires communication and social aptitudes. As Dewey noted at the turn of the century, these skills improve as students interact with each other and the environment. Technology rapidly draws nations together, making it vital that students develop a spirit of collaboration and good communication skills. Kay writes, “The global economy and democratic society that today’s 10- to 14-year-olds will inherit demand a different kind of preparation than that experienced by any previous generation” (Kay, 2009, p. 1). Not only do teachers need to prepare students academically for global interaction; students must also be ready socially and culturally.

Already envisioning the future, educators are providing students with opportunities to develop science skills geared toward global connection. A common thread connecting all people is the very Earth itself. Around the world, in areas as disparate as Kuwait, Sweden, China, Turkey, and the United States, teachers are enhancing science education by bringing environmental stewardship issues in their classrooms (Al-Naki, 2004; Wei, 2009; Oluk et al., 2007; Hellden, 2000).

Administrative Records

California's Board of Education began focusing on science standards over 12 years ago when educators realized that academic common ground was needed across California. Potential problems could arise when the focus in one science classroom may have been entirely different from another just a few miles away. Prior to 1998, teachers determined the best curriculum to teach in their classrooms, often based upon community need, future college requirements, or teacher expertise (personal communication, L. LaVere, March 23, 2010). Guidelines were necessary to equalize educational opportunities and eliminate ambiguity. In 1998, the California State Board of Education published academic standards for science content for all grades through high school (California Department of Education, 1998). This was the state's first comprehensive effort to ensure that public school students statewide were taught the same science principles at each grade level. Teachers were expected to design their lesson plans based on the state standards. To make the standards accessible, publishing houses began printing the standards in both teacher and student editions of text books. Teachers, students, and parents could easily identify the goals of each chapter and match them to the standards. Accessibility encouraged observance, helping to minimize inconsistencies across the state.

As a reference guide, the state also printed Science Frameworks to accompany the standards. The Frameworks give detailed theory and facts behind each standard, adding to teachers' knowledge base. Although the Frameworks help enlighten teachers with additional background, without prior experience, some teachers still may not understand how to adapt their skills to science lessons. Frameworks suggest the methods teachers should use to deliver instruction in the classroom, such as when to conduct lab activities, but the state does not require them in middle school. As Arne Duncan had alluded to in his press statement, science teachers must be fully versed with their subject (Bohrer, 2009). The classroom teacher must understand how to engage their students to make science exciting. If not experienced in teaching science, teachers may not utilize ways to make science relevant in students' lives, losing their interest (Lieberman & Hoody, 1998; Louv, 2005).

California's Education Code and the State Standards should work hand-in-hand. Embedded in the Education Code is language written to make science interesting and further clarify the goals of the science standards. California Education Code § 8700 – 8707 clearly state that educational institutions have the responsibility to teach students curriculum from an early age that is designed to strengthen their understanding of the interrelatedness of all life. The code specifies that the curriculum is supposed to be objective and balanced, examining the environment from both a scientific viewpoint and from the perspective of moral responsibility toward its care.

The State of California recognized that the science standards did not fully follow the education code. In an effort to correct the deficit, a science curriculum committee was formed to explore possible changes to the state science standards. New topics under consideration included the previously missing water and ocean studies (California Department of Education, Agenda, 2008; CDE Curriculum Goals of 2009). Other environmental concepts under consideration included:

- environmental sustainability
- fish and wildlife resources
- oceans
- toxins and hazardous waste
- pollution prevention
- resource conservation and recycling

Once due to be revised and adopted by 2012, progress was stalled in July, 2009, presumably because of state budget woes (California Department of Education, 2009). As of the date of this paper, there is no indication of exactly when the committee will be able to make any comprehensive changes to the state science standards.

While individual states maintain or slowly update their science standards, influential private organizations have helped create national standards. The American Association for the Advancement of Sciences is a national non-profit organization dedicated to science education from kindergarten through high school. Upon close examination, their suggested national standards highlight holes in California's science standards. For example, one national standard for middle school students is that humans are dependent upon two distinct food webs. One web begins with terrestrial plants; the other and most important begins with microscopic ocean plants called phytoplankton (American Association for the Advancement of Sciences, 2009). The distinction between the two is not part of California middle school standards. Two state standards, presented in the sixth grade, mention food webs and corresponding energy transfers. Standard 6.5a states, "Students know energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis and then from organism to organism through food webs" (California Department of Education, 1998, p. 20). Standard 6.5b states, "Students know matter is transferred over time from one organism to others in the food web and between organisms and the physical environment" (California Department of Education, 1998, p. 21). NASA scientists report that the entire marine food web, upon which humans are fully dependent, is nourished through the photosynthesis of phytoplankton (National Aeronautics and Space Administration, 2009). The California standards missed this important point.

With over 1,200 miles of coastline in California (California Secretary of State, 2009), the phytoplankton food web is an important concept students need to learn and need time to absorb (Reif, 1985). But just asking students to learn concepts or memorize facts will not necessarily translate into meaningful understanding if they do not see the information as having value to their own lives (Cakir, 2008). Connecting concepts to empirical classroom experiences help students appreciate how the concepts apply to their own backyards. With a firm foundation, they will have the tools for their own investigations and begin using critical thinking skills earlier, as Education Secretary Arne Duncan suggested (Bohrer, 2009).

In California, one of the pushes toward education improvement is a direct result from the Federal No Child Left Behind Act. Although well-intended, the Act is flawed because of the way success is measured. Each year in California, statewide testing occurs to determine how well students are learning the Standards. To improve test scores, teachers are urged to “make sure at each grade level your students are taught the standards they are expected to learn” (Bushman et al., 2003, p. 29). Kay (2009) feels that students do not make enough connections between real-world situations and their classroom educations. They have not had a chance to apply what they have learned in their science classes to the world around them or enough time to form a proper foundation (Kay, 2009). Kinkead (2005) writes that teachers find it difficult to teach without directing instruction toward standardized tests, and that they are losing the passion necessary for successful teaching (Kinkead, 2005). It appears that both students and teachers are negatively impacted by No Child Left Behind.

Teachers are concerned about this trend toward superficial education, but high stakes are involved. Annual state test results are scrutinized. Schools performing poorly are subject to complete takeover by the state, with the possibility of loss of funding, replacement of all school personnel, and trustee appointment to run the school (Crane et al., 2008). Fearing unfavorable test scores, teachers have little time to delve deeper into topics or supplement student education with interesting activities that would invite curiosity. Students are not given a chance to probe topics of current interest that would build and cement science skills and concepts. Yet California Education Code § 8702 directs educational institutions to encourage students to become active participants in their local communities (California Education Code, 2010). Many reliable reports have been written regarding the benefits of learning about the natural environment, and how it has awakened student interest (Bogo, 2005; Byrd et al., 2007; Lieberman & Hoody, 1998; Moore, 2008; Ryan et al., 2001). When teachers are forced to be more concerned about raising test scores than sparking curiosity, the opportunity to broaden relations with students' local communities, both environmentally and socially, is lost. The No Child Left Behind legislation leaves teachers with unfortunate ultimatums (Crane et al., 2008; Kinkead, 2005).

Another factor distancing schools from their communities stems from the very text books teachers depend upon. Text books are expensive to produce, sometimes requiring the efforts of hundreds of people. To minimize publishers' costs, books used in California school districts are often written to appeal broadly to Texas residents. The pages are filled with basic information and then mass-marketed (Bandlow, 2001). After minimal changes, the books are routinely adopted in California. The brand new text books perpetuate community disconnection because they lack enough stimulating details about local conditions (Spring, 2005).

Statistical Information

Educational comparisons between American students and their peers around the world illustrate differences between educational outcomes. Two tests in particular are routinely used to monitor student progress, the The Programme for International Assessment (PISA), and the Trends in Mathematics and Science Study (TIMSS). The two tests measure student success in application of concepts. Unfortunately, from beyond the borders of the United States comes disturbing news.

PISA measures science literacy of 15-year olds, testing how well students can apply what they have learned. Approximately 57 countries participate (Brown & LaVine Brown, 2007). In a recent test, American students scored higher in science than students in just 11 other participating countries (United States Department of Education, 2008).

American students also do not compare well with their foreign peers on the TIMSS, a measure of conceptual application of math and science. Approximately 25 countries participated in the science testing in 2003. Results showed American fourth graders ranked 6th of the 25 participating nations. They lagged behind students in China, Korea, Taiwan, Singapore, and the Netherlands, who are our close economic competitors (Brown & Brown, 2007).

Comparison of high school students within the United States shows that test scores have declined in physical science and biology (United States Department of Education, 2008). Middle school, usually grades six through eight, appears to be an important turning point, setting the stage for future advancement or decline in science (Martin et al., 1996). Many factors, including social and academic, may be to blame.

For example, Brown and LaVine Brown (2007) believe that the planning and delivery of science lessons is at fault. Students need to be intrigued before they are willing to relate to the material and learn it well. If they are not given experiences designed to spark their imaginations and challenge skill building, their depth of scientific understanding becomes superficial (Bushman et al., 2003). Some report successfully teaching concepts through unusual hands-on methods, such as creating cartoons to illustrate concepts (Oluk & Ozalp, 2007). Although the teaching methods may be varied, if students are not given time to examine and absorb concepts, they lose meaning. Student will be unable to apply their knowledge to real-life situations later in their lives, limiting the value of their educations (Bandlow, 2001). Other nations seem to have grasped this revelation and have incorporated it into their educational expectations.

Although statistical evidence is scattered and direct comparisons are difficult to make, some reliable comparisons can be made among nations (Munson, 2009). New Zealand, for example, is one country that outshines the United States in science comprehension tests. During grades seven and eight, students in New Zealand are expected to be able to describe how environmental factors influence natural selection, and how species differentiation arises slowly over time due to long-term changing environmental conditions (Munson & Bornfreund, 2010). The integration of these foundational concepts is spread across at least two years of science studies in New

Zealand. In California, the broad concepts are condensed into a few quick units of study during the seventh grade.

At least nine other industrialized countries take a different approach, helping students develop higher-order thinking skills through what they feel is a more complete, comprehensive education. In-depth studies and projects are part of the daily curriculum in New Zealand. Superficiality does not seem to be a problem, as is suspect with the American school system. The United States is the single industrialized nation that still clings to the belief that simple mastery of basic skills in grades K-12 is a sufficient education.

Katherine Gabbard is a California public school administrator with 34 years' experience in education. She disagrees with the goal of basic mastery of skills, believing that it is insufficient and narrow in scope. She believes that students need opportunities to broaden their knowledge base. Hands-on methods, whether in science or other subjects, allow students to experience knowledge in ways that support core academics. Her experience has shown that knowledge can be further enhanced through integration of academic subjects (K. Gabbard, personal communication, April 2, 2010).

Another factor which may help explain the decline in science test scores was highlighted in a study done by in 2007. The authors wanted to see how students perceived the level of difficulty of certain academic subjects. They found that in grades six through eight, students considered life science topics more difficult than math, history, and languages. Students felt they need to work harder to understand science (Bahar & Polat, 2007). Perhaps the lack of opportunities for empirical studies results in the perception that science is so difficult. Dozens of reports read during the literature review for this paper specified the benefits of lab activities, including easing the stress of learning.

Many authors report that students become more engaged in learning life science when they can apply their knowledge. Being involved with their local communities makes a positive impression on students (Bogo, 2005; Byrd et al., 2007; Moore, 2008; Parr, 2007; Powers, 2004). The Environmental Protection Agency reports that when students focus on the environment, they become intrinsically motivated to improve the quality of their own natural surroundings (Environmental Protection Agency Basic Information, 2009). Many investigators have found that students are concerned about the environment and are motivated to do what they feel is their part (Byrd et al., 2007). Participation gives them the chance to practice applying their knowledge in meaningful ways, deepening their understanding of the scientific principles they learn in class. It also follows California Education Code § 8705, which instructs schools to help students develop a positive attitude regarding their responsibility toward the environment. Again, as with lab activities, California loses the opportunity to engage students by not requiring that they learn about their local environments.

Good stewardship practices are not only felt intrinsically; they can also be measured quantitatively. Classroom teachers report fewer behavior problems at school, enhancing classroom learning in general. Seventy percent of educators who chose hands-on activities based on relevant environmental issues reported noticeable improvements.

Specifically, they noticed that students had an improved sense of self-esteem and were more patient and civil toward each other. Adults seem to notice the difference, too. Eighty-five percent of adults polled believed that education involving the environment helps build character and a respectful attitude (NEEF, 2008), principles that can be difficult to solidify in a public school classroom.

Other studies suggest a positive correlation between the integration of applied science in the environment and improved test scores (Bogo, 2005; Wei, 2009). Perhaps the most revealing findings are from the results of a 1998 educational roundtable involving 40 schools. Incorporating environmentally-based science lessons produced a 100% increase in science comprehension and over 90% improvement in all other subject areas. There was a 73% increase in grade point average, and a 77% increase in standardized testing results. Possibly the greatest gain toward science comprehension was a 96% improvement in critical thinking skills (Lieberman & Hoody, 1998).

Parr (2007) agrees that when students engage cooperatively in environmental studies, broad, overall learning is facilitated and can be carried over into other subject areas. School field trips such as the one described at the beginning of this paper reinforce classroom learning and allow opportunities for pride in accomplishments. This pride gets carried into local neighborhoods and builds positive community relationships among students, adults, and the local government (Powers, 2004; Ryan, 2001). Caring for the environment is also an important step toward moral responsibility and maturity, projecting a positive moral compass. As Former President Teddy Roosevelt said, “To educate a person in mind and not in morals is to educate a menace to society" (Berkowitz, 2010, ¶ 5).

The same concerns are on the minds of top research scientists. Dr. Pamela Yochem, D.V.M., Ph. D., is the Executive Vice President of Hubbs-Sea World Research Institute in San Diego, California. Hubbs is a renowned research center located adjacent to Sea World in San Diego. Dr. Yochem also serves as a senior marine mammal veterinarian and specialist for Sea World. Traveling extensively around the world in her professional capacity, she has been to the Antarctic several times along with her husband, Dr. Brent Stewart, conducting research involving diving depths of Weddell Seals and other unique projects. She holds positions on the boards of several grant funding agencies and strongly supports the efforts of new researchers in the field of marine sciences.

During an interview in September, 2009, Dr. Yochem confirmed much of the information gathered during the literature searches. She said that new research assistants come to the job without simple practical experience that would enable them to problem solve while conducting research in the field. Although they have a bachelor's degree in marine biology at the minimum and most often are pursuing advanced degrees, she felt that a lot of the assistants seem anxious and need much direction. For example, they do not seem to be able to problem solve when equipment malfunctions, and simply wait for assistance. She is concerned that too many people who enter the field have not spent time developing independent thinking skills.

Lack of other skills concerns her, too. When researchers investigate a problem, sometimes the results do not always match expectations. Dr. Yochem has noticed that new scientists often believe that research results are not reliable if they do not confirm the initial hypothesis. If results are unexpected, they are unsure about how to proceed with the data. They unknowingly begin with bias. Their ability to evaluate information at a basic level still needs to practiced and extended. “They need adequate learning experiences to be able to develop their research in another direction,” she stated. Perhaps earlier in their educations, their teachers lacked the time to allow students to apply their knowledge so they would be better prepared.

A deficit of real world experience also seems to be part of the problem, one that may begin during youth. “Getting outside is huge. There's really no substitute,” explained Dr. Yochem. “That's where you get the spark of curiosity, seeing connections, how things work.” Although they may generally lack empirical experience, beginning research assistants do have impressive computer skills. They are well aware of the computer's role in data analysis; yet the most important step, gathering data, can be problematic.

Social and communication skills are also necessary in the field of science. In her travels as a marine specialist, Dr. Yochem has found that different countries have different perspectives and expectations from their scientists. For example, when she and her team of Americans worked with a Russian group several years ago, the Americans left with a feeling of disappointment. While it was a learning experience in communication, the Russians fell behind their American counterparts in depth of conceptual understanding and scientific skills in general. She advises that because of these kinds of differences, students should work as part of a team to develop the communication skills needed for good relations between countries.

Her advice for middle school science students: “Look at new ideas. Build new skills. Get outside. Tinker around until you understand things. And don't be afraid to jump into action to help protect nature, especially the oceans” (P. Yochem, personal communication, September 23, 2009). See Appendix A.

Ethical Standards

This study adhered to ethical standards as proposed by the American Psychological Association (2009). It was read and approved by my research advisor, Dr. Madalienne Peters.

Summary of Major Themes

Constructivist theories are built around the idea that interaction with the environment builds knowledge. Experiences, whether they are empirical or academic, create scaffolds of information that can be rearranged to accommodate new information. Students need both time and experience to build a sort of reference library, so that when faced with a novel situation, previous knowledge can be retrieved and applied. Works by Dewey, Vygotsky, Gardner, and others support conceptual acquisition of knowledge through scaffold building and the blending of skills.

The California State Standards for Science do not include what is sorely needed to develop a solid science foundation: the requirement to develop science skills through hands-on experiential opportunities in the middle school classroom. Practice solidifies learning. Time is also a critical factor. Without sufficient time to absorb concepts, the learning becomes superficial and lacks meaning. Students cannot begin training for future careers in science until high school, losing precious time.

Today, ecological concerns are grave and well-trained scientists are needed more than ever. Governments around the globe discuss regulations and divide responsibility for cleaning up damaged ecosystems. These endeavors have continued in earnest since 1997 but the intended results have not been realized. The most widely recognized global problems, such as the possibility of permanent climate change caused by buildup of greenhouse gases, are at the forefront as the most immediate environmental concerns. Much cooperative work is needed among governments but work will also need to be done by agencies organized through private organizations and individuals. A well-rounded skill set is crucial. People need to be able to cooperate and communicate effectively across different cultures, and most importantly, they need a firm foundation with clear understanding of scientific procedures.

Comparison of international test data suggests that American students are falling behind students in other countries in the area of science, and scores are falling within American high schools. Perhaps a lack of investigative science activities in the middle school classroom is a contributing factor that later translates into disinterest. Students show academic improvement with applied empirical learning. Some reports show test scores rise considerably across the curricula with integrated project-based learning. Students can achieve deep understanding of science concepts through hands-on activities if given adequate time for practical application of new skills. Chances to practice science should start at least by middle school, since this may be where science interest begins to evaporate.

Science principles taught through engaging activities have many benefits, both academic and non-academic. Academically, science lessons apply to foundational education by building critical thinking, problem solving, and analysis skills. Non-academically, they help develop good interpersonal skills and community relations.

Teachers can complement their lesson plans with project based learning, but they may lack the necessary experience or tools. Text books are the most readily available tool, yet they are intended for a wide audience. They tend to limit information about students' local environment, possibly encouraging isolation from communities. Detriments include loss of civic pride and reducing chances for students to put their knowledge into practice.

Relevant subject matter engages students. Inviting involvement in their neighborhoods help foster pride through positive community relationships, and joining local conservation efforts not only makes their knowledge meaningful but also makes students aware of their surroundings (Schmid, 2008). Lab activities allow students to experience science personally, and it becomes more relevant to their lives. However, although environmental education and empirical instruction are ideally suited as a concentration of study, teachers can feel pressured to fit their curriculum to match the state tests, and may not have adequate time to let students engage in practicing scientific inquiry.

Proposed changes to the state standards that would address the problem of lack of hands-on environmental studies have been stalled indefinitely, possibly due to the poor economic situation. California educators must take the initiative and begin now to educate future scientists instead of waiting for direction from the Board of Education.

How Present Study Will Extend the Literature

California has no focus on its natural environment in the science standards for middle school public education. This study extends the literature by examining the shortfalls created by this, and the benefits of future inclusion of hands-on science studies based on environmental topics relevant to students. It draws on previous research from other investigators and personal experience with middle school students in a Marin County public school. Interviews with experienced classroom teachers, a student survey, and personal observation indicate that middle school students are concerned about environmental issues but lack the educational tools to analyze problems effectively. Science teachers are concerned about the lack of time available to spend on scientific methodology because of pressure created by standardized testing. Scientists and conservationists working in the field concur that young people have not had enough experience in the field to help them problem solve environmental issues.

Chapter 3 Method

Data collection for this research included direct personal observation, interviews with students and colleagues, and a written student survey. Personal observation stemmed from a combination of twelve years' experience as a sixth grade general education teacher/middle school science specialist and ten years' experience mentoring an on-campus environmental club.

In the middle school where this study took place, all curricula are closely aligned with the state standards. Students rotate through classes, spending approximately 45 minutes daily in each class. They are expected to arrive in class with all needed materials. Homework is normally assigned each evening, primarily in math or science, but also in other core subjects.

On any given day in science classes, the agenda may include exchanging papers and correcting homework, taking notes, participating in discussions, working on assignments, watching videos, or performing lab experiments. Variety is carefully added to each lesson, and there is a mixture of lesson plans during each week. All modalities of learning are addressed to encourage development of skills that translate across the curricula. All students are expected to participate in lab activities, encouraging social exchange and physical movement around the room. New lab skills are built upon the previously practiced ones as the year progresses, giving time to refresh old skills and learn new ones.

In addition to a literature search, information was gathered in part through a structured interview with Dr. Pamela Yochem. Opinions were obtained through casual conversations with experienced middle school teachers and through professional training and networking situations. Attending local, state, and national conferences gave opportunities for discussion and additional insight not only into how other teachers impart science skills but also into how students learn science and what they perceive as important and worthy of retention.

Site and Sample

The student survey took place on a public middle school campus in the greater San Francisco Bay area, serving grades six through eight. The most recent statistics available on line for the school site were for 2008/2009. As far as could be determined, these statistics were very similar to the 2009/2010 school year in which the survey took place.

Statistics showed that approximately 656 students attend the school where the survey took place. Of these, approximately 235 were in the seventh grade. The population consisted of 12% Hispanic, 2% African-American, and 76% Caucasian. Of these, slightly over 2% were English-language learners. Ten percent were from socioeconomically disadvantaged backgrounds. The school scored among the upper ten percent of comparable schools on the state standardized tests in mathematics and language (Novato Unified School District, 2010).

The student survey sample population consisted of 76 seventh-grade students with similar characteristics as the school population in general. The student participants were enrolled in my life science classes. The course is a complete and rigorous study of life science standards as set by the state of California. Approximately twenty-five percent of the school year's total class time is devoted to hands-on investigative course work. Some of the respondents had been previously identified as having learning, emotional, or physical differences. Regardless, all students had full access to all classroom activities. All were taking the course for the first time. For most, this was their first opportunity to be fully engaged in lab experiments and apply the special skill set enhanced by empirical activities.

Access and Permissions

The principal was notified well in advance of the study involving students and had no objections because it fell within the scope of the duties of the professional teacher conducting the survey. No parental approval was deemed necessary. The survey was completely voluntary and no individual students were identified. All records were kept in a locked file with access limited only to the investigator, and were destroyed six months after the survey. No classroom instruction was interrupted to conduct the survey. The students were told they would know the results of the survey when analysis was complete.

Data gathering strategies

Student opinion data was gathered through a voluntary survey. The survey was primarily designed to be used for this paper, but it was also intended to be a reflective teaching tool and gathered information regarding the campus environmental club. Obvious elements that commonly defeat validity were minimized. For example, the survey took place in the students' science classroom, which was very familiar to them. Maturation of participants was not an issue since the one-time survey was completed in ten minutes or less. To minimize bias as a threat to the survey's validity, students were assured that participation was completely voluntary and the choice to participate or not participate would have no influence on their science grade.

Sixteen questions were written to gather background information in three main areas: teaching method preferences, knowledge about science and the environment, and their after school activities. Fourteen questions were multiple-choice, and two allowed students to give open-ended responses. See Appendix B.

Age-appropriate middle school vernacular was used, and questions referred to common practice in the students' science classroom. The procedure was compared to their recent prior experience when they participated in the State of California’s Healthy Kids Survey. Although encouraged to complete it, they could stop at any point and skip questions they didn't want to answer. To minimize fatigue, time spent on the survey was limited to ten minutes, although all finished within this time frame. The students had practiced minimizing bias during science investigations all year, and were reminded that this was an opportunity to practice scientific skills. They were eager to participate, with less than ten percent overall declining. Almost all non-participants chose to read a library book, which was required homework for another class.

Chapter 4 Analysis

Surveys were tallied according to individual response. A simple ratio was calculated, and four responses critical to this paper were organized into bar graphs. In a few cases, a student chose not to respond to a question, and therefore no information was tallied for that question. This difference did not affect the percentages calculated.

Two questions were designed to determine if students preferred lab activities over the other common classroom teaching methods. The first question allowed students to choose from four methods: working alone, working on experiments in groups, listening to the teacher, or doing worksheets/workbook pages. Seventy-four students responded, with 70.2% preferring to work as groups on lab activities. See Appendix C, Figure 1. When asked if students would enjoy science class as much if the lab activities were removed from the curricula, 93.4% of the 76 students answering responded negatively: science would not be as enjoyable. See Appendix C, Figure 2.

A question was designed to see if the emotional benefits of feeling successful about science class affected performance in other academic areas. Students confirmed that they did feel more motivated in other classes when they did well in science. Data from 73 respondents showed that 72.6% tried harder in other classes once they were successful in science. See Appendix C, Figure 3. Another question addressed a possible increase in self-esteem with academic success. Of the 73 students responding, 90.6%

confirmed that getting a good grade in science improved their self-esteem for the rest of the day.

One question was written to gain insight into student perceptions about gender abilities in conducting lab activities. The survey showed that of the 75 students responding, 13.3% felt that boys performed better, 24.0% reported that girls performed better, and 62.7% believed that performance was equal. See Appendix C, Figure 4.

Chapter 5 Discussion

The results of the survey supported the findings of the literature review for this paper. They were further confirmed through personal experience, communication with students and colleagues, and the interview with Dr. Yochem. The results of one question that will be discussed at the end of this section regarded perceived gender differences. This topic was not encountered during the literature search and deserves further attention.

When asked how students preferred to learn science, they overwhelmingly responded positively to lab activities. Given a choice of regularly used classroom teaching strategies, students chose hands-on lab activities as their favorite method of learning. The first bar graph indicates that all four classes surveyed felt they learned science best through group activities involving labs. According to Dr. Yochem and many others cited in this study, this is exactly what students need: a chance to learn by doing.

From familiarity as a science educator and environmental stewardship club mentor, I have no doubt that student interest is piqued when they become engaged. Learning is enhanced when it becomes more play than work. In the science classroom, this means involvement through regular opportunities for hands-on, empirical learning.

In opposition, ineffective direct teaching methods, sometimes called seatwork, are still being used in many California science classrooms. A typical science classroom scene could be students sitting at their desks, reading through textbooks, working on workbooks or worksheets, and occasionally indulging in an informative video. The teacher delivers the material and the students are expected to learn it.

To learn, students work at separating facts into discrete units and commit them to memory. Pieces of information are mentally stored away in a discrete box called science, the lid of which may never again be lifted once the test is over. The dull grey information remains isolated from what the student feels is more stimulating material, something to which he or she can personally relate through some sort of experience.

The teacher, is essence, uses a shotgun approach. But this does not serve to reinforce understanding since little accommodation is made for students' individual learning styles. Teaching, and learning, is reduced to a common denominator.

When students take an active, involved role in their learning process, they develop ownership of the material (Parr, 2007; Powers, 2004). In the survey, student opinion showed that direct teaching is not their preferred learning method. It is not nearly as effective as allowing students opportunities to explore through the actual experimental process. Personal experience shows that students retain information better when they use empirical learning. Concepts become more meaningful. Pieces of knowledge begin to join together and interrelate when students are given a large measure of self-direction to solve a problem. This is foundational learning at its best.

Results from the second question in the survey support the first question. Responses showed that students would not enjoy science class as much if the lab activities were taken out of the curriculum. The students surveyed were accustomed to several commonly used classroom teaching methods, some of which were, by necessity, direct teaching methods. When given a choice of standard teaching methods (seatwork) over hands-on lab activities, they confirmed that lab activities were widely preferred over the other teaching methods.

As a teacher, at the beginning of the school year I receive several written requests from parents wishing to excuse their students from certain lab activities. Vague reasoning, if any, is usually offered. Yet personal observation has consistently shown that reluctant students look forward to lab activities just a few experiments later and often excel in their written lab work, sometimes to their parents' chagrin. Hesitation may result from an initial lack of confidence since students have not yet had adequate opportunities to familiarize themselves with simple lab procedures. Naturally, parents want their child’s educational experience to be positive. The purpose of this report is to show educational deficits created because California does not require lab activities before high school. The activities get students' attention as a positive learning experience and should begin much earlier in their educations. If those reluctant students had not been expected to contribute to the lab activities, they clearly would have lost an important portion of their educations.

In the survey, students confirmed that they prefer to learn by doing. Limiting their opportunities denies them a chance to experience in-depth learning situations. Some researchers believe that students begin to lose interest in science during middle school and do not fully recover (Martin et al., 1996), yet the survey and personal experience indicates this is not the case when empirical investigation is used in middle school.

Personal classroom observation shows that if a student has difficulties understanding scientific academic language, such as with English language learners, a deeper understanding of concepts can be obtained when students reinforce their new vocabulary during labs. The conversational exchange of academic terms helps reinforce language acquisition in general, even for non-English learners. Observation also shows that students who may be struggling to learn scientific academic language in particular develop a deeper understanding of concepts when they use the language to apply knowledge during labs.

Science labs intrigue students and create enthusiasm, a positive learning situation that contradicts superficial learning (Bushman et al., 2003). Brown and LaVine Brown (2007) express that making curricula interesting is imperative for sharpening problem solving skills, an important facet of science that transcends into other subject matters. Labs give students opportunities to develop and practice critical thinking skills, which is the key to learning deeply (Lieberman & Hoody, 1998).

The third survey question, regarding student self esteem, did not deliver unexpected results, since it is logical that getting a good grade in science could boost a student's morale. The level of their sensitivity, though, was a bit surprising, since over 90% indicated a positive effect. After the survey, some students remarked that the positive effects of a good grade lingered throughout day. Observations show a good grade renews interest, and students carry the feeling of success forward by arriving in class eager and better focused. When they leave school for the day, they still feel optimistic about their abilities.

For many years, I have talked to my students about their impressions of the difficulty level of their classes. Students consistently name math as the most challenging and important subject. The school culture promotes math aptitude as a way to prepare students for college later in their lives. Of the other subjects, science was usually named next, followed by English language skills (personal communication, 1998 - present). This led me to wonder how students felt about getting a good grade in science compared to getting a good grade in their other subjects. Bahar and Polat (2007) reported that students do perceive science as one of the most difficult academic subjects. If the study of science is considered difficult, making it meaningful to students can help ease the strain. Because they have a natural curiosity that can be all too easily flattened, relevance to their lives takes on a major role when learning academic material. The direct instruction method, with minds passively engaged, does not work if students are to learn science deeply. They need to be out of their seats, at a laboratory counter or outside, discovering their world and developing skills that extend outside the classroom.

Question four regarded gender differences and lab ability. The responses were unexpected. Students reported that they felt there was little difference between boys’ and girls’ abilities to conduct lab experiments. Approximately equal numbers of boys and girls participated in the survey, with both genders perceived to perform equally well during lab activities.

The results were contrary to the beliefs of colleagues, but not necessarily contrary to personal observation. During several casual conversations with colleagues, it was revealed that some experienced teachers still follow traditional lines of thinking regarding gender and certain academic skills. For example, some teachers believe that middle school girls are better readers by far and have stronger language skills than middle school boys. They also believe that boys will be consistently better in science. This seems to be confirmed by Zittleman and Sadker (2002), who write that males outdistance females in science comprehension. However, results from the survey indicate that students feel there is little difference; gender differences blur with hands-on science activities. This could support an important consideration in education, one where science becomes an equal opportunity subject matter when using project-based learning.

There is another vitally important advantage to consider when students work together. Future scientists will need a range of skills - social, verbal, and written - so they can communicate with their colleagues world wide. Working cooperatively in groups promotes social interaction, which will become a key issue for future global communication (Kay, 2009). It facilitates learning by developing many multiple intelligences simultaneously (Gardner, 1998; Smith, 2008), all of which will be necessary to solve environmental problems. It is clear that students learn best through hands-on group inquiry investigation. With the give-and-take of working in a social situation, foundational skills are formulated in many areas that will continue to grow as students progress in their educations.

An interesting sidelight to the survey was that afterwards, many students said thanks for giving them to chance to offer their opinions. They felt respected. Several articulated how it was an example of the scientific method. As the results were tallied, it appeared that the students answered the questions honestly and to the best of their ability, showing that they felt their opinions were of value. They seemed to be objective and open-minded, and verbal discussions with them afterwards indicated that the questions were well understood.

Because the survey confirmed knowledge from personal experience and what other researchers have found, it seemed valid. The unexpected results regarding gender perception also added to the validity.

Open-ended comment was invited at the end of the survey. Some of the students' written comments include:

> Science is my favorite class. I like it even better than my elective.
>
> Sometimes I'd like more time to dissect something.
>
> What else can we dissect?
>
> Science is great! Nothing to add.
>
> I love science and it always makes me feel excellent when I get a good grade or do well on a lab or test.
>
> Science has been pretty fun this year.
>
> I would like to do more labs… (multiple similar responses)

Summary of Major Findings

Twelve years of daily classroom observations and conversations with students *in situ* has afforded a wealth of understanding about how adolescents view their world, and ways they desire to interact with it. The focus of this paper concerns the lack of direction in California's public middle schools that would develop a deep understanding of science through empirical investigation. Deep learning is not fostered in science classes unless students have opportunities to develop foundational science skills. Reinforcement of the skills through practice can only help, not hinder, students, preparing them for the future.

Constructivists such as Dewey, Vygotsky, and Piaget strived to determine how people learn. All believed that knowledge is acquired slowly, over time, and requires experience as reinforcement. Dewey believed that learning is most concrete when students have social and physical aspects along with interactions with their environment. Vygotsky emphasized that experiences are critical in foundational learning, particularly in childhood. Learning occurs during exposure to novel situations, where new information is added to an existing framework of understanding. A greater detailed map of understanding results with continued exposure to new situations. Piaget believed that cognitive development begins very early in childhood. A child must be allowed to interact with the environment in novel situations if learning is occur.

Gardner's theory of multiple intelligences describes the complexity behind the idea of intelligence. An individual's intelligence cannot be measured easily because it exists in eight distinct areas, each separate but dependent upon the others. To describe a person's level of intelligence is therefore complex.

Conceptual understanding of science requires laying foundations, built slowly and with great care. To understand how concepts relate to each other, students need practical application. If they do not have opportunities to put their knowledge into action, learning becomes superficial, a collection of random facts stored without connection to each other. The information will not form a cohesive map to which the student can refer in the future.

Many scientists and lay people agree that the Earth is in peril because of the influence of humans. Scientists will be needed from around the world to solve the problems of a burgeoning population. Individuals will need to be multi-skilled; future jobs in science and supporting fields have not yet been identified. This creates an assortment of possibilities that need to be considered. If students are to be prepared for success in college science classes and beyond, experiential opportunities in science must be offered at all levels of education, at least beginning with middle school. Unfortunately, empirical investigations are not required in California's public middle schools.

California's Board of Education may be missing an important point. When compared to their peers in other nations, American students lack the conceptual comprehension and ability to apply scientific theory that is demonstrated by their foreign peers. Some researchers believe that during middle school, interest in science begins to wane and it is not recovered when students progress in their educations. It appears that superficial learning has taken the place of more deep, meaningful understanding.

The benefits of empirical learning are numerous, particularly when applied to environmental studies to which students can relate. Improved test scores across all subject matters have been reported when science is integrated throughout the curriculum. Teachers specify that communication skills improve. They have seen an overall improvement in social skills in the classroom because students cooperate, and fewer behavior problems occur in the classroom. With an improved social climate, students focus better in general.

Including project-based inquiry piques interest and facilitates learning, creating situations where meaningful learning can occur. Personal observation has shown that middle school students enjoy experiencing science first-hand. They become engaged when learning about their local environments. Sitting at a classroom desk day after day becomes monotonous. Learning is not facilitated through boredom, but is heightened, extended, and retained through activity. If a student is actively engaged and uses different modalities of learning, his or her science education becomes deeply understood. Hands-on activities can act as adhesive that holds together a mosaic of skills, helping to expand knowledge in general.

A survey done in a San Francisco Bay Area public middle school showed that students overwhelmingly prefer to learn science through lab activities. Being able to work on labs generates a feeling of excitement and makes students felt more successful. Personal classroom observation shows that students who may be struggling to learn scientific academic language develop a deep understanding of concepts when they apply their knowledge during labs.

Students report that they would not enjoy science class as much if the lab activities were taken out of the curriculum. It has been seen through personal observation that test scores increase and concepts are retained longer when students are able to participate in empirical investigations. Written work is also more comprehensive when students have had an opportunity to reinforce concepts through hands-on activities.

Science is perceived among students to be a difficult subject. Incorporating experiential investigations eases the sense of difficulty and helps students feel successful. Students say that getting a good grade in science motivates them in their other classes. Not only does the feeling of success extend into other coursework; it is also carried out into the community when the student leaves school for the day.

Traditional thought follows the lines that boys are better in certain academic areas than girls, including science. However, personal experience and the survey shows that students feel boys and girls perform lab activities equally well. This was an unexpected aspect of the survey.

California does not strictly require that science lab activities be a part of the middle school curriculum. When evidence points to the overwhelming success of adding lab investigations, it is time for the State Board of Education to reconsider its science standards and include lab activities to make science meaningful to its student population.

Today's students will become tomorrow's scientists only if they are given adequate time to practice and reinforce scientific concepts and their theoretical application.

Limitations/Gaps in the Literature

The results of this survey were not intended to be projected to other groups beyond the seventh grade life science classes at the study site, but a description of the school population was provided for reference as a comparative tool for other interested researchers. It is reasonable to assume that the results would be similar for California middle school students in general.

During the literature search for this report, it was discovered that information related to this topic is highly fragmented. While many individual papers were available as sources, there were no comprehensive collections of studies correlating directly to the topic of this paper with the same study group. Many federal and state government agencies maintain websites where information can be obtained, but sorting through the voluminous information was often clumsy and tedious.

Studies related directly to the California public middle school student population and the benefits of science labs in those classrooms were somewhat limited. Much information was available related to elementary, high school, and college science studies in general. When searching for the benefits of adding science labs to middle school classrooms, most of the information found related to outdoor education.

Implications for Future Research

While this study discusses the importance of lab activities in middle school science, it also brings up several questions for future study.

Students indicated that they would not enjoy science class as much if opportunities to participate in labs were unavailable. This study did not attempt to discover the underlying reason. Some possibilities could include the loss of social interaction, not being able to use lab equipment, or simply being unable to move around the classroom as freely.

Do students who perform no lab activities still develop a deep understanding of science? To confirm or question the importance of lab activities, researchers may want to conduct a study comparing two science classes, one where lab activities are included, one where they are excluded. Naturally, many factors would need to be considered and controlled in a study of this type, since manipulating student education can be risky. Excluding lab activities could be detrimental to a student's education.

Computers are becoming indispensable in the lives of students at all levels, and are not confined to the classroom. Since computers for classroom use were not available at this study site, it was not a teaching method choice. If computers were used regularly as a teaching tool, results of the survey may have been different.

Another follow-up study might involve computer-related technology and distance learning. Students who participate in distance learning via the Internet bring the classroom into their homes, but may miss out on some important opportunities to learn science through activities. If they perform simple experiments at home, would their comprehension increase? Several at-home study programs available to the public through private educators in California include these types of labs, indicating that empirical study is considered important. Whether or not a visual measure of success using video is included is unknown. Also, while the lab could be similar to a classroom activity, it would lack the social context of a classroom. Yet, when combined with assigned written work, the student may have similar opportunities as his or her peers in a traditional classroom setting. Comparison of assessment before and after lab activities could help determine the importance of participation in lab activities for the distance learner.

Gender differences need to be explored in detail as only one survey question addressed this concept. This study reported that students felt gender does not play an important role in the ability to conduct lab experiments successfully. From this anonymous survey, it was impossible to determine whether an individual survey was completed by a boy or a girl, and therefore what their individual answers were. Although attempts were made to minimize bias and approximately equal numbers of boys and girls participated in the survey, one may question why students felt boys and girls were equally successful when conducting experiments. Did they have predetermined opinions influencing their answers that resulted from the traditional social cues previously discussed? Was the data specific to this one middle school, or could it be applied to other school sites, and other grade levels? Did class size, which was approximately 30 students per class, influence the result?

The importance of including lab activities in California middle schools cannot be downplayed. Education theorists explain that knowledge is acquired through scaffolding, which requires time and some repetition. Slight changes in understanding are made with each novel situation, and concepts are learned at a deeper level when students have opportunities that make science relevant to their lives. Many skills are developed through inquiry learning. Some are academic, such as problem solving and critical thinking. Other skills are social, such as verbal communication and cooperation. Students gain a feeling of success and learn to appreciate their communities when they learn about the environment.

Human activity has created a world where pollution and shortages have become a fact of life, and our own species is certainly not the only one to suffer. Scientists must cooperate globally to help solve problems that we are as yet unaware. The skills necessary to resolve those issues have not even been fully identified, and no doubt will evolve rapidly with each situation. If we expect to be able to solve global environmental problems, we must educate for the future by expanding opportunities today.

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Appendix A

Questions and Responses from Interview with Dr. Pamela Yochem, D.V.M., Ph. D., from September 23, 2009

1. What environmental concerns do you see as the most problematic in today's world?

    That the land-sea interface is downplayed. We're seeing Valley Fever in sea otters and dolphins. That's a land organism. The environments are linked. Sustainability of aquaculture is a concern. There's a right way and a wrong way to farm the sea.

2. For future scientists, how important are these skills?

    a. knowledge of scientific methodology: Very! They'll need to evaluate information in daily life.

    b. analysis, synthesis, problem-solving and critical thinking skills: (See write-up)

    c. field experience: (See write-up)

    d. social, interpersonal, communication skills: (See write-up)

3. California state standards for grades 6 – 8 have very little provision for ocean sciences, marine biology, or concepts about the interdependence of all life as it's linked to the world's oceans. What potential problems do you see in the future with this limited approach? The first thing that pops to mind is what people do when disasters occur, such as the wreck of an oil tanker. It creates a huge mess, on the shore, in the water. It coats

everything. There are passive people and people who jump into action. Before you can do anything useful, you need some background. You need to know where to begin. How will students know where to start if they're not taught it at an early age?

Appendix B

QUESTIONS FOR STUDENTS
Don't put your name on this paper. It will be anonymous, like the Healthy Kids Survey we took a few weeks ago.

Dear Student,
For this survey, I'd like your opinion on what we do in science class. Please think about each question before you answer it. No question has a right or wrong answer. Choose the answer you think is best, not the one you think I want you to choose.

You and Science Class

1. How do you think you learn science ideas best? (Pick one.)

_____ working alone instead of in groups
_____ listening to the teacher talk
_____ working on an experiment in groups
_____ doing worksheets or the workbook

2. Rate each part of science class with a number. Your favorite would be a "1", your least favorite would be a "4".

_____ taking notes
_____ discussing science ideas during class
_____ doing labs
_____ taking tests and quizzes

3. If all the lab experiments were taken out of science class completely, how would you feel about learning science?

_____ I'd like it better
_____ It wouldn't be as much fun

4. We've done many types of science assignments this semester. Please give a number to each one, from your favorite to your least favorite. Your favorite = 1, next favorite = 2, etc. and least favorite = 6.

_____ worksheets
_____ reading the book
_____ writing lab reports
_____ doing lab activities
_____ workbook
_____ Cell Model

5. When you get a good grade on an important science assignment, does it make you feel pretty good about yourself for the rest of the day?

_______ Yes
________ No

6. When you feel successful in science, does it help you feel successful in other classes? (For example, would you try a little harder in another class if you did well in science or really liked the science lesson that day?)

_______ Yes   ________ No

7. Do you think that learning science helps you to learn other subjects in school?

_______ Yes   ________ No

Which subject or subjects do you think it helps you the most with? _____________

8. After you've done a lab, does it make you feel like you'd like to do more of them?

_______ Yes   ________ No

9. Do you think boys or girls are better at doing lab experiments (not the write-ups)?

_______ Boys   ________ Girls   _________ They're both equally good

10. We haven't talked much yet this year about ecosystems, but give a number to each ecosystem according to how important you feel each one is. (There aren't any right or wrong answers here.)

The most important = 1, second most important = 2, etc. The least important = 5.

_____ Rainforest   ______ Wetlands

_____ Desert   ______ Oceans

_____ Lakes, rivers, and creeks

What You Like to Do After School

11. When you have free time, do you go outside and just "hang" around, maybe out in your yard or at a nearby park?

_______ Yes   ________ No

12. If you do go outside, about how many times a week do you go out?

About _______ times a week (not playing sports, etc., just being outside)

(go to next page)

13. When you go outside, what are the kinds of things you like to do? (You can include sports.)

____
____
____

Recycling at Home

14. How important do you think it is for people to recycle paper and plastics?
_______ Very important _______ Sort of important _______ A little important

15. How much do you estimate your family recycles every week?
_______ We recycle ALL of our plastics, metals, newspapers and junk mail
_______ We recycle most of our plastics, metals, newspapers and junk mail
_______ We recycle some of our plastics, metals, newspapers and junk mail

16. Please add any ideas or opinions you would like. You can write about science or about this survey if you want. You can also talk to me later about it.

____

____

____

____

Thanks for taking this survey. I'll let you know what the results are soon.

Appendix C

Figure 1. Student Learning Choices

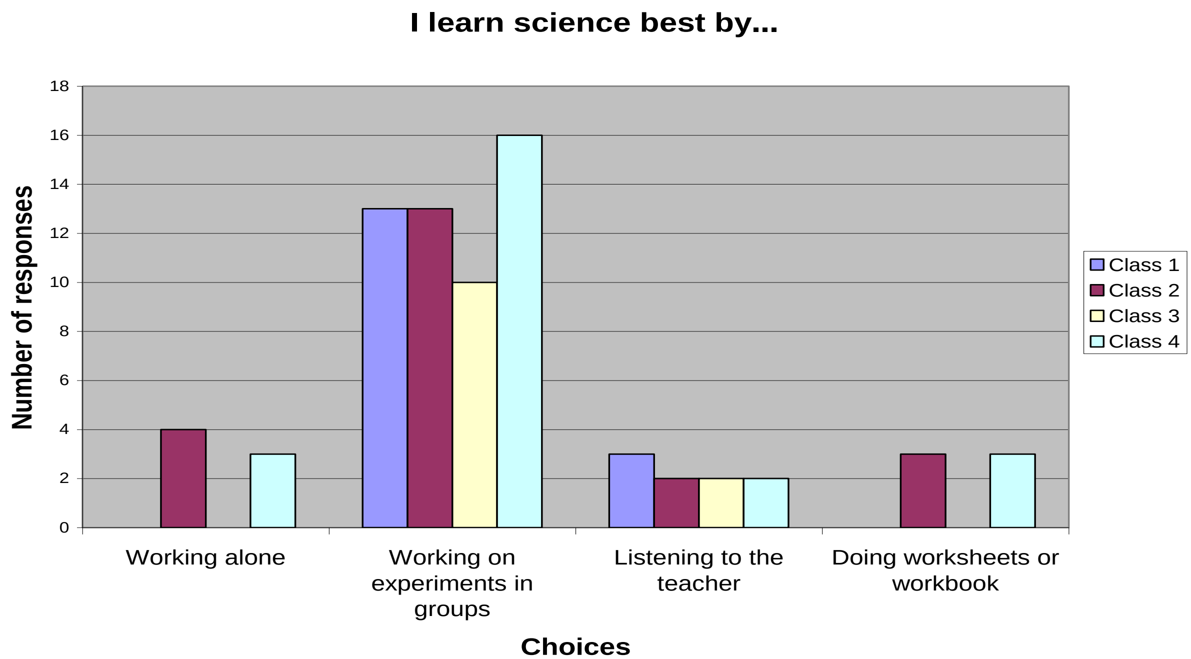
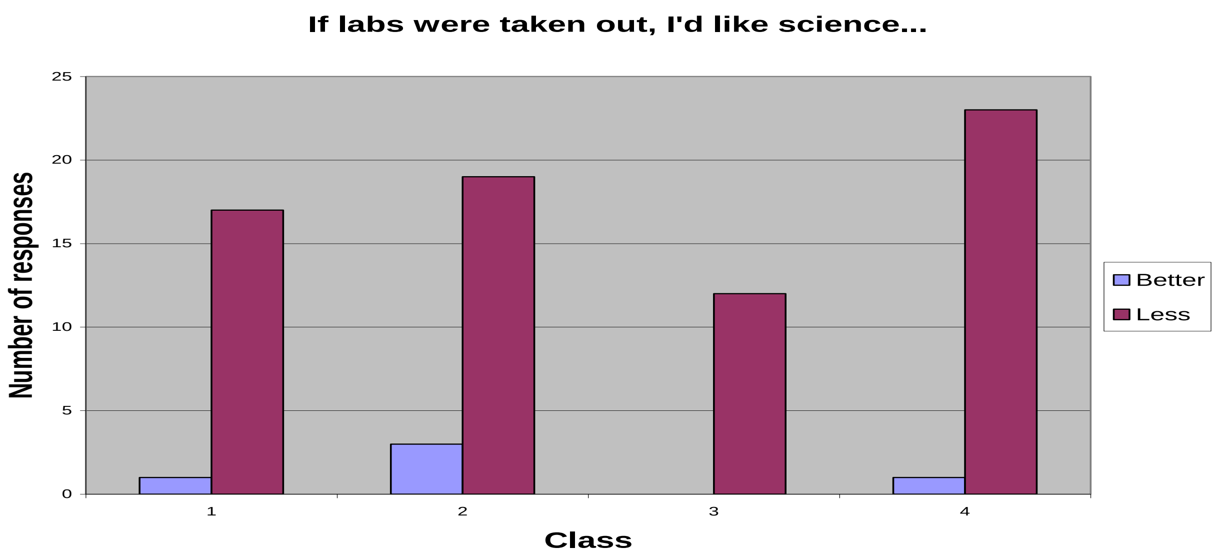


Figure 2. Preference of Lab Inclusion



Appendix C continued

Figure 3. Science Success Influences Motivation in Other Classes

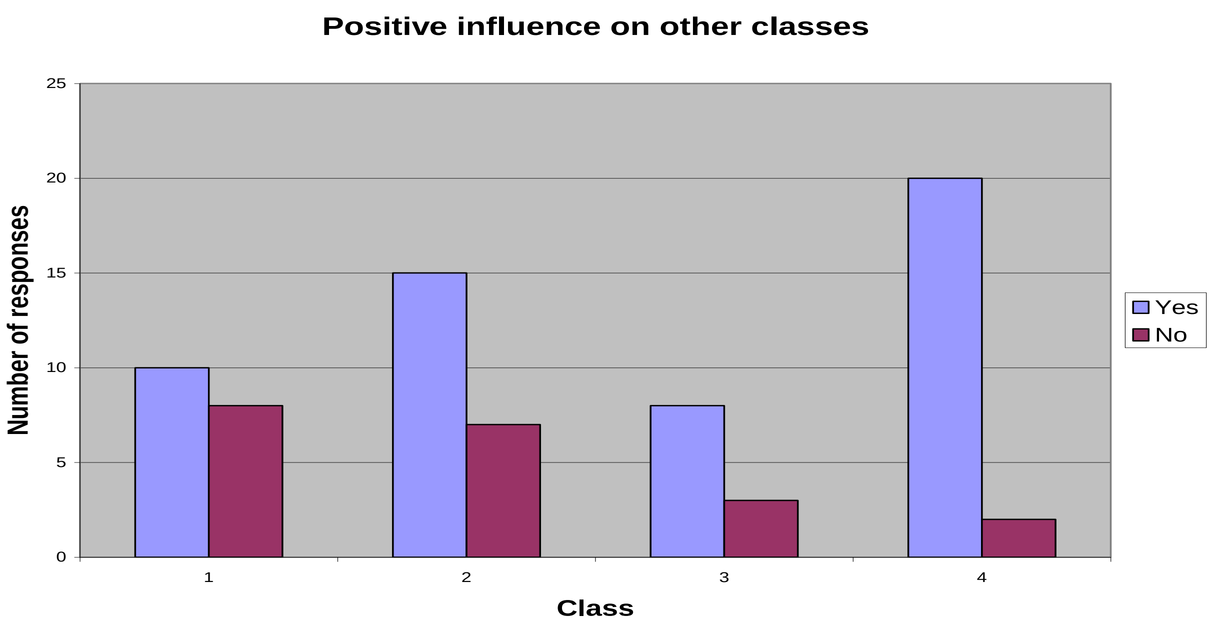


Figure 4. Gender and Lab Activities