Socioscientific Decision Making and the Ocean: A Case Study of 7th Grade Life Science Students

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Abstract

The purpose of achieving ocean literacy, like scientific literacy, is for citizens to be able to make informed decisions based on science. One approach for teaching students about decision making is to use socioscientific issues, or "SSI." The case study included a group of students participating in an ocean literacy-focused curriculum called *Signals of Spring – ACES*. The authors used focus group interviews, student-produced documents, and a decision-making task to explore decision making as it relates to the ocean. Findings contradict previous ones that students do not rely on what they learn in science class when making decisions. The 7th grade students in this study were able to apply ocean concepts pertaining to physical and biological processes to personal and societal decision making related to pollution, food choice, and on a sample SSI-based task. The results suggest that students are empowered by the knowledge of the ocean gained through the ACES curriculum and that using SSI may be a way to help students achieve ocean literacy.

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Introduction

Since the inception of the science literacy movement, it has been argued that students must become scientifically literate in order to become functional members of society. The argument is that citizens must have strong science content knowledge and understanding of the nature of science, as well as reasoning ability, in order to make good personal and societal decisions related to science (American Association for the Advancement of Science, 1989; Bybee, 1993; National Research Council, 1996; Wallace & Douden, 1998). The notion of "ocean literacy" also encompasses decision making, but in relation to the ocean and marine-related issues such as fisheries management, coastal development, and climate change (National Geographic Society, 2006). Given the ocean's critical role in the functioning of the earth system, ocean literacy is intrinsic to scientific literacy (Strang, DeCharon, & Schoedinger, 2007). This case study of 7th grade life science students sought to examine students' personal and societal decision making as it relates to the ocean, following their year-long participation in an ocean literacy-focused science curriculum program.

Ocean Literacy

Marine education, focusing around marine and coastal environments, has its roots in the environmental movement of the 1960s and 1970s. Since that time, educators, environmentalists, scientists, and the Federal Government have recognized the importance of educating the public about the ocean (COSEE, 2007; Fortner, 1991; Hoffman & Barstow, 2007; Nowell, 2000; Pew Oceans Commission, 2003; U.S. Commission on Ocean Policy, 2004). There have been numerous marine curricula developed by zoos and aquaria, the National Oceanic and Atmospheric Administration (NOAA), local groups, and others for intended use in formal K-12 classrooms (Fortner, 1991). Published literature in marine education, however, has been very sparse. Most studies have focused on particular small-scale local programs (Calkins, 1985; Fortner, 1985; Fortner & Lyon, 1985; Hammer, 2001; Lambert, 2001; Leek, 1980; Mathewson, 1996; Wilson, 1981). Many of these studies are master's theses and doctoral dissertations. In fact, there is only one journal dedicated to marine education, namely, *Current*, the journal of the National Marine Educators Association. *Current* is not a research journal, but rather an information source for practitioners. Researchers in marine education have traditionally used the principles of environmental education as their framework (Calkins, 1985; Fortner, 1991; Giles, 1999). Unfortunately, environmental education is often seen as an "add-on" to the curriculum, and marine education has consequently been relegated to this status (Gruenewald & Manteaw, 2007; Lambert, 2006; Walker, Coble, & Larkin, 2000).

In addition to a lack of published research on marine education, it is evident that marine education is not well infused into K-12 classrooms. One concern is that "current ocean and coastal educational materials are not as effective or useful to educators as they could be because they are often not closely related to mandatory curricula and are highly variable in quality" (NOAA, 1999). The result is a society of people who are ocean illiterate (AAAS, 2004; Schoedinger, Cava, & Jewell, 2006; Steel, 2006; Steel, Court Smith, Curiel, & Warner-Stell, 2005; The Ocean Project, 1999a, 1999b). Even the Federal Government has acknowledged the lack of marine education in our nation's schools. During "*The Year of the Ocean*," a federal ocean awareness initiative in 1998, the Department of Commerce released a report identifying ongoing concerns about the ocean and established scientific and education-related recommendations for understanding and protecting "America's Ocean Future." The report discussed the disjointed nature of ocean education, even at the federal level, and cited the lack of teacher education in the marine sciences as a related problem.

In 2004, the U.S. Commission on Ocean Policy recommended using the framework of scientific literacy for marine education—using teaching and learning about the ocean in order to improve students' scientific literacy. As Lambert (2001, 2006) notes, marine science is a truly integrated science that covers all of the major topic areas outlined in state and local standards and considered necessary for achieving scientific literacy. Therefore, there is much promise for using this framework of scientific literacy rather than that of environmental education.

The ocean literacy movement was born about 2004. A diverse group of marine education professionals, including those working for government agencies, aquaria, non-profits, and universities, as well as classroom teachers, joined to draft a common framework that defined what it meant to be "ocean literate." The group met several times, both in person and through online virtual conferences, to develop what they termed the *Essential Principles and Fundamental Concepts of Ocean Literacy*. These *Principles* and *Concepts* represent what students graduating from 12th grade should know and understand about the ocean (National Geographic Society, 2006). The *Principles* (Table 1) are broad ideas modeled after the *National Science Education Standards*(National Research Council, 1996) and are not meant to add another layer of standards to an already filled curriculum for teachers, but are instead aligned with the *Standards* in order to help teachers use the ocean to support their curricular demands (Jewell, Schoedinger, Cava, Strang, & Lewis, 2006). Each of the *Principles* is underpinned by a series of *Fundamental Concepts*, which are smaller concepts that students should know and understand.

Table 1. The Essential Principles of Ocean Literacy

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.

Socioscientific Decision Making

Using controversial socioscientific issues (SSI) in the classroom has been discussed in the literature as a potentially effective way to prepare students for the real-life decisions they will encounter as adults (Sadler, 2004; Zeidler, Sadler, Simmons, & Howes, 2005). SSI emerged from criticisms of the Science Technology Society (STS) approach to curriculum and pedagogy in science education. In STS curricula, "science content is connected and integrated with students' everyday worlds" (Aikenhead, n.d., p. 2). However, the concern with STS science teaching in support of scientific literacy is that students are often asked to examine issues that they find irrelevant and uninteresting, often unrelated to their personal lives (Shamos, 1995; Zeidler, et al., 2005). The focus on SSI is to empower students as they face personal and societal decisions related to science (Sadler, 2004; Zeidler, et al., 2005). Unfortunately, training young students and even adults to draw upon science concepts, and particularly scientific data, is difficult (Grace & Ratcliffe, 2002; Ratcliffe, 1997; Sadler, 2004; Zeidler, et al., 2005). In fact, a study by Robinson and Kaleta (1999) found that even after training on environmental issues, secondary students relied more on personal experiences than on the scientific knowledge they had gained in school.

Since the ultimate goal of improving ocean literacy is to enhance citizens' decision making related to the ocean, in this study we sought to explore the following question: In what ways do students engaged in an ocean literacy-focused curriculum draw upon *scientific* concepts of the ocean when considering personal and societal decisions related to it? Drawing upon Grace and Ratcliffe (2002), we define a concept as "a functional unit of the mind, a construct of mind which has a stable meaning" (p. 1158). We also note that concepts, of course, are overlapping. Ocean-related concepts about which students in this case study had learned included earth science concepts such as watersheds, currents, tides, and waves, as well as life science concepts such as food webs, productivity, adaptations, and habitats.

Methodology

To explore students' decision making as it relates to ocean literacy, we conducted a case study (Merriam, 1998) of a 7th grade life science classroom in northern California. Focus group interviews, field notes, student-produced documents, and questionnaires were used as sources of data and analyzed using the principles of grounded theory analysis (Glaser & Strauss, 1967; Strauss & Corbin, 1990) to create a rich, thick description of this group of students and to peer into their thinking.

Setting and Participants

This study was conducted at Mountain Middle School (all names are pseudonyms), a high-performing middle school of approximately 550 students located in the suburbs of San Francisco. The community, and therefore the school, is socioeconomically and ethnically diverse, with the school made up of approximately 56% White, 30% Hispanic, 5% African American, 4% Asian, and 5% other students. About 35% of students qualify for free or reduced lunch, whereas other families are quite wealthy.

Mountain Middle School is known for dedicated faculty and a principal who supports faculty members as well as innovative instructional programs. Instruction and student success are the top priorities for the school administration, and these ideas are continuously reinforced. For example, the principal would not allow students to participate in focus group interviews for this study during their study hall period. She explained that students need the study hall period to get extra help from their teachers as necessary and that *nothing* interferes with this important time of day. Although instruction is clearly the focus, student life and activities are also important. School corridors are decorated with flyers advertising student activities, including student council elections and spirit days. Students play sports and participate in other activities, including an active music program.

Fifty-two students, comprising two sections of 7th grade life science taught by the same teacher, took part in the study. The teacher, Jenna, explained that her personal focus for the school year was to incorporate more technology into instruction. She infused many different technological tools into her life science curriculum, including web quests to introduce ecosystems, podcasts illustrating health principles, animations showing cell division, and online animal tracking to discuss the needs of living things. Jenna was committed to an inquiry-based approach that challenged students and forced them to think for themselves.

The ACES Program

One researcher met Jenna while facilitating a summer workshop for teachers on the *Signals of Spring – ACES* [Animals in Curriculum-based Ecosystem Studies] program (www.signalsofspring.net/aces). "ACES" was developed by U.S. Satellite Laboratory, Inc. and supported by a grant from the National Oceanic and Atmospheric Administration

(NOAA) under a program to improve students' ocean literacy. In ACES, middle and high school students use earth imagery to explain the movements of marine animals that are tracked by satellite. Students follow animal movements in real time through the Internet and analyze earth data, including chlorophyll concentration, wind velocity, sea surface temperature, and bathymetry. As they learn more about their animals, students encounter many of the environmental issues affecting the ocean, including marine debris, overfishing, and climate change.

At the summer workshop, Jenna committed to implementing the entire ACES program with her 7th graders. The ACES program includes standards-based classroom lessons, earth imagery interpretation, analysis of animal movements, and completion of issue-based investigations. The animal tracking is often the longest part of the program and can take place over the course of several months. During that time, students analyze real-time data and describe their findings in online journals. Since ACES covers many standards-based topics, such as seasons, food, and energy transfer, and biological adaptations in the context of the ocean, it is intended to replace sections of teachers' regular curriculum, rather than being an addition to it.

Jenna commenced the ACES classroom lessons with her students at the beginning of the school year in August, and they began the animal tracking portion of the program in December. Students continued to follow the animals and analyzed their movements until early June. Mountain Middle School students studied the movements of polar bears, loggerhead sea turtles, and gray seals.

Data Collection

Participant Observation

Multiple data sources were used to construct this case study (Creswell, 2007; Merriam, 1998). Two school visits were conducted, for a total of six full school days, three in October and three in June. During the visits, the first author acted as a participant observer (Jorgensen, 1989), observing students as they analyzed the movements of their animals and wrote in their online journals. Students were aware that the researcher was one of the developers of ACES and therefore asked many questions about the animals, scientists, earth imagery, etc. The researcher also worked with students, co-teaching with Jenna, on a sample ocean-related decision-making task (described below). Extensive field notes were recorded during the classroom visits.

Interviews

Thirteen students returned parental and student consent forms in order to participate in this study. In both October and June, focus group interviews were conducted during students' lunch periods. Groups of two to three students met with one of the researchers outside in the school courtyard for 10-15 minute interviews. Focus group interviews are often used when time is short (Creswell, 2007). Focus groups, rather than individual interviews, were also selected in order to make the students more comfortable and willing to talk with an adult with whom they were largely unfamiliar, particularly during the October interviews.

The interviews were semi-structured with a conversational feel. In October, the purpose was to explore students' prior knowledge about the ocean, what they considered to be interesting and important about it, and from which sources they believed they learned about it. During the June interviews, the purpose shifted, as we focused more on students' personal behaviors as they related to the ocean and the ideas they believed they would take with them going forward. Interviews were audiotaped and transcribed by the researchers.

The Problem-based Case

Much of the criticism of STS science teaching in support of scientific literacy is that students are often asked to examine issues they find irrelevant and uninteresting, often unrelated to their personal lives (Shamos, 1995; Zeidler, et al., 2005). In line with the SSI theoretical framework outlined by Zeidler et al., we purposely chose a problem that was local, timely, and relevant for students to analyze in order to examine their decision-making process. The chosen issue and pedagogy required students to reflect upon the sociological, cultural, and scientific contexts of a particular problem as they worked with peers and came to a consensus through discourse.

Jenna and the lead author shared with students a PowerPoint presentation that outlined a proposed plan to build an offshore power plant that would harness the ocean's wave energy and convert that energy into electricity to be used by homes and businesses in the students' local area. The presentation was based on an actual proposal and utilized graphics and data, including maps, graphs, and pictures of the wave power plants. Students were encouraged to ask questions during the presentation and then were broken up into teams of three in order to respond to the case. Student teams worked through a guided analysis of the case in which they were asked to: (a) provide questions they would ask of the power plant developers; (b) give possible positive results of the construction of the wave power plant; (c) give possible negative results of the construction of the wave power plant; and (d) determine their final recommendation based on the information they had at the time. Students worked in their teams for approximately 30 minutes, during which time Jenna and a researcher circulated among the groups and recorded field notes. After 30 minutes, we conducted a 20-minute group discussion in which student teams shared their questions, pros, cons, and final recommendations. Field notes were also recorded during and after these discussions. Additionally, the teams' worksheets were collected for analysis. This process took place in the two 7th grade life science classes on the same day.

Data Analysis

The data were analyzed using standard procedures of grounded theory analysis (Glaser & Strauss, 1967; Strauss & Corbin, 1990). Each data source (transcribed interviews, field notes, and documents) was first read through individually, and major ideas were grouped together (open coding). Next, the major ideas that were related to one another were grouped through the process of axial coding. The final step was to analyze student responses through the lens of the *Essential Principles and Fundamental Concepts of Ocean Literacy* (National Geographic Society, 2006), looking for evidence that students were drawing on these ideas as they discussed personal and societal decisions. For example, several students discussed issues related to bycatch and overfishing. They were aware that the ocean's resources are not limitless and that humans are over-consuming them. Students described ways by which they could reasonably and responsibly use marine resources, i.e., by choosing to eat only sustainable seafood. These ideas fall under *Fundamental Concept* 1h, "Although the ocean is large, it is finite and resources are limited" (National Geographic Society, 2006, n.p.).

Data analysis was ongoing and iterative throughout the data collection process, from October 2007 through June 2008. Finally, the different data sources were compared with one another for triangulation of emergent themes, a hallmark of excellence in qualitative research. Peer debriefing was employed throughout the analysis process as an additional element of rigor (Creswell, 2007; Guba & Lincoln, 1989).

Findings

The findings from the analysis of data sources are presented as three major themes: *personal decisions, societal decision making,* and *ocean literacy and students' decisions.*

Personal Decisions

The first theme was personal decisions. For example, when asked about their behaviors and decision making related to the ocean, many students focused on *food choice* and *pollution.* In their discussions, they indicated that they understood the direct impact of personal decisions on ocean organisms. As they discussed their decision making, they related their choices to underlying scientific concepts, for instance, giving examples of how pollution on land actually affects the ocean through watersheds, or discussing important ocean-related concepts of overfishing and bycatch. Overfishing refers to the depletion of a certain species due to fishing or other external pressures; bycatch describes when a species is caught inadvertently while another species is sought. For example, sea turtles are often caught in shrimp nets.

Food Choice

Several groups of students discussed how their food choices were related to and had an impact on the ocean. Following is a discussion three boys had with the researcher regarding the relationship between agriculture on land and how ocean organisms are affected by it.

Interviewer: So, what do you think are some of the really important things that adults should know about the ocean if they don't know?
Travis: Like, how many animals live there and stuff. Like, it's sad when there is a kill off.
Stanley: They should know not to exceed the amount of fertilizer that people need.
Interviewer: Why?
Stephen: Because, um, if there's too much fertilizer, it kills the fish, when it goes into the lakes, or rivers, and it dumps in the ocean.
Interviewer: Well, we have to eat food right? What are some ways to . . . .how can we not use fertilizer?
Travis: Well, we don't have to. We can find biodegradable stuff.
Stanley: And don't use them when the rain is coming.
Travis: Or, don't use a lot.
Stephen: Don't use it on your lawn.
Travis: Try to minimize how much makes it to the ocean. Build a thing around your farm.
Stanley: Sometimes, organic food is good because they don't use pesticides and stuff.
Interviewer: So, do you feel like these types of things that you're learning, for example not putting fertilizer on your lawn before we're going to have a big storm, are things that you can share with your family? Are they receptive to you?
Travis: Yeah, my family does.
Stephen: My mom buys organic stuff which is better because fertilizers won't get into the ocean and cause big blooms of algae.

Interviewer: Why is that bad?
Stephen: Well, they affect the fish and stuff.
Travis: And cause dead zones.

In this excerpt, the boys discussed with ease several different concepts they had learned about in class, as well as how the decisions they and their families made were related to these concepts. This short discussion indicated that students were drawing upon knowledge of watersheds and runoff as well as phytoplankton growth and eutrophication. They clearly saw the connection between activities on land and the ocean, and believed that, for example, choosing organically-grown food could reduce negative impacts on ocean ecosystems.

During one of our June focus group interviews, three girls spoke more specifically about personal food choices directly related to the ocean (seafood) and considered issues such as bycatch and overfishing.

Interviewer: Claire, you mentioned "save the animals" as the most important thing. Why do you say that?
Claire: Well, because ... the animals, they're like, if there are fish that we eat and they are gone, then we won't have them to eat.
Grace: Yeah, a lot of other things affect us.
Interviewer: How so?
Grace: Like, the phytoplankton, they feed the fish and they are a big part of our economy.
Barbara: And other animals eat fish ...
Claire: Endangerment of animals is important. Like, I am totally against when they take out fishing nets to catch fish and they take dolphins too. And, even though sharks are dangerous at times, how dare they catch sharks by accident! And, the shark fin soup—that's disgusting.
Interviewer: But how is that different from you eating tuna fish?
Claire: That's something they should think about in their daily lives. That tuna fish had a family!
Barbara: 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.
Interviewer: How do you know where the fish comes from?
Barbara: 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.

Interviewer: Mmhmm.

Grace: I think it's just important for people to be in the know about what they're eating. And, they can eat fish and stuff, but they should at least .understand what they are eating.

Interviewer: How can you continue to keep yourselves in the know? You are leaving this class next week!

Claire: You could research about it; make sure that you are eating the kinds of things that were treated humanely and not only in the ocean, but chicken and stuff like that.

Barbara: The Beach Clean Ups. You can go to those and help people clean up the pollution, which helps the animals. That will help you picture what is out there in the ocean. . .

Grace: I would like to continue learning about the ocean, and learning about the animals.

Claire: I want to know if fishers and people are really taking the concerns seriously. There are a lot of reports out there about how fish are being treated and how fishers are catching things in illegal areas. I want to know how they are doing it—I want to know that they are fishing in a way that's going to be respectful.

The students' discussion in this excerpt indicated several underlying scientific principles as well as socioscientific issues. For example, Barbara and Grace discussed phytoplankton and alluded to the organisms' support of ocean food webs as they mentioned how fish rely on phytoplankton, and how other fish eat those fish, etc. The discussion related to overfishing indicates that these students understood that the ocean's resources are not limitless, but finite.

More interestingly, it was evident from this discussion that these students had truly considered the issues surrounding seafood prior to this interaction. They mentioned specific examples of ways that bycatch in the ocean had been mitigated by certain fisheries, discussing, for example, the "dolphin-safe tuna" campaign as well as alluding to the idea of Turtle Excluder Devices, special contraptions that allow sea turtles to escape when accidentally caught in nets. They also indicated knowledge of the regulation of fisheries, and that fisheries management is a complex and difficult process. Barbara and Grace described specific actions by which they could become more knowledgeable about sustainable seafood and informing the choices they make. They also discussed their responsibility to follow regulations and support others who follow them in order to maintain populations of fish and other species.

It must also be noted that students were bringing their own personal values into their decision making. Previous studies (Brody, 1996; Grace & Ratcliffe, 2002; Ratcliffe, 1997; Sadler, 2004) have discussed that it is expected that students will project their own values onto an SSI. Grace and Ratcliffe (2002) note values similar to those expressed by the students above, i.e., anthropomorphizing animals (“*that tuna fish had a family!”*) and indicating species’ intrinsic right to existence (“*it’s sad when there is a kill off*”). It is interesting, however, that the students also relied on the underlying science concepts as reasons to support the decisions they had made.

Pollution

In addition to food, many students discussed their personal choices as they related to pollution of the ocean. Their choices indicate an understanding of the concepts of watersheds, point and nonpoint source pollution, and specific examples of how pollution affects marine animals.

Interviewer: What do you think are the most important things that people should know about the ocean? Particularly those who aren’t as familiar with the ocean, or haven’t had the experiences you have?

Travis: That maybe you should be more careful about what you put in your recycle, or what you litter, because it could go down a storm drain.

Stanley: Yeah, the littering is bad.

Interviewer: Why?

Travis: Because it becomes runoff, and it goes into the ocean.

Stanley: Like, if you change your car oil, don’t let it fall away. Put it in a thing . . .

Stephen: Yeah, I would teach them that what you do can contribute to your environment, can harm your environment, and also make it better.

Interviewer: What kinds of things make it better? What can you do?

Travis: Use less fertilizer, don’t use fertilizer when it’s gonna rain.

Stephen: You could drive hybrid cars so you don’t contribute to global warming.

Stanley: Don’t wash your car in the street ...

These boys, similar to their previous discussion of food choice and agriculture, recognized the concept of watersheds and applying this scientific principle to decision making.

In a similar vein, the topic continued as the students discussed plastic and marine debris, which can be huge hazards for marine animals.

Interviewer: What kind of decisions would you like to be making that maybe your parents aren't?
Stephen: Buying things that didn't have as much plastic, or buying organic food so they weren't using fertilizers.
Interviewer: Why do you think your parents might not always do that?
Stephen: Because they weren't properly educated. <all laugh>
Interviewer: If you have kids someday, how will you teach them?
Stanley: I would tell them about things. . .
Interviewer: Like what?
Stanley: Like, I would show them how to cut those things that soda comes in, like you should.
Travis: Not let them throw things out the car window.
Stephen: And you should reuse bags.
Stanley: I would teach them to recycle, the importance of it, and to take care 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.

In the above interaction, the boys discussed how they changed the types of personal decisions they made based on the science they had learned, i.e., related to the concepts of marine debris and watersheds. The students indicated an awareness of the direct effects on marine animals—that seabirds and sea turtles are directly affected as they consume marine debris when mistaking items for foods. Stanley mentioned the plastic connectors for six-packs of cans, which can entangle marine animals such as seabirds and seals.

Of course, all of the students interviewed also exhibited an emotional component of their decision making, particularly when related to the animals they had studied all year, once again projecting values onto the animals. This was an expected and normal reaction. Even adults use emotion as they make decisions. It is significant, however, that these students also discussed the underlying scientific principles about *how* the animals would be affected by their decisions.

Societal Decision Making

The second theme was societal decision making. For this theme, the teacher and the researchers were quite impressed with the students' work on the decision-making task related to the offshore wave power plant. Student teams remained engaged in their discussions and, guided by the worksheet, truly debated both sides of the issue. The questions students asked that were not related to the ocean were important ones as well (note all student responses are given as written or verbal, including spelling/grammatical errors), e.g., *About how many homes can it power in 10 years?; How much will it cost?; How long would it take to make a station?; If the wave energy [plant] were to be damaged who would pay for it?; Would it send electrical shocks into the water?; What will the companies do to make sure that nothing bad will happen to the wave bombs?* These questions indicate that students sought to explore the issue further and were thinking about the real social issues related to the proposed construction of the plant.

Physical Processes in the Ocean

Analysis of student work and field notes related to the decision-making task also revealed that, while students again had the expected emotional and value-related responses to the issue at hand, particularly when concerning animals or climate change, they also drew upon what they had learned in class related to the ocean. For example, in their discussions, several student teams brought up physical oceanic processes, including wave formation, upwelling, and coastal erosion. One group in particular debated whether placing the "booms" necessary to harness wave energy on the sea surface would affect the coastlines. They discussed how erosion patterns could change based on the placement of the booms and how that might affect animals that live on the coasts, for example, California sea lions. Several groups also talked about how the booms might impact the waves, including wave formation and wave direction. One team wrote as a question on their worksheet, "*Would it make the waves smaller*?" Another group discussed the process of upwelling, when cold, nutrient-rich water from below is brought up to the ocean's surface due to wind and surface current action. Upwelling drives the entire oceanic food web along the California coastline, and the students were concerned about the impact of the proposed plant on this important process, even asking on their worksheet: "*How would it affect upwelling?*" Upwelling is a concept stressed in the ACES curricular materials.

Biological Systems in the Ocean

Knowing the students' ultimate interests lay with the animals, and the fact that they had studied animal movement all year, it was not surprising that the majority of their discussions centered on how living things in the ocean would be affected by the proposed plant. The students did, however, considered the impact of the plant on animals through the lenses of different concepts, i.e., habitat, ecosystems, food webs, etc. Questions posed by the groups included:

- *How would the feeding of the animals change?*
- *What would happen if the animals chewed on the wires?*
- *Will it cause under water plants any troubel?*
- *If the wires were to break or the plant to power down, how would it affect the ocean habitats?*
- *How would the booms and electricity affect the ocean life?*
- *Can the boom brake and shock the ocean?*
- *What happens when a fish encounters the boom?*

Similar broad lenses of effects on animals were evident in the groups' listing of potential "negatives" related to the proposed plant. Student groups discussed how a wide range of organisms, from phytoplankton to fish to seabirds to marine mammals, could be affected. A major point of discussion seemed to be how food for a variety of organisms would be affected. In the area of *effects on food webs*, student teams wrote, for example:

- *It might scare the birds away from getting to the fish.*
- *It might kill phytoplankton.*
- *It could bring down the fish population because it could scare away the fish and that could be where the food is.*
- *Be harder for animals to get around and find food.*

Another major point of discussion for students was the effect on habitats. During their dialogues, students demonstrated an understanding of bottom as well as surface habitats and expressed concern that these habitats could be disrupted or destroyed.

Sample written responses related to effect on habitats included:

- *It can interfear with some of the animal's homes because they will kill their habitats.*
- *Habitats at the bottom of the sea could be destroyed by the power plants.*
- *They might squish the fish with the anchors.*
- *The thing they put on the ground could destroy a habitat.*
- *It could hurt the animals and their habitats because the anchors could crush their habitats.*
- *Ecosystems might get disrupted.*
- *They [animals] might be attracted by the light and might die.*
- *Fish could have layed eggs and it could disturb the eggs.*
- *The cords could affect the sand by possibly sending an electric shock through the sand, causing the animals that live in the sand like clams to die.*

Human Uses for the Ocean

In addition to students' consideration of how the wave power plant could potentially affect marine life, another area of concern was human uses for the ocean. As they discussed how the power plant could potentially benefit their community and others nearby by providing a renewable source of electric power and decreasing the amount of pollutants released into the air, particularly greenhouse gases, they also considered how other aspects of human life in the local communities would be affected. Sample questions coded under this theme included: "*Would it effect sailboats and ships?"; "Would it be near sanctuaries?"; "What would happen if a boat ran into it?"; "Would it affect the import and export of items because of the boats?"* Students' descriptions of possible negative effects also reflected this theme. Sample responses included: "*Boats could run into the buoy. It can destroy ships because if a ship hits it the ship can sink because it would make a big hole in the ship causing logs of water to fill up the ship and sinking it."*

After completing the worksheet, student teams shared with the class sample questions as well as potential positive and negative impacts of the proposed plant. The teams discussed these ideas and then were asked to describe whether they were "for" or "against" the construction of the wave power plant and the reasons for their decision.

Approximately two-thirds of the teams indicated that they were in favor of the project. Most groups cited the availability of a renewable energy source and concerns about global warming as their reasons for supporting the plant construction. Groups that were "against" the plant supported their decision with concerns about the impacts of the plant on ocean organisms and habitats. The discussions in each class were lively as students debated the pros and cons of the plant. Many students expressed that this particular decision was a difficult one; several student teams on the "pro" side were concerned about the impacts on the ocean.

Ocean Literacy and Students' Decisions

The third theme that emerged from the analysis of data came from the final step of analysis of the 7th graders' decision making as it related to the ocean literacy. We were interested in examining how the *Essential Principles and Fundamental Concepts of Ocean Literacy* (National Geographic Society, 2006) were reflected in student responses. *Fundamental Concept* 1g states, "The ocean is connected to major lakes, watersheds and waterways because all major watersheds on Earth drain to the ocean. Rivers and streams transport nutrients, salts, sediments and pollutants from watersheds to estuaries and to the ocean." In their discussions of *food choices* and *pollution,* several students, including those quoted above, demonstrated an understanding of this *Fundamental Concept* and the ability of it to support personal decision making as to whether they chose organic foods or not to litter. For example, one student explained

> There's a lot of sewer pipes that have signs that will say—that will have a picture of crab—and will say "don't dump, goes to the ocean" and yet some people still don't care. Another thing I've learned that even if you toss things on the streets, it can still get washed down by the runon and it can still go into the sewers and ocean again.

While this student probably intended to use the term "runoff," his understanding of the concept of watersheds is evident. Several lessons in the ACES curriculum gave students the opportunity to explore and apply the concept of watersheds.

Fundamental Concept 1h, "Although the ocean is large, it is finite and resources are limited," was also used by students to support their personal decisions. The students' discussions of the concepts of bycatch and overfishing as related to seafood choices reflect that they understood this concept. Similarly, students drew upon an understanding of much of *Fundamental Concept* 6e, "Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (point source, non-point source, and noise pollution) ..." (National Geographic Society, 2006, n.p.). Students gave many examples of human-induced pollution, both point and non-point. They also illustrated that they were aware that laws and regulations are in place to protect the ocean. During a focus group interview, the subject of law-making arose, and one student noted, "Like, if they pass on laws, like closing sanctuaries or protected areas, that could be a major problem because the fish and other species need to be kept alive." During the decision making task, at least one team discussed how local National Marine Sanctuaries might be affected by construction of a wave power plant. In their discussions of seafood choices, students discussed regulations that are in place to ensure sustainability of fish species

As they discussed the wave power issue and responded to interview questions, several groups of students indicated comprehension of much of *Fundamental Concept* 6b, "From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security." Of course, seafood was a hot topic, but students also mentioned how economic issues, shipping, and even cruising would be affected by the proposed wave power plant. Students' conversations about the potential negative effects of the plant on ocean habitats demonstrated that many of them had a working understanding of the majority of *Fundamental Concept* 5e, "The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor...." They discussed how bottom-dwelling organisms such as mollusks and fish, as well as animals feeding at the surface, such as seabirds, would be affected by the wave plant anchors and booms, respectively. Probably the most significant *Fundamental Concept* upon which students drew as they discussed personal and societal decisions was 6g: "Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all" (National Geographic Society, 2006, n.p.).

Discussion and Conclusion

The findings indicate that the 7th grade students in this study are able to apply "ocean concepts" to personal and societal decision making related to pollution, food choice, and on a sample SSI-based task. While students projected values and emotions onto the decision-making process as expected (Grace & Ratcliffe, 2002; Ratcliffe, 1997; Robinson & Kaleta, 1999; Sadler, 2004), they also draw upon important science concepts and the *Fundamental Concepts of Ocean Literacy* (National Geographic Society, 2006). The study, therefore, supports the crux of scientific literacy and of ocean literacy—that students and citizens must understand scientific concepts and then be able to draw upon them when making decisions. Previous studies indicate that this is a very difficult task to achieve; that students do not, in fact, rely on what they learn in science class when faced with decisions (Robinson & Kaleta, 1999; Shamos, 1995). However, the findings of this study contradict earlier research and supports Grace and Ratcliffe's (2002) idea that students rely on both science concepts *and* values when making decisions about environmental issues. Therefore, using SSI as a curricular strategy for marine education seems quite promising, particularly in our current global climate, where issues such as offshore drilling, depletion of fish species, aquaculture, and climate change are under constant debate and scrutiny.

As a way to discuss the findings, two major points are brought out: first, making personal and societal decisions, and second, the ACES curriculum.

First, in the SSI theoretical framework outlined by Zeidler et al. (2005), the authors distinguish between personal and societal decision making. Even 7th graders make personal decisions related to the ocean and can influence their families' decisions. The findings of this study indicate that these students believe that their study of the ocean has impacted their personal decision making now, particularly as they make decisions related to *food* and *pollution*, and will continue to do so in the future. Because most 11- and 12-year-olds have few opportunities to make societal decisions, the sample decision-making task is used as a mechanism to approximate these types of choices. Of course, the real test might be years later when they order fish in a restaurant or write a letter to their Congressperson opposing offshore drilling.

It is evident that, in both personal and societal decisions, students draw upon scientific concepts including *effects on physical processes, effects on biological systems,* and *human uses for the ocean* which are ideas they learned in class as they make their choices. In line with what Grace and Ratcliffe (2002) found, the 7th graders sometimes describe scientific concepts without using the terms and conversely use terms without defining them. Likewise, in our study, if the terms are used appropriately in the context of the discussion, students were not asked to clarify their meanings during interviews or the decision-making task.

The findings raise the question of how the students in this study are able to apply the underlying ocean-related science concepts to their personal and societal decisions. The data suggest that participation in ACES helped students apply what they had learned. Through their studies and connections with their marine animals, students develop the critical component necessary to build environmental stewardship, a desire to take care of the environment. However, studies have shown that simple awareness and knowledge of the environments are not enough to promote stewardship. Students must build a personal connection to the environment under study and be aware that their own decisions and actions have an effect; they must feel empowered to make a difference in their world (Hungerford & Volk, 1990). As an example, when discussing the concept of marine debris, several students referred to specific activities that they did as part of the ACES program, including a watershed lesson and learning about the Pacific Garbage Patches, huge areas of concentrated floating plastic found in the Pacific Ocean. Students discussed their experiences of taking part in the International Coastal Cleanup and how shocked and appalled they were with the amount of garbage littering local shorelines. As they researched their animals, they likely began to understand how this debris would affect marine animals. They were also able to watch videos and listen to podcasts about this topic on the ACES website.

The results of this study indicate that engagement in the ACES curriculum allows students to construct their knowledge and build a personal connection to the ocean. By investigating the issues that the animals face within the context of tracking them, students begin to see that their own actions, e.g., littering, actually do directly affect the animals. Upon conferring with the teacher regarding the student interviews, we found that she never explicitly taught the concepts of bycatch and overfishing. These concepts, however, are discussed on the ACES website, and it is likely that students came across this information as they researched their animals and analyzed their movements. They were making their decisions because they understood and felt a connection to the animals.

Many students alluded to or specifically mentioned the concept of watersheds. The ACES curriculum includes several activities related to watersheds, including interpreting phytoplankton imagery and conducting local water testing. By analyzing the imagery, the students learned that the mouths of rivers are areas of great phytoplankton growth due to the nutrients (both natural and unnatural) brought down from the surrounding watershed.

In the same lesson, they read about the eutrophication process and the "dead zone," a hypoxic area that forms each summer in the Gulf of Mexico. Jenna also took students on a field trip to their local stream. At the stream, students conducted water quality measures, including temperature, turbidity, and nutrient content. Some students also participated in the International Coastal Cleanup, assigned as an extra credit project. All of these activities were mentioned by students during the focus group interviews, and they represent different ways in which students built a personal connection to the ocean, using both hands-on activities in the field and technological tools, such as maps that display authentic real-time data.

Hence, the students truly internalized the information learned during their study of the ACES curriculum and making personal and societal decision making. The students are able to identify specific behaviors for which they themselves could be accountable; they took on the identity of ocean scientists, decision makers, and stewards, and these identities were apparent in their communications about the ocean, another key component of ocean literacy.

Qualitative research is not meant to be generalized, but these findings indicate that larger-scale (and possibly quantitative) studies are needed to isolate the factors that allow these students to apply what they learn in science class to ocean decisions. It would also be interesting and beneficial to conduct longitudinal studies to examine whether students continue to draw upon their knowledge of the ocean as they become voting citizens. In the meantime, the results are promising: students engaged in curricula such as ACES may be able to apply what they learn about the ocean to ocean-related decision making—the crux of ocean literacy.

References

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

AAAS. (2004). AAAS survey report. Retrieved from http://www.aaas.org/news/releases/2004/aaas_survey_report.pdf

Aikenhead, G. (n.d.). What is STS Science Teaching? Retrieved August 7, 2008, from http://www.usask.ca/education/people/aikenhead/sts05.htm

Brody, M. J. (1996). An assessment of 4th-, 8th, and 11th-grade students' enviroinmental science knowledge related to Oregon's marine resources. *Journal of Environmental Education, 27*(3), 21-27.

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

Calkins, J. R. (1985). *The production and evaluation of a marine education video program: Comparing Piagetian developmental levels to video learning with junior high school, high school, and college groups.*, University of Maine, Portland.

COSEE. (2007). Advancing ocean sciences education. Retrieved February 11 2008, from http://www.cosee.net/

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

Fortner, R. W. (1985). Relative effectiveness of classroom and documentary film presentations on marine mammals [Abstract]. *Journal of Research in Science Teaching, 22*(2), 115-122.

Fortner, R. W. (1991). *Abstracts of research in marine and aquatic education 1975-1990*. Columbus: Ohio State University.

Fortner, R. W., & Lyon, A. E. (1985). Effects of Cousteau television special on viewer knowledge and attitudes [Abstract]. *The Journal of Environmental Education, 16*(3), 12-20.

Giles, S. A. (1999). *Ocean conservation: A baseline study of knowledge and attitudes of fifth graders.* San Jose State University, San Jose.

Glaser, B. C., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Chicago: Aldine.

Grace, M. M., & Ratcliffe, M. (2002). The science and values that young people draw upon to make decisions about biological conservation issues. *International Journal of Science Education, 24*(11), 1157-1169.

Gruenewald, 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. G., & Lincoln, Y. S. (1989). Judging the quality of fourth generation evaluation *Fourth Generation Evaluation* (pp. 228-251). Thousand Oaks: Sage.

Hammer, M. A. (2001). *Bringing ocean science to the classroom through technology: A case study of the Topex/Poseidon educational program project.* Texas A&M University, College Station.

Hoffman, M., & Barstow, D. (2007). *Revolutionizing earth system science for the 21st century: Report and recommendations from a 50-state analysis of earth science education standards.* Cambridge, MA: TERC.

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

Jewell, B., Schoedinger, S., Cava, F., Strang, C., & Lewis, M. (2006). *Ocean literacy through science standards . . . a year later*. Paper presented at the Annual Conference of the National Marine Educators Association.

Jorgensen, D. L. (1989). Participant observation: A methodology for human studies (Vol. 15,

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.

Lambert, J. (2006). High school marine science and scientific literacy: The promise of an integrated science course. *International Journal of Science Education, 28*(6), 633-654.

Leek, M. L. (1980). *Project coast's tests of marine environment awareness: A validation study.* University of Delaware, Newark, DE.

Mathewson, R. D. (1996). *An interdisciplinary middle school module in marine science and archaeology: "If shipwrecks could talk".* The Union Institute College of Graduate Studies, Cincinnati.

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

National Geographic Society. (2006). *Ocean literacy: The essential principles of the ocean sciences*. Washington, D.C.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

NOAA. (1999). *Turning to the sea: America's ocean future*.

Nowell, A. (2000). Education in oceanography: History, purpose, and prognosis *50 years of Ocean Discovery: National Science Foundation 1950-2000* (pp. 195-200). Washington DC: National Academy Press.

Pew Oceans Commission. (2003). *A report to the nation: Recommendations for a new ocean policy*.

Ratcliffe, M. (1997). Pupil decision-making about socio-scientific issues within the science curriculum. *International Journal of Science Education, 19*(2), 167-182.

Robinson, M., & Kaleta, P. (1999). Global environmental priorities of secondary students in Zabrze, Poland. *International Journal of Science Education, 21*(5), 499-514.

Sadler, T. D. (2004). Informal Reasoning Regarding Socioscientific Issues: A Critical Review of Research. *Journal of Research in Science Teaching, 41*(5), 513-536.

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

Shamos, M. H. (1995). *The myth of scientific literacy*. New Brunswick, NJ: Rutgers University Press.

Steel, B. S. (2006). Ocean and Coastal Literacy in the United States. *Sea Technology, July 2006*. Retrieved from http://findarticles.com/p/articles/mi_qa5367/is_200607/ai_n21395918

Steel, B. S., Court Smith, L. O., Curiel, S., & Warner-Stell, 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 August 1, 2010, from http://www.theoceanproject.org/what_we_do/research.html

The Ocean Project. (1999b). Summary Analysis of Six Focus Groups. Retrieved June 16, 2010, from http://www.theoceanproject.org/images/doc/focusgroup.pdf

U.S. Commission on Ocean Policy. (2004). *An ocean blueprint for the 21st century final report of the U.S. Commission on Ocean Policy*. Washington DC.

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.

Wilson, D. L. (1981). *High school students' attitudes toward science and the marine environment following a summer marine science program.*, University of Alabama, Tuscaloosa, AL.

Zeidler, D. L., Sadler, T. D., Simmons, M. L., & Howes, E. V. (2005). Beyond STS: A Research-based framework for socioscientific issues education. *Science Education, 89*(357-377).