# Recent Ocean Literacy Research in United States Public Schools: Results and Implications

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***Abstract***
Recent research conducted on adults in the United States indicates low ocean literacy (Ocean Project, 2009b, 1999), but there is a dearth of peer-reviewed research on K-12 students' ocean literacy. This paper presents two research studies that examined the ocean and environmental literacy of 464 K-12 students in five states. Like the majority of American adults, most of the student participants in these studies had low initial levels of ocean literacy. Both of these studies, while conducted with different populations of students, suggest that engagement in an ocean literacy-focused program may lead to higher ocean literacy and increased responsible environmental behaviors that help the ocean. The encouraging results of these studies, and their implications, are discussed in relation to the ocean literacy and environmental education communities and the critical need for further large scale and longitudinal empirical studies to support increased significance of ocean literacy in the United States.

***Keywords***: Ocean literacy, K-12 environmental education, responsible environmental behaviors

## Introduction

The catastrophic Gulf of Mexico oil spill has certainly brought the health of the ocean to the forefront of the minds of some United States citizens, policymakers, and media members. Unfortunately, most Americans probably do not fully understand the issues surrounding the event, due to poor understanding of the ocean, its characteristics and processes, and the interdependency of the ocean and humanity. In other words, public ocean literacy in the United States of America is poor and is likely to impact the public's understanding of the consequences of the oil spill.

Ocean literacy, defined as "an understanding of the ocean's influence on you, and your influence on the ocean," (National Geographic Society, 2006)

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is a relatively new term coined by a group of dedicated formal and informal educators, scientists, government professionals, and others interested in promoting ocean sciences education. Beginning in about 2004, many individuals from across the USA and beyond have convened, both in person and virtually to discuss the ideas related to the ocean with which all citizens should be familiar. The team, supported by organizations including the National Marine Educators Association (NMEA), the National Oceanic and Atmospheric Administration (NOAA), the National Geographic Society, the Centers for Ocean Sciences Education Excellence (COSEE) and others, worked to develop a framework of the *Essential Principles* and *Fundamental Concepts of Ocean Sciences*. Seven *Essential Principles* (Table1) overarch 45 *Fundamental Concepts*, representing the major ideas that high school graduates should know and understand about the ocean and its significance in the earth system. Since the initial *Principles* and *Concepts* were developed, the team has continued work to create a scope and sequence, delineating the ideas and connections that students at the K-4, 5-8, and 9-12 levels should know and make (Schoedinger, Tran, & Whitley, 2010; Strang, DeCharon, & Schoedinger, 2007).

***Table 1. The seven essential principles of ocean sciences****

| | |
|---|---|
| 1. | *The Earth has one big ocean with many features.* |
| 2. | *The ocean and life in the ocean shape the features of the Earth.* |
| 3. | *The ocean is a major influence on weather and climate.* |
| 4. | *The ocean makes Earth habitable.* |
| 5. | *The ocean supports a great diversity of life and ecosystems.* |
| 6. | *The ocean and humans are inextricably interconnected.* |
| 7. | *The ocean is largely unexplored.* |

* Defined by the Ocean Literacy Network (2008).

*Ocean Literacy in the United States*

Previous large survey efforts have shown that ocean literacy is low in the United States and that the health of the ocean is a low priority for most Americans (Ocean Project, 1999; Steel, Smith, Opsommer, Curiel, & Warner-Steel, 2005). The most recent national study on ocean literacy shows these trends continuing, “not much progress has been made in the last 10 years in increasing either the literacy of the American public about the ocean or awareness and concern about the environmental issues threatening the future of a healthy, life-sustaining ocean” (Ocean Project, 2009a, p. 2). The study shows that Americans continue to be more literate in entertainment pursuits than the ocean:

> Specific knowledge of ocean issues remains negligible. Of the sampled respondents, 35% cannot identify a single ocean-related issue affecting the

> United States. Compared to similar recent research, the American public possesses significantly greater literacy about topics such as college football, the Academy Awards, luxury automobiles, casino gambling, and video games than it does the ocean (Ocean Project, 2009c, p. 3).

Overall, ocean literacy is low, especially among adults, and "Americans are generally unable to articulate valid reasons explaining the importance of the ocean beyond simple declarations such as, 'We can't live without water' and 'We need fish to survive' (Ocean Project, 2009c, p. 3). The low ocean literacy and low level of concern from the American public about the future of the ocean stands in stark contrast to the high level of concern among scientists about the survival of the ocean's inhabitants and its ecosystems. The peer-reviewed literature contains a diverse assemblage of articles that document the potential collapse of all major commercial fisheries by 2048 (Worm et al., 2006), destruction of the majority of coral reefs by 2050 (O. Hoegh-Guldberg et al., 2007) and the collapse of most coastal ecosystems that has already occurred around the world (Jackson et al., 2001).

One of the most troubling disconnects of the American public is the lack of understanding about the connection between climate change, carbon pollution, and the ocean. "Climate change is the environmental issue of most concern to the public. However, the public does not associate climate change and carbon pollution with ocean health" (Ocean Project, 2009b). Yet, scientists have clearly established several direct connections between carbon pollution and ocean health that have already occurred, including a lowered oceanic pH, decreased ocean productivity, altered food web dynamics, reduced abundance of habitat-forming species, shifting species distributions, and a greater incidence of disease (Hoegh-Guldberg & Bruno, 2010). Partly in response to the overwhelming scientific research that the oceans are not being adequately protected, the USA constituted the Interagency Ocean Policy Task Force charged with developing an ecosystem based National Ocean Policy (NOP) in June, 2009 (Lubchenco & Sutley, 2010). On July 19th, 2010, President Obama signed an executive order to implement the NOP (White House, 2010). An ocean literate public will improve the chances that the long-term aspects of the NOP will succeed.

An encouraging finding in the 2009 Ocean Project survey is that young people are more informed about environmental issues and more concerned about climate change. Unfortunately, ocean science topics are typically minimized or ignored in the K-12 classroom (Lambert, 2001; Walker, Coble, & Larkin, 2000). A major obstacle is that in today's educational culture of accountability, teachers are pressed to find time to teach topics that are not in the standards, and therefore to not appear on state assessments. A 2007 study examined state standards across the USA, with respect to the 35 Ocean Literacy *Fundamental Concepts* related to the earth sciences. The study revealed that 10 states address fewer than five *Concepts*, and no state included more than 20 (Hoffman & Barstow, 2007). If the public is going to be convinced that ocean health is a critical issue, then policies will need to be implemented that raises the priority of ocean literacy in the K-12 system in the USA and around the world. Critical pieces of information that will be needed to shape any future policy include understanding students' ocean literacy, science literacy, scientific misconceptions, and approaches that work to develop their ocean literacy, engagement, and desire to be part of a solution.

Scientific literacy is most often described as what citizens should know to participate in society and make good decisions based on science, and encompasses the knowledge of scientific concepts, processes, and the nature of science (AAAS, 1989; DeBoer, 2000; Wallace & Douden, 1998). Environmental education has several competing definitions, but is perhaps best defined as:

> that aspect of education that develops individuals who are environmentally knowledgeable and, above all, skilled and dedicated to working, individually and collectively, toward achieving and or maintaining a dynamic equilibrium between the quality of life and the quality of the environment. (Marcinkowski, Volk, & Hungerford, 1990)

Environmental education and scientific literacy should prepare students to be citizens capable of making good decisions when faced with science-based issues such as environmental problems (Bybee, 1993).

While educational programs about the ocean have existed for decades, they have varied widely in quality (National Oceanic and Atmospheric Administration, 1999) and have suffered from many of the same issues facing the integration of environmental education into mainstream science education, namely that it is misunderstood and neglected (Gruenweld & Manteaw, 2007). The currently accepted definition of ocean literacy was not established until 2004 (Schoedinger, Tran, & Whitley, 2010). This has led to a shortage of research studies that have examined ocean literacy at all levels of education.

Although some literature (Schoedinger, Cava, & Jewell, 2006; Schoedinger, Tran, & Whitley, 2010), presentations (Gillan & Capobianco, 2008) and unpublished works (Kinzel, 2009) reference the ocean literacy standards, very limited research (Gillan & Capobianco, 2008; Kinzel, 2009; Rice, 2007) has been presented utilizing the ocean literacy *Essential Principles and Fundamental Concepts*. This article summarizes the results of two research studies that focused on K-12 students' ocean literacy (Plankis, 2009; Marrero, 2009). A focal point for both studies was collecting data on teachers' and students' voices, as environmental education and scientific literacy research have shown that these voices have been severely neglected and are crucial to attaining environmental and scientific literacy (Brown, Reveles, & Kelly, 2005; Eisenhart, Finkel, & Marion, 1996; Hart & Nolan, 1999; Rickinson, 2001). Given the dearth of information about students' ideas about the ocean since the new ocean literacy *Essential Principles and Fundamental Concepts* were published, studies like these are necessary to begin mapping the mileu of this important research area. Discussion will focus on the students' ocean literacy and how the results can help inform future research and policy programs.

## Methods

### *Marrero, 2009 Methods*

Using the conceptual and theoretical frameworks of scientific literacy and constructivism (Matthews, 1993; Piaget, 1973), Marrero constructed a collective case study (Creswell, 2007; Merriam, 1998) to examine the ocean literacy of two classrooms of students, one in New York and one in California. A constructivist theoretical framework examines student learning with the view that they learn from experiences, and that these experiences connect with what they already know and understand. The 19 New York students were 11th and 12th graders at a New York City public high school enrolled in a marine science elective course. The 52 California students were 7th grade life science students located in the San Francisco suburbs. Both classes were ethnically diverse and students ranged in ability level, from classified special education students through gifted learners.

The students under study were engaged in a NOAA-sponsored ocean literacy-focused program called Signals of Spring – ACES. In 'ACES', students learn ocean sciences content topics (including bathymetry, food webs, currents, and more) and apply their understandings as they track live marine animals (e.g., sea turtles, whales, and penguins) online. The instructional design of ACES is built upon a constructivist framework, further supporting the use of the constructivist theoretical framework in this study. In ACES, students use earth imagery, including chlorophyll and sea surface data sets, to explain the movements of animals that are tracked by satellite. The major research question for this study was, "In what ways do students' ideas about the ocean change through engagement in ACES?"

Both teachers had participated in training for the ACES program in the summer prior to the study. These two classrooms were chosen as representative cases for the ACES program, because the teachers were following the ACES curriculum with a high fidelity of implementation (FOI). That is, the teachers used the instructional materials and philosophies intended by designers of the curriculum, as determined by pre-surveys and short (about 10 minute), informal telephone interviews with these educators. The author used purposeful sampling (Merriam, 1998) to choose one school at the middle school and one at high school level that had a high FOI of ACES in their classrooms.

Data sources for the case studies included field notes, open-ended questionnaires administered to students, focus group interviews, teacher interviews, and student-produced documents (student work). Short (20 minute) questionnaires were administered online, by the teachers, at the beginning and end of the year. These questionnaires asked about student experiences with the ocean, and how students perceived the ocean affecting their lives. The author visited both classrooms several times over the course of a school year to observe students working on ACES lessons, including animal tracking, and recorded extensive field notes, which included student comments and ideas shared, observations of student and teacher behavior and engagement, etc. She conducted two 30 minute conversational interviews with each teacher (Merriam, 1998), one early in the school year and one in June. With students, focus groups of 3-6 students were convened at the same times of the year, and lasted between 15 and 28 minutes, depending on the group. Both teachers saved student work including posters, writing assignments, and data activities, throughout the year. Additionally, ACES students write in online journals as they track their animals, providing another source of data to examine student content knowledge. Merriam (1998) notes that documents, in this case student-produced, are a strong data source for qualitative analysis because they are not influenced by the researcher. Data were collected over the course of a school year and analyzed using the methods of grounded theory (Charmaz, 2000; Strauss & Corbin, 1990), a step-by-step, inductive approach intended to make meaning from the data and identify emergent themes. Each data source was considered individually, and then compared to data already analyzed, as analysis was ongoing throughout the school year, a technique known as constant comparison (Strauss & Corbin, 1990; Creswell, 2007). Through these methods, major themes across data sources were identified. In the case of the open-ended questionnaire data, the prevalence of themes were quantified using simple percentages (Ward, 2007). A final step was to relate the emergent themes to the *Essential Principles of Ocean Sciences*. Methods used to establish trustworthiness and creditability in the data analysis included member checking, prolonged engagement, triangulation of data sources, and peer debriefing (Guba & Lincoln, 1989).

*Plankis 2009 Methods*

Plankis' (2009) study was also based on the theoretical framework of constructivism (Matthews, 1993; Piaget, 1973), the IEEIA curriculum framework (Marcinkowski, 2001), and utilized mixed methodology, combining a quantitative quasi-experimental nonequivalent control-group design and a qualitative component that utilized an embedded case study design (Yin, 2003). A case study approach is the preferred strategy for conducting research to answer "how" or "why" questions that focuses on a contemporary phenomenon within some real-life context. In a case study, the researcher has little control over events and the borders between the phenomenon and context are not always clear (Yin, 2003). Methods of data collection included two quantitative tests, one for environmental literacy, the Secondary Science Environmental Literacy Instrument (SSELI) (Marcinkowski & Rehrig, 1995), and a new instrument for ocean literacy described below, along with student interviews, teacher interviews, discussion forum postings, and additional student opinion surveys. The two quantitative tests were analyzed utilizing analysis of covariance (ANCOVA), the preferred statistical method for comparing experimental and control group means (Gall, Gall, & Borg, 2003). The level of significance was set at .05. Because the focus of this paper is on the qualitative emergent themes found in both studies, the quantitative results will only be addressed briefly.

The teacher interviews were conducted twice for all four teachers, once at the end of the teacher development training and once at the end of the research study. The two Texas teachers were selected to be the embedded case study teachers and were interviewed two additional times during the course of the study (at approximately weeks 8 and 12). The teacher interviews lasted from 22 minutes to 87 minutes, with an average of 30 minutes for the first interviews and 60 minutes for all remaining interviews. The student interviews were done only at the end of the research study in a teacher office at the high school. The student interviews lasted from 8 minutes to 19 minutes, with an average of approximately 11 minutes. The teacher and student interview scripts contained 8 and 10 initial questions respectively. The interview scripts were developed, administered, and analyzed using Carspecken's (1996) semi-structured interview methodology.

The independent variable was participation or non-participation in the Ocean Foundation-sponsored Connecting the Ocean Reefs Aquariums Literacy and Stewardship (CORALS) ocean literacy program designed by the Reef Stewardship Foundation. The dependent variables were environmental literacy (as measured by the SSELI instrument) and ocean literacy (as measured by the Students' Ocean Literacy Viewpoints and Engagement (SOLVE) instrument, see Appendix A) of the students. The CORALS program is a new ocean literacy program based on the ocean literacy standards that utilizes the IEEIA curriculum framework (Marcinkowski, 2001) and textbook (Hungerford, Volk, Ramsey, Litherland, & Peyton, 2003). The program, which was planned to last 18 weeks, ran for 15 weeks due to three weeks of disruption from Hurricane Ike in Texas and Ohio and tropical storm Fay in Florida. Additional details on the CORALS program can be found in Plankis & Klein (2010).

The study involved three groups of participants. The first participants were four high school science teachers of either environmental science or marine science courses. Both courses are considered integrated science courses, with elements of ecology, chemistry, biology, and physics contained in the course objectives and curriculum. Integrated science courses have been shown to increase science literacy (Lambert, 2001) and are proposed as the best courses to be used for improving knowledge of environmental problems (Mayer, 2006) in a high school setting.

Three of the teachers were from Title 1 schools in Texas and Ohio and the fourth was from a suburban school in Florida. The teachers were recruited nationally through announcements for on the Reef Stewardship Foundation (RSF) website and through emails to the RSF member list. Local recruiting efforts were done through recruiting announcements and emails at a local teacher professional development provider. Due to strict logistical deadlines for the study, recruiting was only done over a two-month period. Any teachers interested in participating were required to have at least one control and one experimental classroom of students that were enrolled in the same science courses to be considered for inclusion in the study. This requirement was obligatory to avoid comparing disparate curriculum over time (For example, a biology classroom vs. a marine science classroom) or comparing classrooms where different teachers taught the students. A total of 10 teachers applied to participate in the study. Two teachers were eliminated because they could not provide two classrooms of the same curriculum and four others were eliminated because their school administrators wanted all classrooms in their school to receive the experimental curriculum.

The second group of participants was approximately 393 high school students in the teachers' classrooms who were primarily seniors with a few high performing juniors. (169 students in the experimental classrooms, 224 students in the control classrooms) The third group of participants included four expert moderators and scientists that participated via the CORALS discussion forums. Data was collected from all three groups to help analyze the results of the study.

The purpose of the study was to examine the effects of technology-infused issue investigations on high school students' environmental and ocean literacies. While the research study had nine research questions, only the three questions pertaining to ocean literacy will be addressed in this manuscript:

1. What was the effect of the CORALS program on high school students' ocean literacy, as measured by the SOLVE instrument?
2. What were the teachers' thoughts and reactions to the CORALS program?
3. What were the students' thoughts and reactions to the CORALS program?

*Development of the Students' Ocean Literacy Viewpoints and Engagement (SOLVE) Instrument*

One recognized deficiency for the ocean literacy movement is a lack of reliable and valid assessments (Hoffman & Barstow, 2007). A search of existing ocean literacy and marine science assessment instruments revealed few published instruments, most notably Cudabeck (2008) and Lambert (2001), but none were based on the ocean literacy *Essential Principles* or considered a standard in the literature. With assessment of ocean literacy is still in its infancy, Plankis (2009) developed a new instrument based on the ocean literacy *Essential Principles*.

Plankis developed the Students' Ocean Literacy, Viewpoints, and Engagement (SOLVE) instrument (see Appendix A), which was composed of four parts. Part I is composed of 20 multiple-choice questions examining students' knowledge of five of the seven ocean literacy *Essential Principles*. Part II measures students' knowledge of oceanic environmental problems by asking them to list the problem, cause, and effect. Part III measures students' concern for the oceanic environmental problems they listed in Part II. Part IV, administered during the posttest only, was a series of open-ended opinion questions designed to help expand upon student viewpoints and engagement. Parts II and III of the SOLVE instrument are similar in structure and question format to Test 1, Part I and Test 1, Part II of the SSELI instrument, respectively. However, the questions were modified to address ocean literacy and coral reefs, instead of environmental problems in general.

Plankis collaborated with a group of ocean literacy experts from a team assembled by the U.S. Satellite Laboratory in Rye, NY. A total of three scientists, five educators, and one graduate student who work on ocean literacy education reviewed the questions for face validity, grammar, and suggested question alterations. The feedback received resulted in minor changes that improved some of the questions.

Reliability coefficients for the SOLVE instrument are presented in Table 2. Both Part II and Part III are scales that meet the +.70 minimum standard for Cronbach's Alpha. Part I is not intended to be a composite scale, it is simply a collection of knowledge items, so the low reliability coefficient is less of a concern. The resulting SOLVE instrument was designed to be completed in one class period (45 minutes) or less and all teachers reported their students were able to finish within the allotted time.

***Table 2. Reliability coefficients for three sections of the SOLVE***

| Section | Reliability coefficient |
|---|---|
| Knowledge of Ocean Literacy *Essential Principles* (Part I) | .28 |
| Ability to Identify Oceanic Environmental Problems (Part II) | .72 |
| Attitude (Part III) | .85 |

* *Cronbach's Alpha*

It should be noted that the SOLVE instrument was developed from the beginning to be a partial ocean literacy instrument. This was done because the CORALS program was not intended to be a full ocean literacy program addressing all seven of the *Essential Principles* and an instrument designed to reliably and validly measure all seven principles would have been too long to administer to the students in this study. Because of the low reliability coefficient for Part I, and that Part I contained questions on multiple *Essential Principles*, the results of the SOLVE instrument cannot be used to state that a student either understands or doesn't understand a particular *Essential Principle*. Additional work is needed to develop the SOLVE instrument into a full measure of ocean literacy, but the instrument is presented here as a potential starting point given the lack of existing instruments.

*Reliability of Subjective Scoring*

*Analysis of Part II of the SOLVE* instrument relies on subjective scoring of the student responses to open-ended items. It is important in research studies with subjective scoring of tests to report reliability figures to support the study's validity. Riffe, Lacy, & Fico (1998) insist, "failure to report reliability virtually invalidates whatever usefulness a…study may have" (p. 134). Percent agreement is the most commonly reported ratio of reliability figures, but is not considered a standard.

There are several coefficients that account for chance agreement with no standard, so the researcher selected Krippendorff's alpha (see Krippendorff, 2004). Krippendorff's alpha was calculated using Hayes & Krippendorff's (2007) SPSS macro and percent agreement was calculated manually in Excel. Percent agreement was reported even though it doesn't account for chance agreement, because reporting multiple reliability indices is of importance considering the fact that no unambiguous standards are available to judge reliability values (De Wever *et al.*, 2006).

To improve the validity of the scoring of SOLVE Part II that required subjective scoring decisions, a portion of the posttests were independently graded by the researcher and a fellow graduate student who was trained on the SOLVE scoring procedures. The researcher and fellow graduate student met face-to-face twice to discuss the scoring procedures. The purpose of the first meeting was to discuss the scoring procedures of both instruments and to practice scoring one classroom of tests together. A subsequent meeting was held to independently score additional tests and discuss scoring problems after the scoring was completed. The results of this validity check are presented in Table 3.

***Table 3. Reliability figures for subjective scoring decisions of SOLVE Part II***

| Scoring run | Scoring decisions | Percent agreement | Krippendorf's alpha |
|---|---|---|---|
| Training | 74 | 0.89 | 0.82 |
| Independent Scoring | 281 | 0.80 | 0.67 |

The values reported for the independent scoring run are the most important. Percent agreement for the SOLVE instrument Part II scoring was .80. There is no consensus on what is considered the minimal level of agreement for percent agreement, with De Wever et al. (2006) mentioning the cut-off figure as 0.75-0.80. Neuendorf (2002) and Rourke, Anderson, Garrison, & Archer (2001) state that a value of .70 can be considered reliable. Utilizing both standards, the SOLVE scoring can be considered reliable according to percent agreement.

The value calculated for Krippendorff's alpha for the SOLVE Part II scoring was 0.67. Krippendorff has suggested that a value above 0.75-0.80 indicates excellent agreement, values below 0.40 poor agreement beyond chance, and values in between represent fair to good agreement beyond chance. The value for the SOLVE instrument is therefore considered good agreement and falls just short of the minimum value for excellent agreement. So the subjective scoring of the SOLVE instruments can be considered reliable according to both percent agreement and Krippendorff's alpha. Additional details on the SOLVE instrument development and validity can be found in Plankis (2009).

## Results and Discussion

### *SOLVE Instrument Quantitative Results*

The results from the SOLVE instrument quantitative sections were significant and indicated that the students held a moderate to high level of ocean literacy at the end of the study, compared to the low to moderate ocean literacy they held at the beginning of the study. Table 4 summarizes the effect sizes and their significance by the main effect of class type (whether or not the students were in experimental or control room classrooms) and the class type*teacher interaction (whether or not individual teachers had more or less of an effect than all teachers combined). The main effect of class type was found to be significant for the SOLVE total score, $F(1,229) = 67.97$, $p < .01$, students' knowledge of ocean literacy principles subscale, $F(1,229) = 79.64$, $p < .01$, students' ability to identify oceanic environmental problems subscale, $F(1,173) = 25.46$, $p < .01$, and students' attitudes concerning the ocean subscale, $F(1,163) = 8.00$, $p < .01$. The interaction of class type*teacher was found to be significant for the SOLVE total score, $F(2,229) = 30.27$, $p < .01$, students' knowledge of ocean literacy principles subscale, $F(2,229) = 54.30$, $p < .01$, students' ability to identify oceanic environmental problems subscale, $F(2,173) = 8.55$, $p < .001$. The interaction of class type*teacher was not found to be significant for the students' attitudes concerning the ocean subscale.

It is encouraging to see that the students in the experimental classrooms in Plankis (2009) had a large increase in ocean literacy overall, but the individual teachers also appeared to have a statistically significant impact. It should be noted that the students for Teacher B had the highest initial ocean literacy scores (considered moderate) and the students for Teacher D had the lowest initial ocean literacy scores (considered low) and had the most dramatic gains in their scores, with scores for Part II more than doubling from their initial values. Given the moderate size of the SOLVE instrument sample (121 experimental group students) and the small number of students for Teacher D (15), these results are encouraging, but replicate studies are needed to get a more accurate picture of the impact of the CORALS program on students' ocean literacy.

***Table 4. Summary of effect sizes for SOLVE total score composite scale and SOLVE instrument subscales by class type and class type x teacher***

| | | Class type x teacher effect sizes | | |
|---|---|---|---|---|
| Scale | Class type effect size | Teacher B | Teacher C | Teacher D |
| SOLVE total score composite scale | +0.90** | +0.34** | +0.64** | +2.21** |
| Knowledge of ocean literacy essential principles subscale (Part I) | +0.94** | +0.19** | +0.31** | +3.84** |
| Ability to identify oceanic environmental problems subscale (Part II) | +1.10** | +0.39** | +0.31** | +3.11** |
| Attitude towards oceanic environmental problems (Part III) | +0.48** | +0.38 | +0.75 | +0.34 |

*$p$ < .05. **$p$ < .01.

*Combined Qualitative Results from Both Studies*

The results of the SOLVE instrument scores are presented in Table 4 to provide a sample of the quantitative results from Plankis (2009), but the focus of the remainder of the paper is on the similar qualitative finds from both studies. Even though the two studies examined different populations of students in five states, three major themes emerged concerning the study groups' ocean literacy: 1) initial interest but low knowledge levels about the ocean, 2) low awareness of the urgency of ocean issues, and 3) student-reported interest in behavior changes to protect the ocean.

*Initial Interest but Low Knowledge Levels about the Ocean*

Both authors found that at a baseline level, students found the ocean to be something interesting and worthy of study, but only knew about the ocean at a very superficial level. Before the beginning the ACES program, the New York and California students responded to an online open-ended questionnaire, monitored by their teachers. One question asked, "Why is the ocean important?" Sixty-seven student questionnaires were analyzed and coded, and the major themes quantified. The most prevalent themes were *ocean as a source of food* (39% of respondents) and *to support marine organisms* (25% of respondents).

Responses coded under the first theme included:

- *because we eat things from there. ex. fish, sharks*
- *so we can eat the fishes*
- *we get food from it*

Sample responses for the second theme, *to support marine organisms,* included:

- *because if there was no ocean a lot of animals would be dead*
- *it is home to many plants and animals*
- *keeps many creatures alive*

Another question posed to students in the questionnaire was, "How does the ocean affect your life?" Similarly, 25% of student responses centered upon food; 35% of students, however, were either "*it doesn't affect my life*," or "*I don't know,*" indicating that more than 1/3 of students surveyed, all of whom went to school within 10 miles of the nearest bay, could not name one way in which the ocean affects their lives. The interview data supported this finding. For example, when Christopher, a New York 12th grader, was asked how the ocean affects his life, he explained,

> *In a sense, in a way, it doesn't. . . but then again, it does because when you look at the ocean, you say to yourself, wow, it takes up like the whole Earth. You don't realize that, from land, how big it is.*

The above student answers reflect the predominantly superficial level of responses, which was also noted in other data sources, including the focus group interviews. Data collected from these interviews also focused on food and animals. When asked what they knew about the ocean in focus group interviews, students noted that there are fish and other living organisms, that it is a source of seafood, etc. When asked what she found most interesting about the ocean, Kylie, a 7th grader in California, explained that she was always interested in animals, noting, "*They are all so different. Like, when you see them underwater, it is so cool.*" Benjamin, an 11th grader in New York described his experience of going to the ocean on vacation:

> *. . .one of the beaches, there were all different types of fish, and if you go a little further, there's sharks-- but we didn't go that far. There are a lot of different fish, there's a lot you can see through, so you can hardly even see them, and then there's goldfish and Nemo fish, clownfish, many different kinds . . . I've seen seaweed, when you come to the beach, there's a small path covered in seaweed.*

This student, like many others, focused on the living things in the ocean. When asked why the ocean was important, he indicated the ocean's role as a habitat for living things, reiterating some of the ideas above about seaweeds and fish. In one California focus group, four students discussed that the ocean was important food source for them, noting that they enjoyed seafood such as tuna fish sandwiches, shrimp and sushi. These results are similar to those found in large-scale studies of adults (Ocean Project, 1999, 2009b; Steel, Smith, Opsommer, Curiel, & Warner-Steel, 2005).

Similar to Marrero (2009), Plankis found that CORALS students were interested in the ocean, but had low levels of knowledge and awareness. Question 34 on the SOLVE instrument asked "Think about when you began the research study. Has your view of the ocean changed? If so, how?" Of the 91 students who responded, 65 (71%) indicated that their view of the ocean had changed, 14 (15%) indicated that their view had not changed significantly, and 6 (7%) indicated they were already informed about the ocean. Ninety-one students provided a written response that elaborated on how their view of the ocean had changed. The results were analyzed and assigned to a category of the *Essential Principles of Ocean Sciences* and a summary is presented in Table 5.

***Table 5. Student written responses classified by Essential Principles of Ocean Sciences***

| Response | Count |
|---|---|
| *EP 1: The Earth has one big ocean with many features* | *0* |
| *EP 2: The ocean and life in the ocean shape the features of the Earth* | *0* |
| *EP 3: The ocean is a major influence on weather and climate.* | *0* |
| *EP 4: The ocean makes Earth habitable.* | *0* |
| *EP 5: The ocean supports a great diversity of life and ecosystems.* | *8* |
| *EP 6: The ocean and humans are inextricably interconnected.* | *57* |
| *EP 7: The ocean is largely unexplored.* | *0* |
| | |
| *No, No, it didn't change, or No, my view did not change.* | *14* |
| *No, previously interested/informed about the ocean* | *6* |
| | |
| *Could not be coded to an Essential Principle* | *6* |

Of the 65 written comments that could be assigned to an *Essential Principle (EP)*, 12% reflected EP 5 and 88% reflected EP 6. A sample of the student comments related to EP 5 included:

- *because I never knew half of the stuff about the smaller organisms of the ocean before this year*
- *because I didn't know so many organisms depended on coral reefs*
- *a little, in depth of species in the ocean*

Some sample student comments related to EP 6 were:

- *I never had known that our ocean became so important to humanity*
- *the view of the ocean has definitely changed because I see the harm we are causing it*
- *because I now know how the ocean is so important to our environment*
- *the ocean has a much larger effect on the way we live & the situation of the world today than I thought*

Many of the student comments indicated that the students had low ocean literacy to begin with and that the study raised it. While a few comments partially reflected EP 1-4 and 7, the majority of the length of all comments still reflected EPs 5 and 6. Even though the comments reflect what the students were remembering from the study, it should be noted that it may not be an accurate reflection of their knowledge of or interest in all seven EPs, because the CORALS program deliberately focused on EP 5 and EP 6 due to limited instructional time.

While the discussion forum postings in Plankis (2009) were initially required for students and teachers and detailed analysis was planned utilizing open coding (Strauss & Corbin, 1990), the three weeks of lost time due to the tropical storms and difficulty in accessing computer labs at the schools resulted in the researcher dropping the requirement for discussion forum participation by week ten of the research study. Some highly engaged students did continue to post on the discussion forums, but their usefulness as a research tool was greatly reduced. One student posting did reflect on one of the implications of this paper, that more emphasis needs to be placed on ocean literacy in the K-12 system for the current low awareness and knowledge levels to be raised:

> Title: I have beef with the school system.
>
> Post: "Since I've lived in Florida, I have never seen a warning sign stating the effects of touching coral or other human interaction with biodiversity issues. Actually I never really knew much about the reefs or anything else related to the ocean until I started taking marine bio. I've lived in Florida for most of my life and I was never aware of these oceanic environmental problems. Why isn't there more stress put upon the importance of the ocean when we live on a peninsula? Why wasn't I taught this in integrated science or previous sciences I took in middle school? Is marine bio. and oceanography a fairly new science? Or is there opposition to its importance? I've talked to a few of my friends and they feel the same way." (Student Tracy, personal communication, November 2, 2008)

This student discussion forum posting does reflect the findings from (Hoffman & Barstow, 2007) that Florida's current state standards poorly address ocean literacy, with only 6 of the 35 *Essential Principles* addressed compared to the national average of 9.6.

*Low Awareness of the Urgency of Oceanic Environmental Issues*

The second theme that developed out of both research studies was that many students were not aware of the urgent need to address oceanic environmental issues, which mirrors the results for adults in the Ocean Project survey (2009b). Question 36 on the SOLVE instrument asked "Before this research study began, were you aware that 2008 had been designated the International Year of the Reef (IYOR)?" The IYOR was an international effort to raise awareness of the immediate dangers facing coral reefs and encourage people to take action (IYOR, 2008). Of the 113 students who responded to the question in August 2008, almost eight months into the IYOR, only ***one*** knew 2008 had been designated the IYOR.

Of the 91 CORALS student comments summarized in Table 3, 19 (21%) of them indicated the student was either not aware of oceanic environmental issues to begin with, or that they initially thought the issues were unimportant or not urgent. Student comments on the CORALS discussion forums and from student interviews also reinforced that many of the participating students were not aware of the urgency of oceanic environmental issues. ACES students' initial views about oceanic environmental issues also did not reflect a sense of urgency or importance. In the post-program focus groups, students discussed how their ideas had changed over the course of the school year. Andrea, a 12th grader talked about her views of pollution prior to ACES, saying,

> *Yeah, like, usually when you think about polluting something, you only think about your general area. You never think that trash or whatever can get all the way to the ocean . . . like through the streams or rivers or whatever. Well, here it goes to the bay.*

Her classmate added, "Learning about the animals makes you care about them—and the ocean, more. So maybe it makes you more concerned. I know it does for me." These students and others implied, without directly stating, that their concern about oceanic environmental issues was low upon beginning the program.

Students in both programs began without a sense of urgency or connection to oceanic environmental issues, much like most adults—as found in large-scale studies (i.e., Belden, Russonello, & Stewart, 1999; The Ocean Project, 1999a, 1999b). It is promising, however, that their views began to shift after engagement in ocean literacy programs, although both programs were of short duration. Longitudinal studies are needed to determine whether the students' sense of urgency reverts to pre-program levels, or whether they truly internalize the understandings and concern they have built.

*Student-reported Interest in Behavior Changes to Protect the Ocean.*

For the CORALS students, when responding to Question 26 on the SOLVE instrument ("To what extent will you change any aspect of how you live based on what you have learned in this research study? Explain.") The question had the students rate their planned changes on a scale from 1 to 5, with 1 indicating to no extent and 5 indicating to a great extent. The majority of the respondents, 83 of the 115 students (72%), indicated a "3", "4", or "5" on the scale. While the question did not specifically ask if the students planned positive changes, of the 37 students who provided a detailed written statement, 6 students indicated they were already environmentally responsible and 20 indicated they were planning positive changes (increased recycling, reduced littering, etc.). Only one student indicated a negative attitude by responding he didn't plan to change to help the environment as he thought "environmental problems were overrated."

The SOLVE Part III posttest score, indicated a moderate improvement of the already positive attitude the participants held concerning the ocean. The experimental group *M* increased to 7.06 from 5.84 on the pretest, which was statistically significant ($p < .01$) and moderately educationally significant (Cohen's $d = +0.48$). With 10 points possible, a score of 2-4.7 would indicate a negative attitude, 4.8-7.5 a moderately positive attitude, and 7.6-10 a strongly positive attitude. The unadjusted posttest means for Teacher B (6.76) and Teacher C (5.93) and Teacher D (7.06) all indicate a moderately positive attitude for their students.

For the ACES students, 53 of 65 students (82%) indicated that their experience and knowledge would lead to a change in behaviors in a positive way based on what they learned ("How, if at all, will what you learned in ACES change your behaviors, now and when you are an adult?"). The balance of students' responses (18%) indicated that they were unsure; no students indicated negative behaviors. Questionnaire responses coded as 'positive behavior changes' included:

- *Stop throwing garbage in the water when I go to the beach.*
- *I will take into conciteration (sic- consideration) the things I throw on the ground.*
- *it will affect how i am with my trash and also how i will vote on things that could affect the ocean*
- *it might reconcitar (sic - reconsider) taking my bike instead of my car*

Focus group interviews revealed the same theme of intention to take positive behaviors. Students described their concern about the ocean and reported steps that they would be willing to take in order to contribute to ocean protection. Caryn, a California 7th grader, explained

> *I think I'm going to have a lot more compassion for like, the animals and the different types of . . . when I'm voting, and I see something that has to do with the ocean, I'm going to vote to protect it, because I feel like I*

> *understand it more. I don't think it's just this big . . . blue, thing of water. I think it's more of something that we should keep protecting.*

During the same focus group, students were asked what they were willing to do in their everyday lives to protect the ocean. One student, Benita noted,

> *Yeah, I think that eating less fish, and less meat, well, not really eating less of it, but just knowing what you're eating and where the fish came from. So, like, taking fish from one of the nets that doesn't have a release for turtles or if it was caught in a protected area, you should know about that and not eat it. . . Sometimes, tuna fish, on the can, it will say 'dolphin safe" or things like that. Or, you can go to that website, if it's a fish and it will tell you where and how it is caught and then you can know.*

Benita acknowledged that there were indeed behaviors within her control, and described specifically how she could enact these behaviors, e.g., by visiting a website that delineates sustainable seafood choices. In the excerpt below, three 7th graders report how they are willing to change their behaviors based on their new understandings of the ocean.

| | |
|---|---|
| *Travis:* | *Recycle more ...* |
| *Interviewer:* | *How would that help?* |
| *Travis:* | *They wouldn't have to make more plastic.* |
| *Interviewer:* | *And why is it bad to make more plastic?* |
| *Travis:* | *Because, we were learning something about plastic pellets, which maybe we could lower down what we use….* |
| *Stanley:* | *If we reuse things, we'll be saving resources on land. And, less will be getting in the ocean.* |
| *Stephen:* | *Like Stanley said, if we keep on making more plastic, the turtles, they mistake plastic for jellyfish and other food, so maybe they'll go and eat it.* |
| *Travis:* | *Plastic in the ocean breaks down to those plastic pellet things and those are really bad for birds and stuff.* |
| *Interviewer:* | *So what are some ways to prevent that?* |
| *Travis:* | *Recycling.* |
| *Stephen:* | *Not throwing things into the ocean…. I try not to pollute.* |
| *Travis:* | *Yeah, now I think about the ocean because now I know about the animals and stuff.* |
| *Interviewer:* | *But specifically, did you actually stop polluting or doing something, or were these things that you were doing already* |
| *Stanley:* | *I don't throw stuff on the ground near the ocean because it ends up in the ocean, even if you are far away, because it still can get to the ocean.* |
| *Interviewer:* | *Are these things that you did before? Did you sometimes throw things on the ground?* |
| *Stanley:* | *Well, no.* |

*Travis:* *Yeah, occasionally I did.*
*Interviewer:* *So, now what? Do you think twice about it?*
*Travis:* *Yeah.*
*Interviewer:* *For real?*
*Travis:* *Yeah, really.*
*Stephen:* *Yeah.*

These students, after an approximately 10 month engagement in the ACES program, began to show concern for the ocean, and also reported intent to change their behaviors, including making seafood choices and littering. The discussion also reflected a deeper level of understanding than the pre-ACES focus groups. As they discussed their littering behavior, these boys also indicated an understanding of *how* their behaviors on land directly affected the ocean, for example, demonstrating an understanding of watersheds. These students knew that any litter thrown on the ground in their neighborhood could, through the watershed, end up in the ocean.

In summary, across the two studies, the most commonly expressed student conceptions of the ocean (aligned to *Essential Principles*) included:

- The ocean is an important source of food. (EP 6)
- The ocean is a place to visit and for recreation. (EP 6)
- The ocean is habitat for many diverse species. (EP 5)
- The ocean is important in human civilizations. (EP 6)
- Humans have many negative effects on the ocean. (EP 6)

All of these ideas are important understandings about the ocean. It is not surprising that many students focused on the relationship between humans and the ocean, as pre-adolescents and adolescents often have an egocentric view of the world and what they are learning (Elkind, 1967). Ocean literacy programs in the future should strive to develop students' understandings related to the other *Essential Principles*, e.g., EP 1: The Earth has one big ocean with many features.

*Implications for Further Research*

Although these two studies had separate populations and similar, but still disparate methodologies, the similarities in results are encouraging for the marine education community. The major implications for future research and program development are:

- Ocean literacy-focused programs, even shorter term interventions of one or two semesters, can lead to improved student knowledge and intent to change behavior.

- 'Hooks' for student engagement can be effective means for promoting ocean literacy.
- Longitudinal studies are needed to determine whether students do, in fact, change their behaviors.
- Additional work needs to be performed in order to develop a full ocean literacy assessment instrument to allow future studies to be compared, reliably and validly measure all seven *Essential Principles*, and for tracking progress in attempting to improve ocean literacy over time.

In the cases studied, middle and high school students were engaged in either half year or yearlong technology-based ocean literacy programs. Findings suggest that students can begin to change their ideas about the ocean in a relatively short time, and report intentions to change their behaviors. The goals of these and other programs are to promote ocean literacy and responsible environmental behaviors (REBs), which ultimately means that one "is able to make informed and responsible decisions regarding the ocean and its resources" (National Geographic, 2006`, n.p.). The collective findings suggest that formal education programs in a variety of settings (e.g., urban/suburban, middle/high school, coastal/inland), may indeed assist students in moving toward becoming ocean literate.

The 'hooks' for the two programs were coral reefs and animal tracking, respectively. When referencing their changes in ideas, the students often referenced the hooks, indicating that they were effective means for promoting student engagement. Marine educators should look for other ways to engage students in learning ocean science and about oceanic environmental issues, and relate these topics to the students' everyday lives.

The results from these two research studies are encouraging for the implementation of and potential impact of ocean literacy curriculum in the United States and represent a significant advance in the understanding of student thinking about ocean literacy in the peer-reviewed literature. One limitation of these studies is that they were not longitudinal. This limitation is not unique, as many studies on student thinking, engagement, and understanding fail to report long term impact on students' motivation for further responsible environmental behavior (REB) on environmental issues (Cobiac, 1995). In an effort to address this concern, Plankis contacted the four teachers from the CORALS research study one year after it ended and asked for an update on the activities of their students. One teacher did not answer, two teachers indicated they were continuing to develop their recycling programs and awareness programs with a new group of students, and the fourth teacher, from Florida, reported her students had indeed initiated REB.

Two of the students who had participated in the CORALS program had convinced the teacher to form a new after-school student club called Students Protecting Land and Sea Habitats (SPLASH). The students, with guidance from the teacher, had conducted activities that directly benefited the environment (a wetlands cleanup) and other activities that were designed to increase awareness of oceanic environmental issues in the local community (educational programs for the local elementary school students, as well as volunteering for local environmental education projects). In a follow-up interview, the two CORALS students that spearheaded the formation of SPLASH indicated that their participation in the CORALS program was a key motivational factor in forming the club.

The quantitative and qualitative results from both of these studies recorded an increase in students' ocean literacy and a desire by the majority of the students (72% of students in CORALS and 82% of the students in ACES), to increase their own REB. However, previous research indicates that the desire to increase REB is only a minor variable in determining if students actually take REB (Hungerford & Volk, 1990). The follow-up discovery of the SPLASH club demonstrates that at least two of the students did indeed take REB, on an even larger scale than anticipated by the researchers. Longitudinal studies that report on the long term impact of ocean literacy curriculum on students' ocean literacy, students' thinking, teachers' thinking, and fostering of lasting REBs are crucial to providing a research base that supports increasing the importance and prevalence of ocean literacy and environmental education in the United States.

**Conclusion**

Like most Americans, most of the student participants in these studies had low levels of ocean literacy, mirroring previous studies of adults in this area (AAAS, 2004; Ocean Project, 1999, 2009b). In many cases, students were unable to explain their own connection to the ocean, or how the ocean affects their lives, indicating that at a very basic level, they had not achieved the definition of ocean literacy, "an understanding of the ocean's influence on you, and your influence on the ocean" (National Geographic Society, 2006).

While the studies were conducted with different populations of students, the results suggest that engagement in an ocean literacy-focused program may lead to students considering changing their behaviors toward protecting the ocean. Larger scale and longitudinal empirical studies are needed to determine whether students do in fact behave differently than their peers who have not been engaged in ocean literacy-focused programs, what factors contribute to ocean literate and engaged students, and ways of fostering future REBs.

Paul Hart points out that we are facing different environmental problems today, "unlike the '60s and '70s when environmental issues were local, we now seem to be facing global issues with their major implications" (Hungerford & Simmons, 2003, p. 10). If the ocean and its vast biodiversity are to be protected and global environmental problems are to be solved, it will be important for educators to find local connections, determine students' understanding of the problems, and examine how to make ocean literacy and global environmental problems relevant. Previous empirical research suggests that the formal classroom setting, utilizing quality long term programs, is the best environment for accomplishing this goal (Zelezny, 1999).

Hart and Nolan (1999) stress the importance of understanding global environmental problems and how theory and metatheory for practice is critical:

> Environmental problems and issues are not going to simply disappear. Quite the contrary, as human population continues to grow, these problems will intensify and the consequences will have global (as opposed to local) implications…What could be more elementary than our common future and more fundamental than our own critical dialogue about 'getting right' the presuppositions of theory and metatheory for practice. (p. 40)

The development of an ocean and environmentally literate citizenry is a high priority for the ocean literacy and environmental education communities. However, ocean literacy and environmental education continues to be marginalized in the K-12 and university systems in the United States, resulting in a citizenry that is not equipped to deal capably with many environmental problems that are considered out of sight and out of mind. With increasingly severe local and global environmental problems, time is running out to develop an ocean literate citizenry that is capable of understanding, supporting, and demanding the policy changes necessary to protect the ocean.

♦ ♦ ♦

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## References

AAAS. (1989). Introduction to science for all Americans. Retrieved October 21st, 2007, from http://www.project2061.org/publications/sfaa/online/intro.htm

AAAS. (2004). AAAS survey report. Retrieved April 1, 2009, from http://www.Aaas.Org/News/Releases/2004/Aaas_Survey_Report.Pdf

Belden, Russonello, & Stewart. (1999). *Review of existing public opinion data on oceans*: The Ocean Project.

Brown, B. A., Reveles, J. M., & Kelly, G. (2005). Scientific literacy and discursive identity: A theoretical framework for understanding science learning. *Science Education, 89*(5), 779-802.

Bybee, R. W. (1993). *Reforming science education: Social perspectives and personal reflections*. New York: Teachers College Press.

Carspecken, P. F. (1996). *Critical ethnography in educational research: A theoretical and practical guide*. NY: Routledge.

Charmaz, K. (2000). Grounded theory: Objectivist and constructivist methods. In Y. S. Lincoln & N. K. Denzin (Eds.), *Handbook of qualitative research* (2nd ed., pp. 509-535). Thousand Oaks, CA: Sage.

Cobiac, S. (1995). *Empowerment through critical teaching.* Unpublished master's thesis, University of South Australia.

Creswell, J. W. (2007). *Qualitative inquiry & research design: Choosing among five approaches* (2nd ed.). Thousand Oaks, CA: Sage.

Cudabeck, C. (2008). Ocean literacy survey. Retrieved January 20, 2008, from http://www4.ncsu.edu/~cncudaba/Education/OceanLit/Jan08_survey.pdf

De Wever, B., Schellens, M., Valcke, M., & Van Keer, H. (2006). Content analysis schemes to analyze transcripts of online asynchronous discussion groups: A review. *Computers & Education, 46*, 6-28.

DeBoer, G. E. (2000). Scientific Literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching, 37*(6), 582-601.

Eisenhart, M., Finkel, E., & Marion, S. F. (1996). Creating the conditions for scientific literacy: A re-examination. *American Educational Research Journal, 33*(2), 261-295.

Elkind, D. (1967). Egocentrism in Adolescence. *Child Development, 38*, 1025-1035.

Gall, M. D., Gall, J. P., & Borg, W. R. (2003). *Educational research: An introduction* (7th ed.). Boston: Allyn And Bacon.

Gillan, A. L., & Capobianco, B. M. (2008). *Teacher researcher day: Using action research to build ocean literacy among middle school science students.* Paper presented at the National Science Teachers Association, Boston, MA.

Gruenweld, D. A., & Manteaw, B. O. (2007). Oil and water still: How No Child Left Behind limits and distorts environmental education in US schools. *Environmental Education Research 13*(2), 171-188.

Guba, E. S., & Lincoln, Y. S. (1989). *Fourth Generation Evaluation*. Thousand Oaks: Sage.

Hart, P., & Nolan, K. (1999). A critical analysis of research in environmental education. *Studies in Science Education, 34*, 1-69.

Hayes, A. F., & Krippendorff, K. (2007). Answering the call for a standard reliability measure for coding data. *Communication Methods and Measures, 1*, 77-89.

Hoegh-Guldberg, O., & Bruno, J. F. (2010). The impact of climate change on the world's marine ecosystems. *Science, 328*(5985), 1523-1528.

Hoegh-Guldberg, O., Mumby, P. J., Hooten, A. J., Steneck, R. S., Greenfield, P., Gomez, E., et al. (2007). Coral reefs under rapid climate change and ocean acidification. *Science, 318*(5857), 1737-1742.

Hoffman, M., & Barstow, D. (2007). *Revolutionizing Earth System Science Education for the 21st Century, Report and Recommendations from a 50-State Analysis of Earth Science Education Standards.* Cambridge, MA: TERC.

Hungerford, H., & Simmons, B. (2003). Environmental educators a conversation with Paul Hart, *Journal of Environmental Education* (Vol. 34, pp. 4-11): Heldref Publications.

Hungerford, H. R., & Volk, T. L. (1990). Changing learner behavior through environmental education. *Journal of Environmental Education, 21*(3), 8-21.

Hungerford, H. R., Volk, T. L., Ramsey, J. R., Litherland, R. A., & Peyton, R. B. (2003). *Investigating and Evaluating Environmental Issues and Actions*. Champaign, IL: Stipes Publishing Co.

IYOR. (2008). International Year of the Reef. Retrieved Feb 12, 2008, from http://www.iyor.org/default.asp

Jackson, J. B. C., Kirby, M. X., Berger, W. H., Bjorndal, K. A., Botsford, L. W., Bourque, B. J., et al. (2001). Historical Overfishing and the Recent Collapse of Coastal Ecosystems. *Science, 293*(5530), 629-638.

Kinzel, M. R. (2009). *Using educational tools and integrative experiences via geovisualizations that incorporate spatial thinking, real world science, and ocean literacy standards in the classroom: A case study examined.* Unpublished Master's thesis, Oregon State University.

Krippendorff, K. (2004). *Content analysis: An introduction to its methodology*. Thousand Oaks, CA: Sage.

Lambert, J. (2001). *A quantitative and qualitative analysis of the impact of high school marine science curricula and instructional strategies on science literacy of students.* Florida State University.

Lubchenco, J., & Sutley, N. (2010). Proposed U.S. Policy for Ocean, Coast, and Great Lakes Stewardship. *Science, 328*(5985), 1485-1486.

Marcinkowski, T. (2001). An overview of an issue and action instruction program for stewardship education. In A. J. Fedler (Ed.), *Defining Best Practices in Boating, Fishing, and Stewardship Education*.

Marcinkowski, T., & Rehrig, L. (1995). *The secondary school report: A final report on the development, pilot testing, validation, and field testing of the secondary school environmental literacy assessment instrument*. Stevens Point, WI: University of Wisconsin-Stevens Point.

Marcinkowski, T., Volk, T. L., & Hungerford, H. (1990). *An environmental education approach to the training of middle level teachers: A prototype programme*: Unesco-UNEP International Environmental Education Programme.

Matthews, M. R. (1993). Introductory comments on philosophy and constructivism in science education. In M. R. Matthews (Ed.), *Constructivism in Science Education: A Philosophical Examination* (pp. 1-10). Boston: Kluwer.

Mayer, V. J. (2006). Using the earth system for integrating the science curriculum. *Science Education, 79*(4), 375-391.

Merriam, S. B. (1998). *Qualitative research and case study applications in education*. Hoboken, NJ: Jossey-Bass.

National Geographic. (2006). *Ocean literacy: The essential principles of ocean science K-12*. Washington, DC.

National Geographic Society. (2006). Ocean literacy: The essential principles and ocean sciences. Retrieved February 4, 2007, from http://www.coexploration.org/oceanliteracy/documents/OceanLitChart.pdf

National Oceanic and Atmospheric Administration. (1999). Turning to the sea: America's ocean future. Retrieved July 3rd, 2010, from http://www.publicaffairs.noaa.gov/pdf/ocean_rpt.pdf

Neuendorf, K. A. (2002). *The content analysis guidebook*. Thousand Oaks, CA: Sage Publications.

Ocean Literacy Network. (2008). Ocean Literacy: Essential principles and fundamental concepts. Retrieved June 20th, 2008, from http://www.cosee-ne.net/about/documents/OSLbroch.pdf

Ocean Project. (1999). Results of national survey. Retrieved April 1, 2009, from http://www.Theoceanproject.Org/What_We_Do/Research.Html

Ocean Project. (2009a). America, the Ocean, and Climate Change: Executive Summary. Retrieved July 6, 2010, from http://theoceanproject.org/ resources/America_the_Ocean_and_Climate_Change_ExecSummary_1Jun09final.pdf

Ocean Project. (2009b). America, the Ocean, and Climate Change: Key Findings. Retrieved July 6, 2010, from http://theoceanproject.org/resources/America_the_Ocean_and_Climate_Change_KeyFindings_1Jun09final.pdf

Ocean Project. (2009c). America, the Ocean, and Climate Change: Summary of Data. Retrieved July 6, 2010, from http://theoceanproject.org/resources/America_the_Ocean_and_Climate_Change_Summary_of_Data_June2009.pdf

Piaget, J. (1973). *The child's conception of the world*. London: Routledge and Kegan Paul.

Plankis, B. J. (2009). *Examining the Effects of Technology-Infused Issue Investigations on High School Students' Environmental and Ocean Literacies.* Unpublished Dissertation, University of Houston, Houston, TX.

Plankis, B. J., & Klein, C. (2010). The CORALS Connection. *The Science Teacher, 77*(2), 47-51.

Rice, B. (2007). Teacher Perspectives in Ocean Sciences Education: A Look at the SMILE-CIOSS Partnership. Retrieved July 2nd, 2010, from http://scholarsarchive.library.oregonstate.edu/jspui/bitstream/1957/6392/1/Bronwen_Rice_MRM_project.pdf

Rickinson, M. (2001). Learners and learning in environmental education: A critical review of the evidence. *Environmental Education Research, 7*(3), 207-320.

Riffe, D., Lacy, S., & Fico, F. (1998). *Analyzing media messages: Using quantitative content analysis in research*. Mahwah, NJ: L. Erlbaum.

Rourke, L., Anderson, T., Garrison, D. R., & Archer, W. (2001). Methodological issues in the content analysis of computer conference transcripts. *International Journal of Artificial Intelligence in Education, 12*, 8–22.

Schoedinger, S., Cava, F., & Jewell, B. (2006). The need for ocean literacy in the classroom. *The Science Teacher, 73*(6), 44-47.

Schoedinger, S., Tran, L. U., & Whitley, L. (2010). From the Principles to the Scope and Sequence: A brief history of the ocean literacy campaign. . *Current: The Journal of Marine Education, Special Report #3*, 3-7.

Steel, B. S., Smith, C., Opsommer, L., Curiel, S., & Warner-Steel, R. (2005). Public ocean literacy in the United States. *Ocean & Coastal Management, 48*(2), 97-114.

Strang, C., DeCharon, A., & Schoedinger, S. (2007). Can you be science literate without being ocean literate? *Current: The Journal of Marine Education, 23*(1), 7-9.

Strauss, A. L., & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques*. Newbury Park, CA: Sage.

The Ocean Project. (1999a). Results of national survey Retrieved October 24, 2007, from http://www.theoceanproject.org/what_we_do/research.html

The Ocean Project. (1999b). Summary Analysis of Six Focus Groups. Retrieved July 6, 2010, from http://www.theoceanproject.org/images/doc/focusgroup.pdf

Walker, S. H., Coble, P., & Larkin, F. L. (2000). Ocean sciences education for the 21st century. *Oceanography, 13*(2), 32-39.

Wallace, J., & Douden, W. (1998). Curriculum change in science: Riding the waves of reform. In B. J. Fraser & K. G. Tobin (Eds.), *International Handbook of Science Education* (pp. 471-485). Great Britian: Kluwer Academic Publishers.

Ward, T. (2007). *Re-gendering Data: Quanityying Qualitative.* Paper presented at the Association for Institutional Research Annual Forum, Kansas City, MO.

White House. (2010). Executive Order: Stewardship of the ocean, our coasts, and the great lakes. Retrieved August 11, 2010, from http://whitehouse.gov/files/documents/2010stewardship-eo.pdf

Worm, B., Barbier, E. B., Beaumont, N., Duffy, J. E., Folke, C., Halpern, B. S., et al. (2006). Impacts of biodiversity loss on ocean ecosystem services. *Science, 314*(5800), 787-790.

Zelezny, L. C. (1999). Educational interventions that improve environmental behaviors: A meta-analysis. *Journal of Environmental Education, 31*(1), 5-15.

## Appendix A

*NOTE: This copy of the SOLVE instrument has been modified from the original instrument administered to the students in the CORALS program to eliminate questions that performed poorly or were not relevant to this publication, and to reduce length. If you would like more information about the SOLVE instrument, please contact the lead author.*

Student Codename: ________________________________

**Students' Ocean Literacy Viewpoints and Engagement (SOLVE) Post-Test**

**Part I: Knowledge of Ocean Literacy *Essential Principles***

**Directions:** Please circle the letter of the correct response for each corresponding multiple-choice item on this test form.

**Example Item**:

45. Which of the following is part of the water cycle?
 a. erosion
 b. ocean tides
 c. evaporation
 d. decomposition

**The correct answer is c, so you would circle "c" on this test.**

1. Approximately how much of the water on Earth is contained in the ocean?
 a. 50%
 b. 70%
 c. 90%
 d. 97%

2. A major reason that the temperature of Earth is more stable than the Moon is because
 a. the Earth rotates on its axis more quickly
 b. the Moon is closer to the Sun
 c. much of the Earth's surface is covered by water
 d. the Moon is geologically inactive

3. Approximately how much of the ocean has been explored?
 a. 95%
 b. 25%
 c. 75%
 d. 5%

4. What percent of the populations of predatory fish and shark species have been harvested by fishing the ocean since the beginning of the industrial revolution?
 a. 90%
 b. 60%
 c. 30%
 d. 10%

5. The most common organisms in the ocean are
 a. seaweeds
 b. bacteria
 c. shellfish
 d. fish

6. Most of the space on Earth for living things to live is found
   a. in lakes
   b. on land
   c. in the ocean
   d. in the atmosphere

7. Anemones and clownfish protect each other from predators. This type of relationship can
   best be described as:
   a. parasitism
   b. mutualism
   c. competition
   d. commensalisms

8. The most productive area of the ocean is the open ocean.
   a. true
   b. false

9. The relationship between coral polyps and zooxanthellae can best be described as:
   a. competition
   b. commensalism
   c. parasitism
   d. mutualism

10. The most biodiversity found on the planet Earth is located:
    a. in lakes and streams
    b. in the ocean
    c. on land
    d. biodiversity is roughly equal between the ocean and land

11. Which of the following ocean ecosystems is not dependent on sunlight as a source of energy:
    a. coral reefs
    b. kelp forests
    c. mangrove forests
    d. hydrothermal vent communities

12. Which of the following environments are not used as nurseries for many marine and aquatic species?
    a. estuaries
    b. coral reefs
    c. mangrove forests
    d. the open ocean

13. Which of the following environments is the source of most of the world's oxygen supply?
    a. the ocean
    b. tropical rain forests
    c. temperate forests
    d. agricultural crops

14. What percentage of the world's population lives within 100km of the ocean?
    a. 90%
    b. 70%
    c. 40%
    d. 20%

15. Of the following communities, which is typically the first ecosystem degraded or destroyed by coastal development?
    a. coral reefs
    b. seagrass beds
    c. mangrove forests
    d. hydrothermal vent communities

16. Which of the follow human sources contributes the largest percentage of worldwide release of oil into the ocean?
    a. urban runoff and discharges from industry
    b. air pollution
    c. oil tanker accidents
    d. drilling for oil

17. Human activity has had ________ on the health of the ocean.
    a. no impact
    b. little impact
    c. moderate impact
    d. significant impact

18. It is estimated that coral reefs contribute economic benefits of ________ annually to the global economy.
    a. $775 million
    b. $125 billion
    c. $375 billion
    d. $950 billion

19. Which of the following absorbs nearly 50% of the carbon dioxide added to the atmosphere by human activities each year.
    a. tropical rainforests
    b. the ocean
    c. wetlands
    d. temperate rainforests

20. The ocean covers approximately ______ of the Earth's surface.
    a. 40%
    b. 60%
    c. 70%
    d. 80%

### Part II: Ability to Identify Oceanic Environmental Problems

**21. Oceanic Environmental Problems With Which I am Familiar**
**Directions:** In this part, please present causes and effects of environmental problems with which you are
familiar: (A) up to 5 environmental problems impacting any part of the ocean;
(B) up to 5 environmental problems impacting coral reefs;
**Do not list any problem in more than one section**.

The example below shows you how to **include both a cause and an effect of each problem you include in your list**.

==================================================================
\# CAUSE --> EFFECT
==================================================================
Ex. Removing kelp from the ocean **-->** Loss of animal food/habitat
==================================================================

**A. Environmental Problems Impacting Any Part of the Ocean**
1.____________________________________________________________
2.____________________________________________________________
3.____________________________________________________________
4.____________________________________________________________
5.____________________________________________________________

**B. Environmental Problems Impacting Coral Reefs**
1.____________________________________________________________
2.____________________________________________________________
3.____________________________________________________________
4.____________________________________________________________
5.____________________________________________________________

### Part III: Attitude

Think carefully before you **circle the 'X' that best reflects how you feel.** There are no right or wrong answers. If you are not sure about your response to the item, leave it blank. **Please be completely honest.**

22. To what extent are you concerned about the environmental problems you listed in your responses to question 21A? (Environmental problems related to the ocean)

| X | X | X | X | X |
|---|---|---|---|---|
| No Extent | | A Moderate Extent | | A Great Extent |

23. To what extent are you concerned about the environmental problems you listed in your responses to question 21B? (Environmental problems related to coral reefs)

| X | X | X | X | X |
|---|---|---|---|---|
| No Extent | | A Moderate Extent | | A Great Extent |

**Part IV: Additional Post Research Study Questions**

24. Has this research study affected your career plans? _____ Yes _______ No Explain.
25. To what extent did this research study help you understand how global environmental problems are connected to your everyday life and community? Explain.

| X | X | X | X | X |
|---|---|---|---|---|
| No Extent | | A Moderate Extent | | A Great Extent |

26. To what extent will you change any aspect of how you live based on what you have learned in this research study? Explain.

| X | X | X | X | X |
|---|---|---|---|---|
| No Extent | | A Moderate Extent | | A Great Extent |

Questions 27, 28, & 29 omitted as not relevant to this publication,
30. Which topics did you find most interesting? Why?
31. Which topics did you find least interesting? Why?
32. If you could change something about this research study to make it more interesting to students like you, what would you change? Why?
33. As a result of your participation in this research study, do you feel more confident in the field of science? ________Yes _______ No Explain.
34. Think about when you began the research study. Has your view of the ocean changed? If so, how?
Question 35 omitted as not relevant to this publication.
36. Before this research study began, were you aware that 2008 had been designated the International Year of the Reef (IYOR)? _______Yes _______ No If yes, where did you hear about IYOR?
37. Do you have any additional comments or ideas about this research study that were not asked above?