Marine Debris Clean-ups as Meaningful Science Learning

Presented: American Geophysical Union 2010 Ocean Sciences Meeting, "*From Observation to Prediction in the 21st Century.*" Feb 22-26, 2010, Portland, OR.

by Carl M. Stepath, PhD, and Joseph Scott Bacon, B.S.

stepath@hawaii.edu, jsbacon@hawaii.edu,

www.saveourseas.org/saveourseas/stepath.html

Kauai Community College, Lihue, HI 96766

Abstract: This seven to eight week hands-on Marine Debris Clean-up Project provided an introduction of marine science ecology, watershed interrelationships, the scientific method, and environmental stewardship to 8th grade middle school students. It utilized inquiry based learning to introduce marine debris sources and impacts to the students, while demonstrating the integration of service learning programs into meaningful learning situations. The goals of the project were to promote inquiry-based learning, address DOE science learning outcomes, improve students' caring for the environment, train students to improve their future through service learning, to develop pedagogy that engages learners in living laboratories by using preparation, action and reflection phases of instruction, and to promote university, community and K-12 cooperation. It was collaboration between the University of Hawaii Marine Option program, a local NGO, and science teachers from the Chiefess Kamakahelei Middle School, Lihue, Kauai, Hawaii, USA.

Students had a chance to learn and apply the scientific method in a real world situation to improve the environment where they live. This program engaged 300 middle school students in activities designed to help them reach Hawaii Department of Education (DOE) science benchmarks, through learning natural systems, monitoring a beach, testing hypotheses, and collection and analysing data associated with a beach clean-up. This outdoor learning experience not only gave the students hands-on science experience, but also provided opportunities for students to write a final report, and give an oral presentation about what they learned.

These students applied the scientific method in a real world situation, which was shown to be meaningful by helping them to improve the local environment where they live through active stewardship participation. The project demonstrated how service-learning projects are opportunities for applied science learning, which address real problems existing in the students' community and the ocean environment. As active participants the students learn to develop real life solutions using scientific principles and concepts, and improves their academic development. The project instructors observed positive change in the students' environmental knowledge and attitudes, which will lead to the students taking individual responsibility for positive long-term actions and consequences. (Contains 1 table, and 6 figures)

Reference: Stepath, C.M. & Bacon, J.S. (2010). *Marine Debris Clean-ups as Meaningful Science Learning*, in proceedings of AGU 2010 Ocean Sciences Meeting, "From Observation to Prediction in the 21st Century." Feb 22-26, 2010, Portland, OR.

Introduction

The Marine Debris Removal Hands-on Learning Project provides middle school students with an introduction of marine science ecology, watershed interrelationships, the scientific method, and environmental stewardship. This project was designed to teach students about marine science in the classroom through the use of multiple teaching methods, and then to perform a hands-on science experiment at a local beach. After the field trip the students returned to the school, analyzed the data, and developed reports and presentations. Applying the science principles taught in the classroom helps reinforce the students' knowledge and increase their achievement of educational outcomes aimed at sustainable futures. It has been proposed that effective "education for sustainability is not just a curriculum issue; it requires the involvement of the whole school" (Department of the Environment and Heritage, Government of Australia, 2005, p.12). In this project we attempted to involve the entire school in a marine debris collection service project in order to work towards a shared vision that included a whole school approach toward sustainable goals and visions.

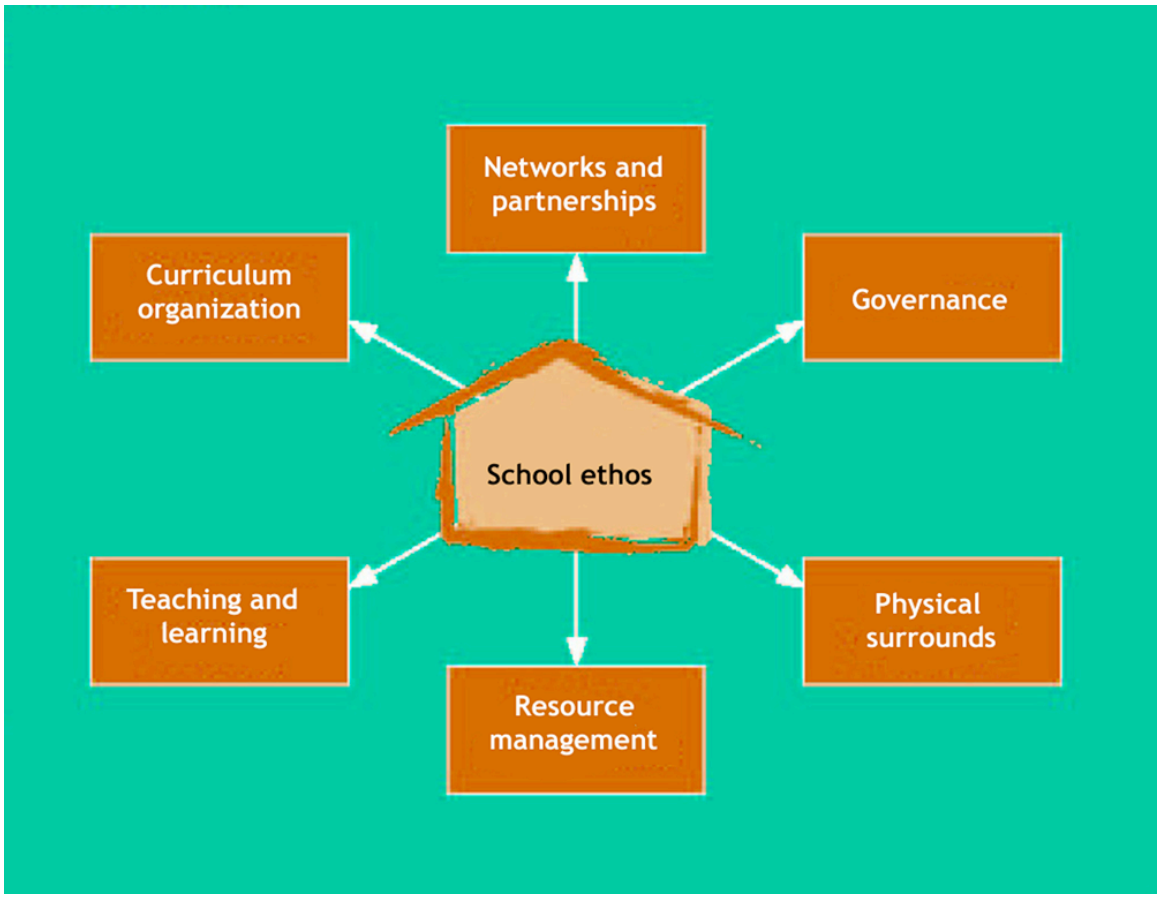

Figure 1. *Educating for a sustainable future: A National Environmental Education Statement for Australian Schools*, Department of the Environment and Heritage, Government of Australia. (2005).

Many students feel disconnected when studying science, and they sometimes think it is too difficult, not important, or even boring. By using a variety of teaching situations, we hoped to make oceanography and marine science easier to understand, more interesting and pertinent to the students' daily lives. We combined their schoolwork with a field trip, and thus let the students apply knowledge learned in classroom situations to an outdoor beach excursion. This showed that science could be fun, interesting, and relevant to their everyday island

lifestyle. Our hope was to inspire students, increase their interest in science, and motivate them to put forth more effort to learn. At the same time, students also gain awareness and connection to their surrounding environment and learn how they can preserve the environment through stewardship for a more sustainable future.

Another purpose of this project was to help students explore the possibilities available to them for future education and employment. Middle school students are in a life stage where they are starting to think about their future. This project brings awareness to the students of the higher education paths and future career opportunities in marine science and other science related fields available to them on Kauai.

The curriculum centered on a beach field trip to test student hypotheses about marine debris sources, impacts, and possible prevention. Through the project's hands-on science learning experiences, students learned about: ocean currents, wave energy, sand composition, beach topography, monitoring techniques, the scientific method, Excel spreadsheets, data analysis, human impacts on natural systems, stewardship, report writing, and oral presentation skills. Through this process of performing hands-on experiments and studying real life problems, students learned the importance of applying the scientific method to understand and create solutions to environmental problems. They developed an understanding of the natural systems and how they affect their everyday lives.

Learning about marine environments and systems in the classroom from books, video and lectures is quite different from learning by hands-on application in

a marine environment. Hands-on application of science instills a greater sense of connection with the marine environment (Stepath & Whitehouse, 2006). This connection helps reinforce their knowledge of the marine ecosystem and motivates students to consider active participation in environmental conservation and a sustainable future. Looking forward, this knowledge and sense of responsibility may help motivate these same students to develop solutions for future marine debris problems.

Education programs in the Hawaii Department of Education (DOE) system must help students meet or exceed their established content and performance standards. Consequently, this project was designed to meet or exceed the standard benchmarks specified by the DOE for science education published in their "Benchmark Maps for Sciences." By focusing the curriculum around DOE benchmarks, we were able to gain the support of the teachers and principal for project implementation.

Because students learn through various different modalities (multiple learning intelligences), several different teaching methods were used to help stimulate learning. The methods used were based on three theories of teaching methods; utilization of multiple intelligences, hands-on proximal learning, and inquiry-based learning.

Multiple Intelligences

Dr. Howard Gardner, the psychologist who developed the theory of "Multiple Intelligences", describes his alternative teaching method as "individually configured education." He explains that where the same material presented in one way may be confusing to a student, it can be presented in a different way to make sense to them (Gardner, 2006, p.151). This method of teaching is an alternative to what Gardner describes as "uniform schooling." Uniform schooling is the method of teaching students all subjects in one way such as lectures from a book. According to Gardner, this method is sometimes believed to be the fairest because all students learn the same material and are assessed in the same way. He believes that uniform schooling is not fair by explaining, "The uniform school is based on the assumption that all individuals are the same and, therefore, that uniform schooling reaches all individuals equally and equitably. But we obviously look different from one another and have different personalities and temperaments. Most important, we also have different kinds of minds" (p.150). One example of Gardner's Multiple Intelligences as it relates to students is titled "The Naturalist". Gardner's description of a naturalist is a person who "demonstrates expertise in the recognition and classification of the numerous species—the flora and fauna—of his or her environment . . . the naturalist is comfortable in the world of organisms and may well possess the talent of caring for, taming, or interacting subtly with various living creatures. They are predisposed to explore the world of nature . . . or detecting novel patterns (pp.49-50). " Examples of these include botanists, biologists, hunters,

fishermen, farmers, gardeners, and even cooks. Using Gardner's theories on "individually configured education" and "Multiple Intelligences" as inspiration, we developed lesson plans to teach as many students as possible.

Hands-on Proximal Learning

Another theory about teaching methods is presented by Carl Stepath and Hilary Whitehouse in their publication titled, "Encouraging proximal relations: Queensland high school students go to the reef" (2006). They explain that as a result of students performing hands-on applications of science principles at a local reef [or beach], in close proximity to where they grow up, a stronger personal connection is developed to that location. It is believed that this connection will, "Ideally . . . help reinforce their knowledge of the marine ecosystem and motivate students to become active participants in environmental preservation" (Stepath and Whitehouse, 2006). This concept is referred to as, "Encouraging proximal relations" (Probyn, 2003). Probyn explains the theory of proximal relations as, "relations of proximity." Probyn describes how perceived relationships to an environment in space and time can cause them to have a, "connection and/or dis/connection" with that place (2003, pp. 290, 298). The result of this field trip was what Rose (1999, p. 252) terms "the space of relation", an imaginably conceived space between differing bodies, and this did change for many of the student learners in this project. Students noted that they had a sense of "being more connected" to and becoming "more familiar" with a beach they had previously taken for granted. This relationship (connection) to place can intensify learning situations related to it,

as well as influence a future relationship, and develop a sense of wanting to help that place.

The purpose of hands-on learning is also to bring science to life for the students. Students learn how science taught in the classroom is applied outside in the real world. At the same time students gained awareness and connection to their surrounding environment and learned how they can preserve the environment through stewardship. This type of hands-on learning is also valuable in promoting active stewardship (Stepath, 2002). "Awareness is only a first step in the process of responsible environmental behavior, not an end in itself. Promoting responsible environmental behavior requires changing human attitudes and linking them to participation. Participatory action should be the desired outcome, and awareness is a necessary step in the process" (Stepath, 2002). Consequently, this type of hands-on learning helps us learn marine science in a way that is related to our everyday lifestyle.

Inquiry-Based Teaching Methods

Kanesa Duncan, an Assistant Professor for the Curriculum Research and Development Group at the University of Hawaii (Manoa), College of Education University Lab School, Science Section, presented this theory at a science teacher-training workshop on Kauai in October 2008. This workshop was titled, "Teaching Science as Inquiry." She explained that students learn the scientific method by making their own observations, asking questions about what they observe, and then using their own critical thinking skills to answer those questions. Inquiry-based

learning is an effective way to engage students in the classroom. Through the process of inquiry-based learning students learn how to use the scientific method in a free form style to gain knowledge (Duncan 2008, in conversation). This type of teaching and learning style was also incorporated into this project.

We incorporated inquiry-based methods with education for sustainability (Nielsen & Henderson, 2009). Education for sustainability is a holistic approach to education and is "generally recognized as education that affords equal consideration to the environment (natural and built), and social political and economic concerns. Learning seeks to build connections between environmental problems and their root causes, which may be social, economic or political. Learners "construct the essential link between their lifestyle, at an individual and society level, with the natural environment" (2009). It has a "strong emphasis on education 'for' the environment, and with the goal of creating positive environmental change by linking learning to actions or behaviors that learners can actually apply. A distinguishing aspect of education for the environment is the notion of taking responsibility for changes that need to happen to achieve sustainability" (2009). Fostering positive environmental change, and encouraging individual responsibility for this change were core objectives of this project.

Description of Activity

This inquiry-based science learning experience provides an introduction to marine science ecology, natural systems, and beach ecosystems. It is a seven to eight week activity centered on a beach field trip for middle school students. The students

learn through inquiry about beach topography and ecology, related natural systems, how to use collected rubbish, and how to make a difference in their community. Skills are developed to effectively communicate science knowledge, and learn how it applies to our daily lives.

Table 1. Timeline for the project

Week 1	*Week 2*	*Week 3*	*Week 4*	*Week 5*	*Week 6*	*Week 7*
Ecology Introduction, Debris Discussion	Natural Systems, Scientific Method	Establish Questions; Hypotheses	Beach Field Trip	Review Data Collected (count, sort and inspect)	Computer Analysis; Data; Charts	Student Oral Presentation and Written Reports

The objectives are to improve local marine and coastline science understanding by providing: 1. Meaningful hands-on training to middle school students and teachers concerning watershed/coastline sustainability and social resilience; 2. Venues for learning by incorporating coastline concepts into science-based learning; 3. Inquiry-based natural systems experience to improve academic performances and connections to coastal areas; 4. Pedagogy to engage learners in living laboratories by using preparation, action and reflection phases of instruction; 5. Support for hands-on science studies in the formal school system and demonstrating its effectiveness with regards to student learning; 6. Improved resource management skills through increased knowledge and a sense of ownership; 7. Project-oriented and investigative experiences with meaningful earth

science education; 8. Investigation experiences, communication opportunities, and multiple intelligences learning with integrated learning approaches; 9. A more developed student capacity and ability to apply knowledge to real world situations; 10. Improved knowledge of natural systemic relationships; and 11. Develop relationships within the community between university and middle school students.

The project works with middle school and local university oceanography students to improve their knowledge and comprehension of natural systems through their work on environmental clean-up projects. This learning situation involves students with local beach clean-up problems, and consequently, they learn about marine coastline ecology and natural change issues in a solution-oriented inquiry-based manner.

Background

It is well known that marine debris, including nets and other rubbish cause many problems to beaches, aquatic habitats, marine ecosystems, and reef life. This project promotes the learning of ocean science, while training students about science related systems and situation, improves their future options in science fields. Young people are taught how they can make a difference through the inclusion and use of science principles while studying oceanography and marine debris clean ups.

Some of the issues addressed with the students are: Why are we going to the

beach to clean up rubbish? Where does this rubbish come from and how does it get to our beaches? What do we want to ask about the purpose of our trip? What types of debris did we find in the different zones and what are the differences? Why is cleaning up marine debris important? What are the prevailing currents and how does this affect the placement of the beach debris? To describe debris and how it could get to our beaches, we explained the huge amount of trash accumulated at the North Pacific gyre. We then used the example of thousands of drifting Nike tennis shoes lost from a ship in the North Pacific Ocean, and when and where they came ashore. This used real world examples to explain how floating debris moves through the Pacific, and then ends up on our beaches here on Kauai.

While at the beach picking up debris, we observed beach topography. In order to graph this area it is necessary to record the distance from the water's edge to the vegetation line, the slope of the beach, and where the sand is located. The beach size, shape, incline and sand location are constantly changing due to a number of natural systems. Sand moves and the shape of the beach changes as wave action varies during different weather patterns and seasonal change. Coastline sand is deposited along our beaches by wave and current action, so sand grains move along the coast (alongshore current and beach drift) as shown in Figure 1. These systems are important to learn, since they affect much of our coastal habitat and resources, as well as help explain how the debris arrives on our shores.

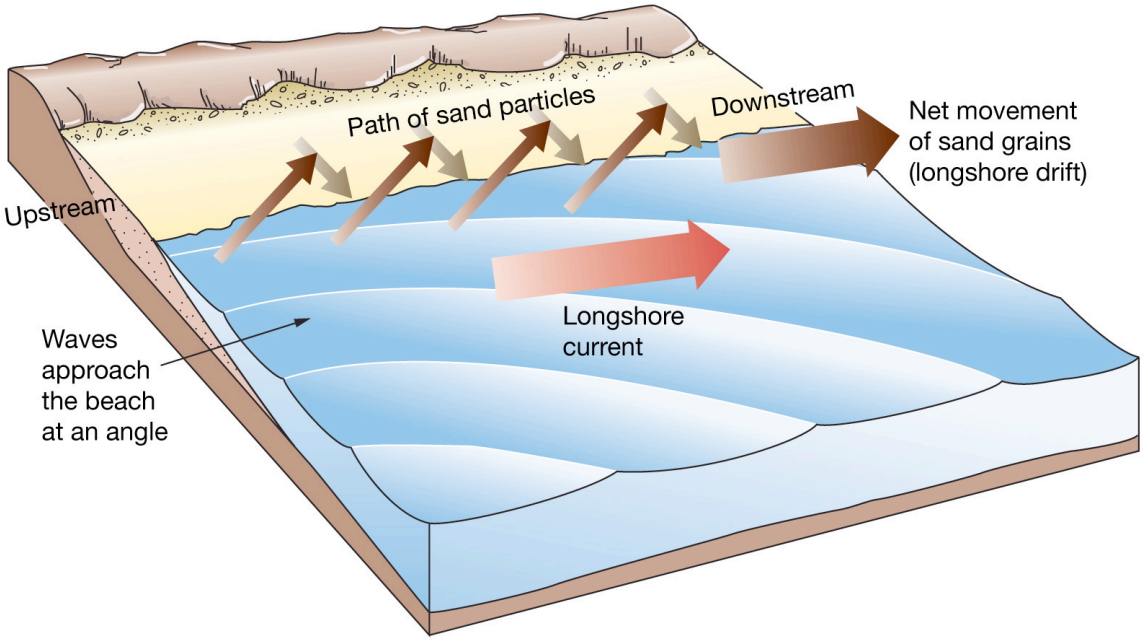

Figure 2. Alongshore current and alongshore drift. Alongshore current, caused by refracting waves, moves water in a zigzag fashion along the shoreline. This causes a net movement of particles along the beach (alongshore drift) from upstream to downstream ends. (Trujillo & Thurman, 2008, p.304)

There are many natural systems the students can observe on their field trip. Visiting the beach, making observations, and recording the varied topography at different times of the year demonstrates how changes in the wave action and currents lead to visible and measurable changes in a beach from summer to winter, for example. This helps us visualize how once the sand is caught up in the waves, it moves along the beach to other parts of the coastline. Students learn about these changes in movement, circulation, and sand transport by observations during the field trip. They make notes and record their observations for their later analysis, graphs, reports, and presentations. This knowledge can be extremely valuable on their island, when they observe negative coastal changes, and need to consider

various actions necessary to address these changes.

Activity

Initially in this project, the students learned about natural ocean systems, beach ecology and debris problems from classroom presentations about oceanic systems to augment their field trip. They learned about what debris is, and the dangers to marine ecosystems and life posed by marine debris on our beaches. Then, in the second week of class they learned about where beach rubbish comes from, how the natural currents work, and how the wind, wave and current systems bring it to shore. During the third week the students learn to use tide tables to predict the tides on the day and time of their trip, how to monitor and categorize marine debris, and devise hypotheses related to research questions. They ask questions preceding the field trip, and the students and teachers establish hypotheses in the classroom. Through this process they actually use inquiry-based learning and the scientific method, while preparing to go on a beach field trip.

The materials necessary for this activity are a three 100m field tape measure; ten 30-gal plastic trash bags; computer lab access with word processors, spreadsheets and related computer programs; pencils with paper; a digital camera to document the activity; measuring sticks to measure the rubbish, as well as magnifying glasses and microscopes to inspect the debris collected. The trash can then be collected, put into the back of a truck and taken to their school for further inspection if desired.

Research Questions and Hypotheses

The generation of research questions by the students is important in inquiry-based learning. Inquiry is the seeking for truth and new knowledge, and this seeking of information by questioning is the basis of this meaningful science project. Through this process individuals reflect upon what they are learning, and learn to make sense of the world. This is augmented by the processes of gathering information and learning to apply it in a real world sense. Here the students derive questions and hypotheses in the classroom while preparing for the field trip. This not only demonstrates the scientific method, it also develops critical thinking and inquiry-based learning skills. The main question these students decided upon as a research question was: "Does most of the rubbish come from offshore sources, or from the island of Kauai, or was it carried here from offshore?"

Students have this and other questions to answer on their field trip. Once at the beach they participate in removal of debris and note beach topography. They rotate every 20-30 minutes between four Group Stations: 1. Remove marine debris by picking up rubbish on the beach along a transect line, listing it, and categorizing it (Figure 3).

Figure 3: Chiefess Kamakahelei Middle School and Kauai Community College students picking up rubbish on the beach along a transect line, and keeping a list of it and categorizing it at Nukoli'I Beach, Kauai. (Photo by Carl Stepath)

2. Determine beach topography with a transect line laid perpendicular to the water's edge to establish beach zones and ecosystems from the vegetation line to the shoreline (interpret beach topography; draw a beach cross section; and discuss beach zonation). 3. Determine if the tidal time they predicted in class is correct by using a watch, physical markers at the shoreline, and the local tide chart. 4. Investigate the beach and determine where it came from, how it is changing and why it is an important part of reef systems. The data are collected, the debris is

sorted, and the beach slope drawn for further analysis in the classroom (Figure 4 and Figure 5).

Figure 4: Sstudents collecting and sorting the debris at Chiefess Kamakahelei Middle School, Kauai. (Photo by J. Scott Bacon)

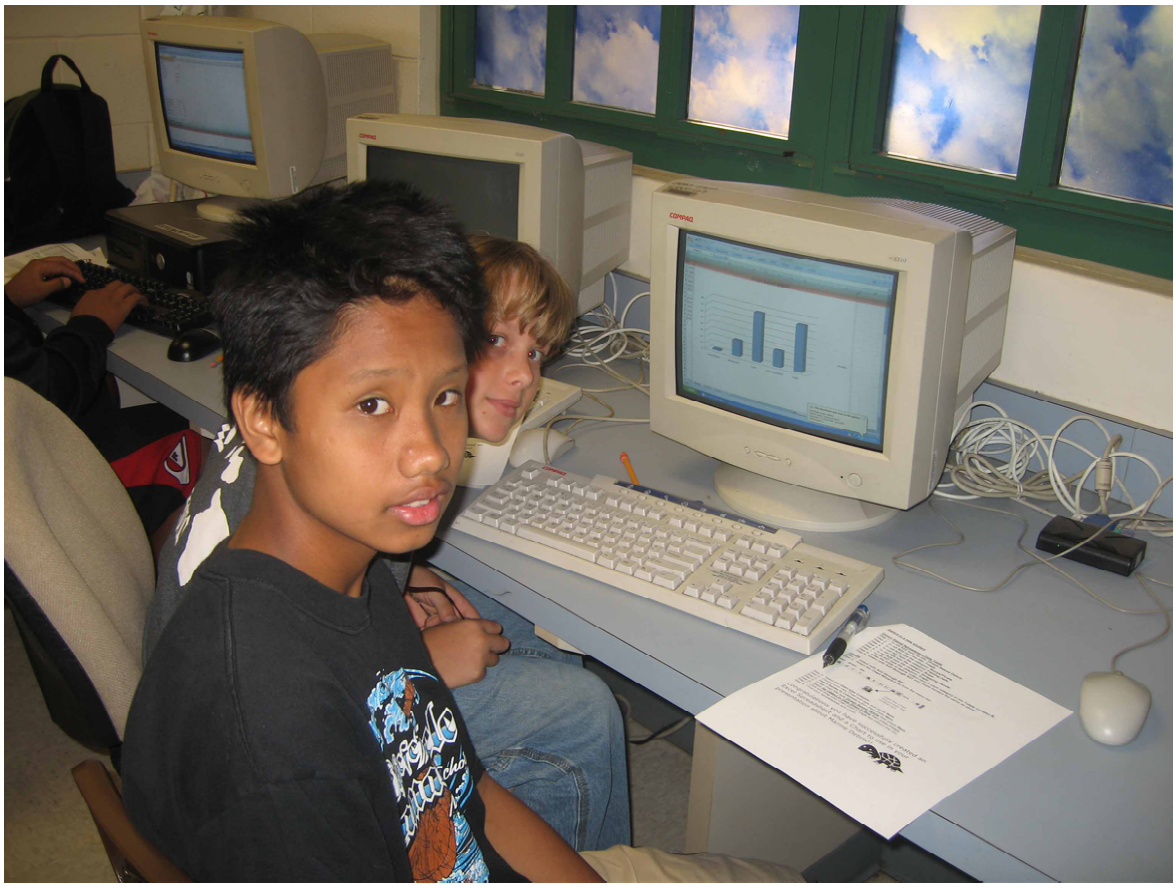

Figure 5. Students at Chiefess Kamakahelei Middle School analyzing the collected data information with computers. Learning to use technical equipment while performing mathematical computations, generating spread sheets and using graphing programs. (Photo by Carl Stepath)

Upon returning to classroom, students input the debris information into a spreadsheet, analyze the data, generate charts and drawings, and use all of this information to make up their reports. After doing trip notations, the students each write a report to list the high points of the field trip, how they thought it made a difference, and what they learned from the experience. Presentations were also developed and shown to others. This taught effective communication skills, and

passed on important science information to classmates and their families about how science applies to our daily lives (Figure 6).

Figure 6. Students at Chiefess Kamakahelei Middle School working on their presentations with Ms Angela Lopez (8th grade science teacher). Learning effective communication skills, and passing on important science information to classmates and their families. (Photo by Carl Stepath)

Desired Learning Outcomes of the Project

This project's success was defined and measured by the student achievement of science standard benchmarks, their level of involvement, and their change in attitudes and behaviours. These science content standards address student understanding of the natural world, and science as inquiry. Therefore this project focused on developing inquiry-based learning and critical thinking skills. In the

course of the project, students practiced utilizing questioning techniques, answering hypotheses through scientific investigation, learning how evidence supports our hypotheses through multiple perspectives, and how these interpretations of problems help us find solutions. They also learned to locate, identify, and utilize a wide variety of information sources, which were used to help them draw conclusions. The students learned to develop questions and then test hypotheses as they observed the beach-debris-wave interactions (Klemm, & Pottage, 1990). These students collected, organized, analyzed and displayed information, used data collection equipment and technology in their analyses and interpretations, as they gained an understanding of their own skills and limitations (Coppersmith, Moffat, & Hager, 1992). The Hawaii standards of education for science and improved learning skills (Hawaii State Department of Education, 2006) were addressed. Then the students' literacy in these standards was demonstrated by project presentations and reports. Knowledge and skills demonstrated are listed:

1. Scientific Investigation: used scientific processes to develop hypotheses, and analyze data to propose theories of marine debris origination and prevention.
2. Nature of Science: learned about marine ecosystems, wave theory and ocean currents and effects on marine debris. How are science, technology and society interrelated in real world situations?
3. Organisms and the Environment: studied beach and reef ecosystems, and learn the effects of marine debris.

4. Structure and Function in Organisms: learned about fringe reefs and beach ecosystems, various species, and zonation.
5. Diversity Genetics and Evolution: studied the origin of marine life, endemic species, and the effects of alien introduced species.
6. Nature of Matter and Energy: studied plastics and recycling processes, the nature of plastics in the environment and the process of creating electricity.
7. Force and Motion: learned about the forces of wave energy, currents and tidal forces and their interrelationship.
8. Earth and Space Science: studied Earth Systems of wind and ocean currents, the gyres created by ocean currents, and the effects of weather systems (Hawaii State Department of Education, 2006).

Conclusion

In this project students learned how different natural systems work, and they identified patterns of change. Their objectivity was enhanced as they examined possible options when investigating a problem, and learned to distinguish between facts and speculation or inferences. This was put into a safe, historical, scientific, and educational technology context, and addressed many of the multiple learning intelligences (Gardner, 2006) to promote sustainability ideas and stewardship.

Students had first-hand proximal experiences of actually cleaning up coastal and marine environments, and observed natural systems in the process of this service project. They learned the value and fun of an outdoors "hands-on" approach to learning, and began the process of understanding and appreciation of the

importance of the natural marine environment and the impact of human activities. Their "relations of proximity" was modified by this field trip experience, and this was highlighted by the students' connection with our beaches and the nearby marine environment. Items from these beaches that are located outside the classroom and often conceived as far away, were brought into the school and discussed using inquiry-based techniques. Students learned about nature and the beach environment's systems in class and then went to the area of study to learn within and on a beach environment during their field trip, and brought that information back the school for continued exploration and learning. Through this process they learned to do things for the beach environment, such as clean up the beach, and then devised ways of getting others to decrease the amount of beach debris and utilize it sustainably by burning it for electricity.

Organized field trips that include beach clean-ups and monitoring activities bring students into direct contact with a myriad of learning skills, including the understanding of natural systems as well as cause and effect relationships. Students often speak of "being more connected," becoming "more familiar" with the natural marine environment, and how the will "never look at it the same way again." They learn to address real problems that exist in their community, and the ocean environment. Students become active participants and develop real life solutions using scientific principles and ideas. We noticed positive changes in the students' environmental knowledge and attitudes, and feel this will lead to them taking individual responsibility for their actions in a way that will have positive long-term consequences.

Acknowledgements: We would like to acknowledge the Bill Healy Foundation and SaveOurSeas.org for their support in this project. Our special thanks go to the principal, teachers and students of Chiefess Kamakahelei Middle School, Lihue, HI.

References:

Coppersmith, A., Moffat, R., and Hager, J.R.E. (1992). Contending with global change, Field studies in the tropical marine environment. Jakarta, Indonesia: UNESCO/ROSTSEA.

Department of the Environment and Heritage, Government of Australia. (2005). *Educating for a sustainable future.* Retrieved January 2, 2010 from http://www.environment.gov.au/education/publications/pubs/sustainable-future.pdf, ISBN: 1 86366 597 8.

Duncan, K. (2008). "Teaching Science as Inquiry," in conversation at Kapaa High School "Teaching Science as Inquiry" workshop. October 2008.

Klemm, B. and Pottage, F.M. (1990). The Fluid Earth (3rd Edition), Curriculum Research & Development Group. Honolulu: University of Hawaii Press.

Gardner, H. (2006). Multiple Intelligences: New Horizons in Theory and Practice. NY: Basic Books.

Hawaii State Department of Education (DOE), Office of Curriculum, Instruction and Student Support, Instructional Services Branch, April 2006. [Accessed on the internet December 24, 2008], http://doe.k12.hi.us/curriculum/accn/ACCN_2006_2010_rev3.pdf

Nielsen, C. and Henderson, R. (2009). Environmental education, transforming the mind and saving the planet. In Wolff, M and Gardener, M. (Eds.)(2009) *Proceedings of the Galápagos Science Symposium 2009*, Galápagos Islands, 20-24 July 2009. Galápagos: Charles Darwin Foundation (pp. 135-138). www.livelearn.org

Probyn, E. (2003). The spatial imperative of subjectivity, in Anderson, K. et al. (Eds.) *Handbook of Cultural Geography*, pp. 290-299. London: SAGE.

Rose, G. 1999. Performing space. In D. Massey, J. Allen, & P. Sarre (Eds.), *Human geography today*, pp. 247-259. Cambridge: Polity Press.

Stepath, C.M. (2002). *Awareness and Community-based monitoring*. Proceedings of the Ninth International Coral Reef Symposium, Bali, 23-27 October 2000, Volume 2. pp. 807-811. 2002.

Stepath, C.M. and Whitehouse, H. (2006). *Encouraging proximal relations: Queensland high school students go to the reef*. Published in proceedings of NZAEE Conference. January 22-25, 2006, at University of Auckland: New Zealand Association for Environmental Education. (ERIC Document Reproduction Service No. ED494918).

Trujillo, A.P. and Thurman, H.B. (2008). *Essentials of Oceanography* (9th Edition). New Jersey: Pearson – Prentice Hall.