Teacher Perspectives in Ocean Sciences Education: A Look at the SMILE-CIOSS Partnership

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Abstract

The Cooperative Institute for Oceanographic Satellite Studies (CIOSS) partners with The Science and Math Investigative Learning Experiences (SMILE) Program to bring ocean sciences and satellite oceanography to high school students and teachers around the state of Oregon. This study was conducted as a formative program assessment during the third year of this partnership. Small group (2-4 person) interviews were conducted with 20 SMILE high school teachers during a professional development workshop in February, 2007. Interview questions focused on usage and understanding of select framing and content terms: *ocean literacy*, *remote sensing* and *satellite oceanography*. Responses from these interviews, as well as individual interviews with a SMILE staff member, former SMILE graduate assistant, and representative from CIOSS, were analyzed for emerging themes. The results from this study are being used to inform the design and implementation of future professional development programming for SMILE high school teachers. In addition, the small-group interviews present a test of a group interview methodology that can easily and inexpensively be included in workshop or professional development components of education programs.

Summary of Conclusions and Recommendations:

Recommendations for SMILE programming:

- Formalize formative evaluation using interview methods.
- Teachers and students represent two distinct program audiences:
  - Teacher comfort with satellite oceanography and remote sensing content may improve with more technical professional development.
  - Students benefit from application, personal connection to material.

Insights for outreach programs in general:

- Ethnographic interviews are a potential method for formative assessment of outreach projects.
- Global environmental problems like climate change present opportunities to reach a broad audience on a personal level.
- Innovative, responsive outreach is important in engaging the public and promoting ocean literacy.

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Introduction

Outreach is an important element of scientific research programs. Not only is it important in generating support for publicly funded research, but scientific literacy is a key component in creating environmental awareness and prompting action on that awareness. Many outreach programs use a similar model: provide professional development for teachers who can then communicate the information to their students, whether children in traditional K–12 classrooms or in museum or other informal settings. This approach allows outreach programs to reach more students than would be possible through more direct means, which would require a greater commitment of resources. This also means that the teachers take on a key role as translators of the science to their students.

This study looks at some fundamental aspects of ocean sciences education in a school-university partnership implementing an oceanographic curriculum. Specifically, this study looks at The SMILE Program which works with scientists, mathematicians and Oregon school districts to provide after-school clubs for science and math enrichment for students in 4th-12th grade, and professional development workshops for teachers. This study explores perspectives of SMILE teachers on ocean sciences and specific SMILE content in order to evaluate past and inform future programming. Through interviews with participating teachers, staff, and research partners, this study helps inform these questions:

What perceptions of program content are shared or divergent among participants?

- What do teachers believe to be best practices for student engagement in ocean sciences education?
- How do teachers use selected framing and content terms: *ocean literacy*, *remote sensing* and *satellite oceanography*?

How practical is this method of folding a formative assessment activity into a planned professional development function?

As part of formative program assessment, data from this study is being used to inform the design and implementation of future professional development programming for SMILE high school teachers. In addition, the small-group interviews present a test of a group interview methodology that can easily and inexpensively be included in workshop or professional development components of education programs.

Background

The Role of Scientist-Teacher Collaboration in Science Outreach

Scientist-teacher partnerships play an important role in achieving both science and ocean literacy in the public. These partnerships manifest in many different ways, from scientist participation in curriculum development to teacher participation in scientific research programs. In whatever form however, the National Academy of Sciences standards stress the need for partnerships between scientists, teacher educators, teachers, and school districts in order to address the shortcomings that have been identified in the United States' traditional approach to science education (Moreno, 1999; National Academy of Sciences, 1996). Studies have shown that teachers in such collaborative programs changed to more inquiry-based styles, better understood current research and the factors influencing it, felt more confident working with the science community and more motivated and competent in their science activities (Haakonsen et al., 1993).

But there are obstacles to achieving effective scientist-teacher collaborations. Some of these obstacles are described by Peleaz and Gonzalez in their report on the 2001 AAAS symposium Sharing Science: Successful Scientist Expert-Teacher Practitioner Interactions (Peleaz & Gonzalez, 2002). This symposium involved feedback from elementary and secondary teachers, science teacher educators, and scientists about their experiences with collaborative projects. Four main themes emerged from the symposium (Peleaz & Gonzalez, 2002, p. 160):

- Scientific literacy was identified as a primary goal
- The importance of personal characteristics and the commitment of project partners
- The need for curricular change to be built on social/developmental goals
- The constraints of incentive/reward structures in universities and school systems

These themes are insightful as they draw our attention to some of the challenges facing scientist-teacher collaboration as a means to achieve science education reform. The emphasis on science literacy is logical based on the shift in approach to learning implied by the collaborative process itself. Personal characteristics and commitment are important as "substantive, meaningful contact between academia and schools requires a thoughtful process… [and do] not simply stem from scientist's approval of a standardized curriculum" (Pelaez & Gonzalez, 2002, p.162). Social and developmental goals must be included to avoid elitist reforms that benefit only the academically talented or otherwise advantaged.

Perhaps most revealing is the symposium participants' discussion of the constraints put on collaborations by the participants' respective institutions. The formal incentive and reward structure of academia does not always acknowledge outreach activities, and they are rarely valued as highly as research and publication activities. As a result, within the academic community scientists do not value the work of their colleagues with teachers and students as highly. Among the symposium participants it was generally acknowledged that only once you reach the top of the promotion hierarchy can you afford to spend a significant amount of time working in outreach. Participants had many examples of "junior faculty whose job status was compromised due to K–12 outreach" and clearly articulated the need for “contributions in K–12 science education to be counted not as ‘service’ but as ‘scholarly and creative activity’” (Pelaez & Gonzalez, 2002, p. 165).

This issue is important for teachers in their institutions as well. Teacher professional development, as participation in scientist collaborations could be viewed, is considered important. However it is not always provided to an extent sufficient to address teacher needs. In addition, and unlike many professionals, teachers are often expected to participate in workshops on their own time and without compensation due to limited ‘release’ days or budgetary constraints. There is generally a lack of time and funding available for teachers to participate in professional development activities to benefit both themselves and their classrooms (Moreno, 1999).

Teachers themselves may not be motivated toward participation in such programs. Current U.S. curricula emphasize the study of more topics in less depth. This reinforces a fact-based approach to learning instead of the inquiry that could be built out of studying fewer topics in greater depth (Moreno, 1999). As long as teachers are being evaluated on their students’ performance on tests designed to assess this broad knowledge, they may lack support to deviate from an outline in a text.

While the benefits of scientist-teacher collaborations would seem to be clear, there are many constraints on the success and effectiveness of these collaborations.

> A useful beginning step toward enhancing the ability of scientists to work with teachers and schools is to promote basic understanding of the issues by all participants. Scientists, teachers, school administrators, and parents all need to recognize the contributions that each of them can make and be able to talk about them using a common language. Mutual understanding of key concepts, approaches, strengths, weaknesses, and barriers is especially important in helping all parties communicate clearly and work together in meaningful ways. (Moreno, 1999, p. 569)

The institutional constraints and differing knowledge and priorities between parties may mean that the collaborators do not always understand each other’s contribution to the process.

The SMILE-CIOSS Partnership at Oregon State University

The Cooperative Institute for Oceanographic Satellite Studies (CIOSS), based at the College of Oceanic and Atmospheric Sciences at Oregon State University (OSU), partners with The Science and Math Investigative Learning Experiences (SMILE) Program to bring ocean sciences and satellite oceanography to underrepresented high school students and teachers around the state of Oregon. The objective is to improve high school graduation rates, as well as increase the number of students attending college and ultimately choosing STEM (Science, Technology, Engineering and Math) careers. SMILE after school club activities culminate in the annual SMILE Oceanography Challenge, a day and a half long event in April on the campuses of Western Oregon University and OSU. At the challenge event student teams are presented with an open-ended community-based problem related to oceanography and work together to gather data and create and present a plan to address the problem. University researchers and students lend expertise to the challenge content and serve as mentors and role models for SMILE participants. Past challenge scenarios have focused on coastal oil spills, fisheries management issues, and locating a vessel lost at sea.

CIOSS funding has employed oceanography and education graduate students to develop club activities for SMILE, with particular emphasis on remote sensing and satellite oceanography. This content promotes CIOSS' objective to "educate and train research scientists, students, policy makers and the public to use, and appreciate the use of, satellite data in research that improves our understanding of the ocean and overlying atmosphere" (CIOSS, 2006). Specific partnership objectives are to:

- engage graduate students and researchers in creating and delivering outreach
- increase teacher understanding of ocean sciences and use of satellite data to engage students
- provide learning opportunities for high school students in clubs and on campus that engage them in applied ocean sciences
- promote students' interest in science, science careers, and the importance of higher education

Much of the most cutting edge oceanographic research involves developments in satellite oceanography and remote sensing technology. Any activity that involves the collection of information by a device that is not in contact with its object of study is technically remote sensing (NASA, 2006). However, the term is generally used to refer to environmental information gathered from aircraft, spacecraft, satellites or ships by detecting and measuring radiation, particles, and fields. Satellite oceanography is an application of remote sensing. Satellites are used to gather large data sets about the ocean including ocean color (indicating chlorophyll and therefore primary productivity), altimetry (sea surface height), sea surface temperature, sea surface winds, and weather patterns. The CIOSS-SMILE partnership is therefore a great way to introduce a wide range of oceanography concepts through this content area.

Interviews as an Evaluation Tool

In order for a scientist-teacher collaborative outreach relationship to be effective, both parties need to share an understanding of the goals of the project and the content and language used. One method to assess this shared understanding and use of terms is laid out by James Spradley in his 1979 text: *The Ethnographic Interview*. Spradley emphasizes the importance of language in ethnographic research, even when conducting research within one's own society and among speakers of a common language. Important semantic differences may exist, especially when interlocutors come from different disciplinary backgrounds.

Discussion of language and shared terminology has important implications for the study of science communication and research outreach. In a 1998 evaluation Rowe studied “unproblematic” cover terms such as *learning*, *education*, *science* and *research* among individuals working at all levels of organization at the Saint Louis Science Center (SLSC). His study uncovered divergent assumptions about the nature of the learning going on in the center, visitor expectations, and the role of objectives in exhibit design (Rowe, 1998). In an example of how such differences can have direct effects on programming, he also observed differences around the term *science research* and the SLSC’s role in presenting that research. If science research is viewed as a complex task that only highly trained scientists can do or understand, then it would not seem appropriate to include it in a science center aimed at the general public. However, if one looks at science research as a basic approach to studying and thinking about the world around us, then one would imagine that having scientists on hand conducting real research would be illuminating and beneficial for the public, and fit with the center’s goals. Science Center staff demonstrated both perspectives.

Due to complexity and unavoidable jargon the sciences present many opportunities for misunderstandings between outreach partners. Both conspicuous and subtle, these misunderstandings have the potential to compromise the effectiveness of educational objectives. Spradley (1979) and Rowe (1998) both illustrate the usefulness of ethnographic techniques in describing such problems. For most outreach programs, ethnographic interviews are not a practical way to describe their audience. However, this project demonstrates how interviews can be used as part of professional development activities. This provides information that helps improve communication between scientists, teachers, and program staff involved in outreach partnerships.

Methodology

Setting: The SMILE Program

The SMILE Program works with school districts and communities around the state of Oregon (Figure 1). The program has a yearly schedule of activities composed of after school clubs and college connection events in SMILE communities, culminating in year-end on-campus challenges for middle and high school students and a camp event for elementary students. The distribution of SMILE clubs around the state means that access to the teachers and students by SMILE staff is limited. In addition to the on-campus challenge event each spring, teachers travel to campus three times over the course of the year for professional development workshops. The interviews in this study were folded into one of these workshops.

Data Collection

All SMILE teachers (20) present at the Winter Teachers' Workshop on February 2nd, 2007 agreed to participate in the research project. Half hour 2-4 person group interviews were conducted during the afternoon oceanography session, concurrently with sessions describing a set of club activities. Interviews were open-ended and encouraged discussion about three aspects of the SMILE programming: 1) strategies for student engagement in ocean sciences given varying degrees of personal connection to the subject, 2) usage and understanding of the term *ocean literacy*, and 3) usage and understanding of the terms *remote sensing* and *satellite oceanography* (See Appendix I for interview instruments). The first question established the open-ended nature of the interviews and asked the interviewees to summarize their thoughts in writing. The second two questions introduced key terms relating to program content and objectives. Individual interviews with SMILE program staff and the CIOSS representative were scheduled separately, lasted between 40 minutes and one hour, and expanded on the same topics (See Appendix I). Interviews were all audiotaped and transcribed.

Study Population

The participants in this study are teachers (20) who currently serve as high school level SMILE club advisors. The SMILE high school teachers were chosen as the study population due to the oceanography content of the high school level programming. All current high school SMILE club teachers (21) were invited to participate. These teachers come from 12 rural school districts across the state (see Figure 1). Table 1 shows background information for participating teachers.

In addition to the teachers, representatives from other partnership members were chosen for individual interviews. One former SMILE graduate assistant, a PhD candidate in Science and Math Education at OSU, and one current SMILE staff member were chosen based on their direct involvement with the oceanography content. These interviews were designed to help describe the perceptions of the individuals who help facilitate the partnership. A senior member of CIOSS was

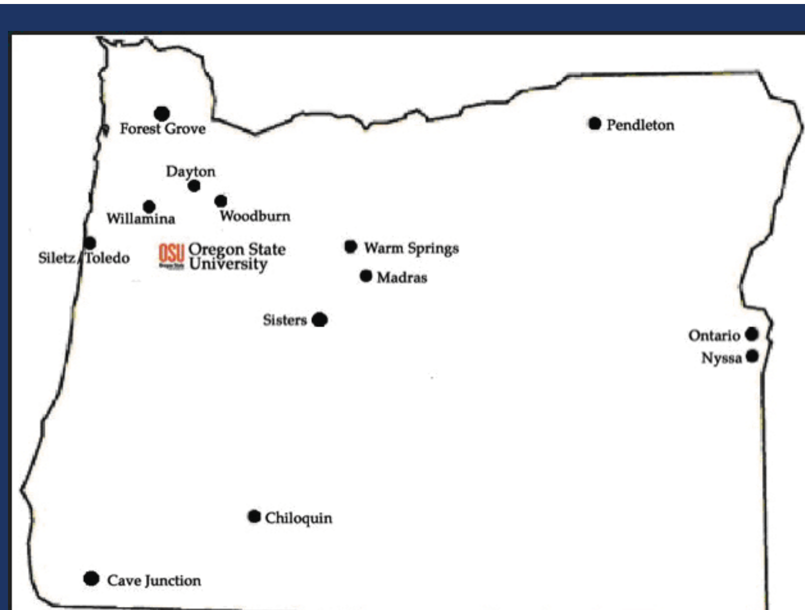


Figure 1: SMILE Communities in Oregon

also selected for an interview to get at the point of view of the program's research partners.

Teacher	Gender	Education	Years Teaching	Years w/ SMILE
T1	F	BS Biology MAT	15	8
T2	F	BS Biology MAT	10	8
T3	F	BS Aquatic Biology MS Science Education	1 (9 years informal)	1
T4	M	BS Geology MAT	30	9
T5	M	BS Biology, BS Animal Science MS Science Education	9	9
T6	F	BS Biology MAT	3	3
T7	F	BS Biology MAT	12	9
T8	M	BS Math Education MS Math Education	15	7
T9	F	BS Multidisciplinary Studies MAT	1	1
T10	F	BS/MS Mathematics Education	27	9
T11	F	BA Education MEd Mathematics	12	11
T12	M	BS Chemistry, BS Biology MS Chemistry	11	1
T13	F	BS in Biology, Minor in Chemistry MAT	3	2
T14	M	BS Integrated Science MS Science Education	17	13
T15	M	BA Chemistry PhD Philosophy	14	14
T16	F	BA Multidisciplinary Studies MA Bilingual Education	6	6
T17	M	BS Natural Resources MS Education	5	5
T18	F	BS Business Administration Teaching Certificate	4	4
T19	M	BS Biology	2	2
T20	M	BS Health MS Education	10	1

Table 1: Background of Teacher Participants

Data Analysis

I conducted an analysis of the transcribed interviews by coding them and looking for emerging themes, a standard procedure in qualitative data analysis. In order to make sense of how these themes are related, I produced a graphical representation of participant perspectives based on the interview responses: a concept map that I used to ground more specific observations (Figure 2). This use of concept maps or other graphical representations of qualitative data to illuminate underlying connections is often referred to as phenomenography (Bledsoe, 2007). After this initial scrutiny I undertook a more in-depth analysis of the particular focus terms (satellite, remote sensing, etc.) using Atlas.ti, a software package that facilitates interpretation of qualitative data. I coded the data in the program based on my first set of themes and proceeded to look for additional and/or disconfirming evidence. This revisitation of the data yielded some new themes and added to the overall picture emerging from the interviews.

Emerging Themes

Interpreting the Theme Map

As I coded my data a picture of how the topics relate to each other began to emerge. The figure I produced (Figure 2) is essentially a *concept map* of my *emerging themes*. It illustrates therefore not only the themes that emerged from my interview responses, but also their relationship to one another. I refer back to this figure frequently in the analysis to help the reader construct the same picture that I took away from the interviews.

My interview questions (see Appendix I) focused on the topics of ocean literacy and satellite oceanography. I realized on interpretation of the results that ocean literacy serves as a good framing term for soliciting attitudes about ocean sciences in general. The first two theme categories at the top of the figure, *Motivation for Ocean Literacy* and *Components of Ocean Literacy*, reflect responses to this question. Satellite oceanography, as the content area SMILE has directly addressed, then becomes an application of these broader ocean literacy concepts. Themes emerging from discussion of this topic are shown in the final theme category: *Satellite Oceanography and Remote Sensing*. All of the themes within these categories may themselves be arranged relative to a broader *perspective spectrum*, shown on the left of the theme map. Sub-themes of *Sense of Place* and *Inquiry vs. Theory* both contribute to this perspective spectrum.

The themes do not represent distinct ‘positions’ on the part of individuals. In fact, more often than not people expressed multiple themes in their discussions of the terms. Sometimes a theme was discussed in terms of a negative definition, i.e. what is *not* required for ocean literacy. So while there was debate about the relevance or importance of individual themes, they are not mutually exclusive but complementary in the sense each was discussed in response to the interview prompt. Each of these categories and themes are discussed below in greater depth.

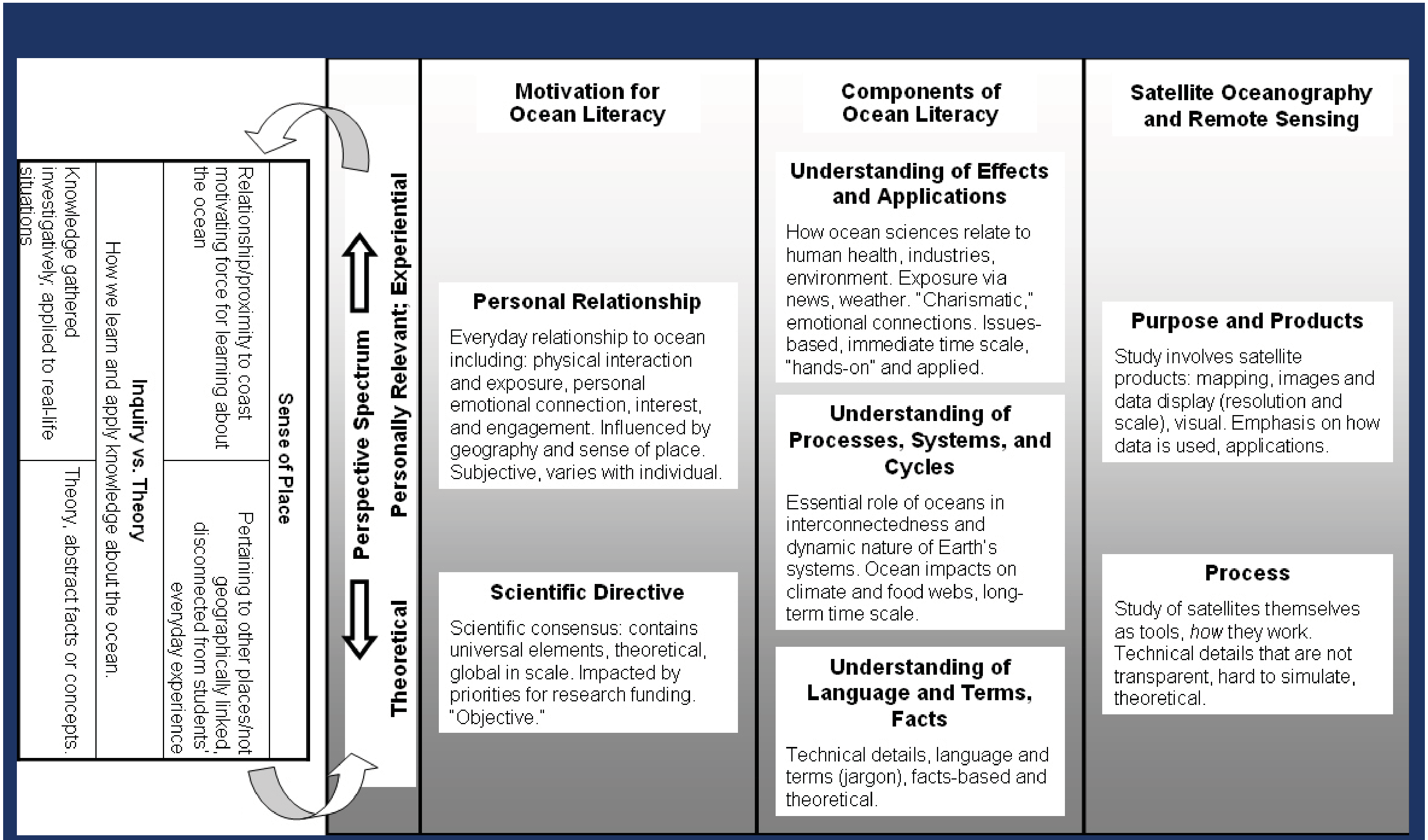
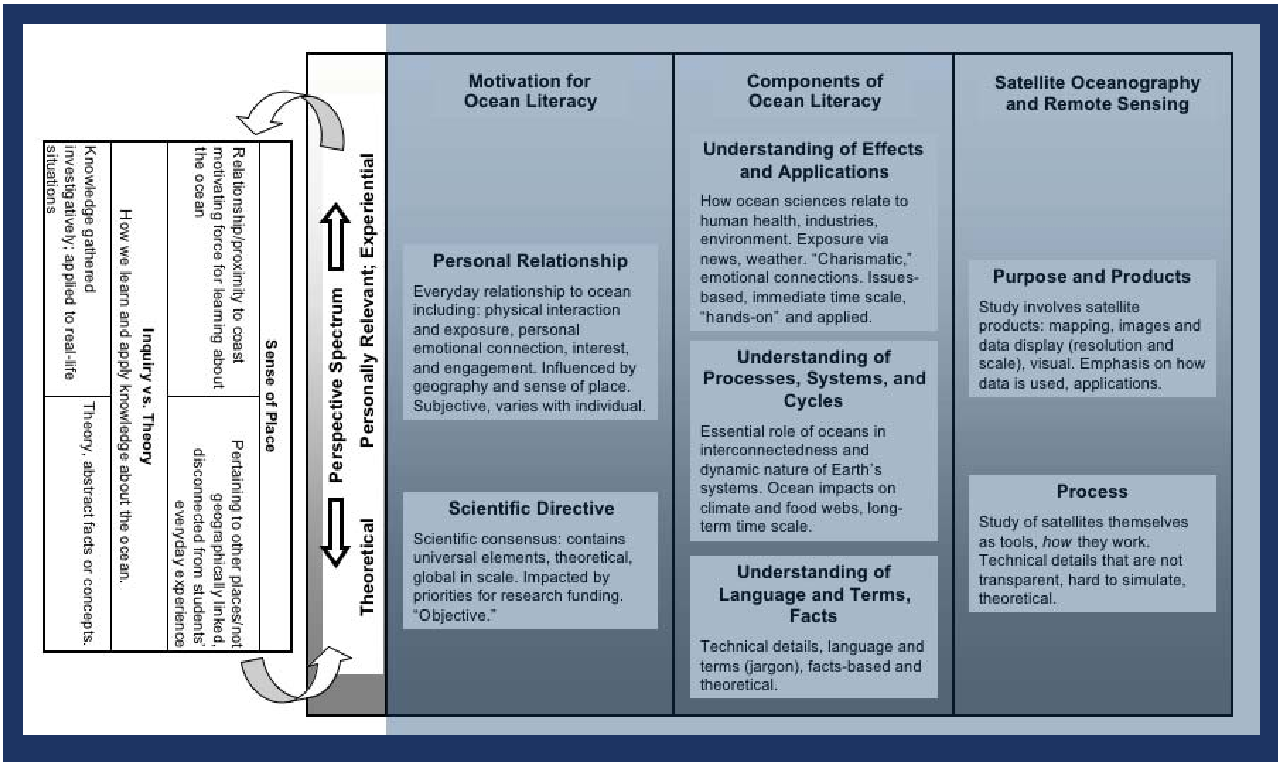


Figure 2: Theme Map



Perspective Spectrum

The first thematic pattern that emerged in the responses was orientation on a spectrum of the more *theoretical* to more *personally relevant and experiential*. The CIOSS representative I interviewed contributed the following quote to illustrate this spectrum:

> I think that people are not excited by just knowing something for the sake of knowing it. Which is the traditional academic. People want to know it because some fisherman went overboard and they want to know if he is going to live. There's a red tide, there's an oil spill. They need the application. Traditionally NOAA is the organization that is supposed to apply science to society's needs. NSF is traditionally an organization that did science for the sake of science. (CIOSS)[1]

This "perspective spectrum" therefore includes two important elements. The first, *sense of place*, has to do with one's own relationship to the ocean in terms of physical proximity, emotional connection, and geography. The second, illustrated in the quote above by the word "application," refers to how we interact with the ocean and information about it, whether we *apply* our knowledge critically in independent and relevant ways, or whether that information is presented to us as decontextualized *theory*. Each of these elements deserves some further discussion.

1 Individual teachers are identified by a number preceded by the letter T (T#). Other codes identify the current SMILE staff member (SMILE Staff), former SMILE graduate assistant (SMILE GA), and CIOSS representative (CIOSS).

Sense of Place

Invariably the concept of place and space came up when people, whether teachers or other SMILE employees and partners, talked about making ocean sciences relevant to students. Given the distribution of SMILE clubs around the state, some from as far away as the Idaho border in eastern Oregon (a full day's drive from the coast), it makes sense that the effect of a physical relationship or proximity to the coast would vary as a motivating force for learning about ocean sciences. As one teacher put it:

> I think the sense of space for them is interesting too because you know a lot of them have never even left the town where they live. Some of them have never seen the ocean. So to be able to talk about places far away, or at least far away to them, opens up the fact that there's so much more out there than, you know, you and your school and your grocery store and that's it. (T6)

This observation has some very real results in practice:

> As soon as they could see Newport was on the map and Siletz was on the map- where they go to school, then all of a sudden this was the coolest activity in the universe just because they could see this is where we are, that's happening right there. (T3)

This manifested in discussion about the *scale* of the term *ocean literacy*. "World definition, I mean, how big are we talking?" (T1).

> Living on the coast, generally I think more people understand about the ocean because that's where we get our weather. But if someone's lets say from… I don't know. North Dakota. Their view of ocean literacy might be something totally different. So what is it? How do we define it? It will mean several things to several different types of people. (T8)

This last quote highlights the fact that this sense of place will be an important factor in individual interest level and valuation of the study of ocean sciences.

Application: Inquiry vs. Theory

Another aspect of this perspective spectrum is reflected by how we learn about the ocean and what we do with that knowledge. *Inquiry* implies the gathering of knowledge investigatively. This type of learning is emphasized in science education, as it is considered by many (including the National Academy of Sciences and the National Research Council) to embody the scientific method: asking questions, making predictions, testing hypotheses, sharing and debating results. By contrast, a more theory-oriented education program might emphasize the memorization of abstract facts and the structures that tie those facts together and might focus on reading or listening (rather than doing hands-on activities) as a way to learn. According to the National Science Education Standards (National Academy of Sciences, 1996), skills gained through inquiry allow for critical thinking about a subject, and the easier application of knowledge in novel situations. According to proponents of direct instruction, without a strong foundation in terminology, ideas, and how they are structured, students can't make sense of new situations. The difference between these two approaches was reflected in some interview responses.

> I know that in elementary school… they go to an outdoor school and then they go to build robots and then we expect them in this one year to make this quantum leap to "I'm not gonna think that playing with robots is cool anymore I'm only going to love being on a college campus and doing data." (T3)

> There have been times at high school challenge where the kids have gotten into the labs and actually gotten to look into the microscopes and actually done things. And they really liked that. Instead of just going and sitting in a room and having somebody tell them about it. (T2)

> I think anytime that they can actually see something happening rather than just hearing that it happens, if they can observe the salinity currents or the temperature curves... Anytime they can make their own observations rather than just having to take your word for it. (T6)

"They like to create something on their own. So something good along those themes of oceanography, that somehow explain and apply some of the concepts" (T4). This idea of *application* is the inquiry model in practice in the classroom and challenge scenarios. Again and again the teachers stressed the importance of this in engaging their students. "We had some real challenges with the satellite ones. Partly because we couldn't get access to the technology we needed and partly because it wasn't really all that hands-on for them. They didn't get to build anything or make anything" (T6). The SMILE staff member said: "When it doesn't work it's because it's too theoretical, and when it works really well it's engaging and fun. But it is meant to be a challenge. And that's again one of those balance points" (SMILE Staff). The past SMILE graduate assistant I interviewed also reflected on the difficulty of striking this balance:

> [It] took a little feedback from the teachers to realize how big to make the activities, how hard, what's the appropriate balance between inquiry and "this is what you need to know so here you need to know it." … But if you want people to do inquiry and sort of discover stuff themselves, you've really got to pare back what you're trying to do. Which is also hard because you're also trying to say: "Well, we've got 5 lessons and we want them to be ready to do a good job and not be overwhelmed at the challenge," so that was always sort of a hard balance to strike in my book. (SMILE GA)

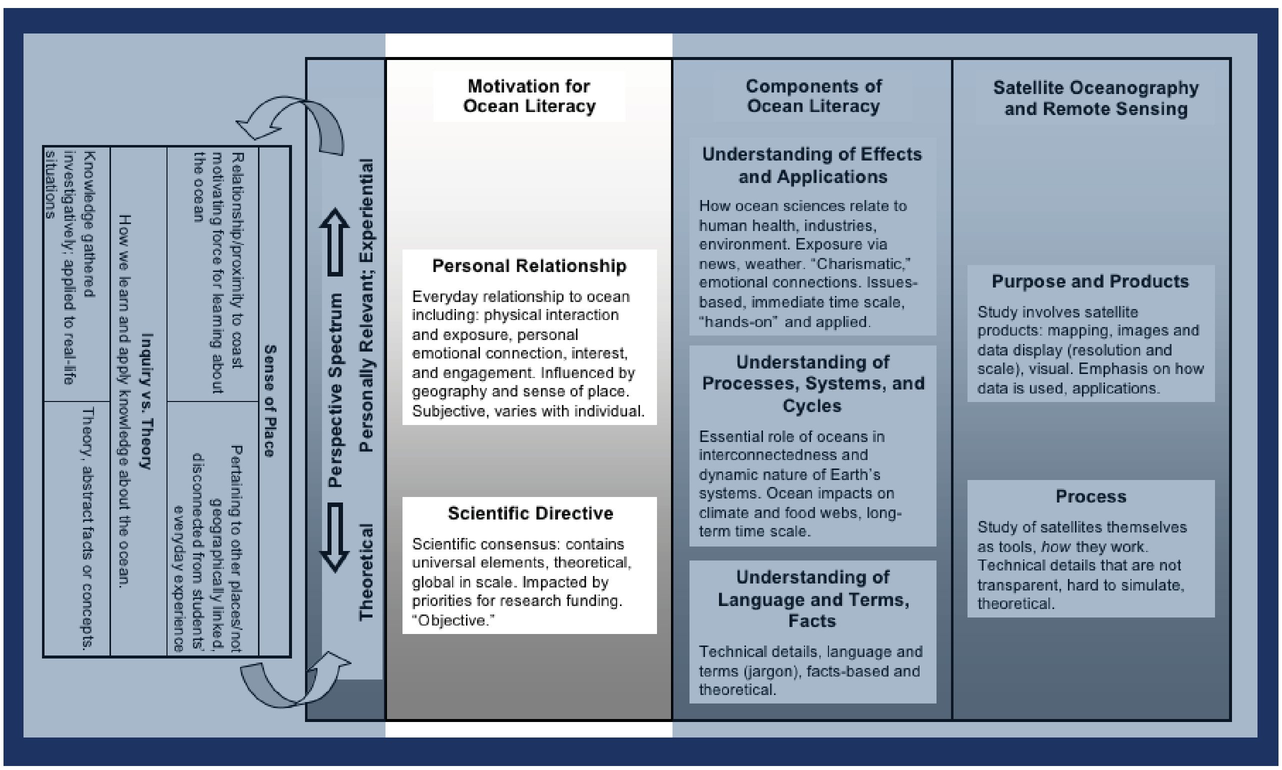
As the CIOSS researcher explained:

> People don't really understand what science is to start with. Studying the ocean, to them- as soon as you say that they think of Jacques Cousteau. If you then talk about something like shellfish closures or harmful algal blooms hurting the sea lions, then they start to have some picture. But the idea that you have to understand the physics of the ocean, understand where things are carried, understand that the ocean is a big part of the climate machine… It would be quite useful if our population was not just ocean literate, but science literate. (CIOSS)

Clearly this issue runs deeper than the ocean sciences subject area, and has a broader audience than the SMILE teachers.

Interpreting the Perspective Spectrum

While this spectrum could potentially be viewed as an either/or dichotomy, people tended to go back and forth depending on what they were talking about and in response to these underlying themes. The theoretical end of the spectrum includes more abstract approaches, knowledge disconnected from personal or geographic relevance. The experiential end reflects knowledge anchored in personal relevance, whether through physical interaction with the ocean, emotional connection, or application of that knowledge in real-world scenarios and problem solving. Everyday instances may incorporate both, but reflect a bias toward one or the other. An example is the difference between scientific literature in the form of journal articles and similar academic publications, versus popular science literature in the form of broadly marketed magazines or novels (c.f., Gee, 2001 for a more in depth discussion). For this reason I have chosen to use this theme as if it were an axis on a graph. I believe that it is helpful to think of it as a spectrum or continuum, on which we can organize the other content themes relative to each other.



Ocean Literacy Motivation

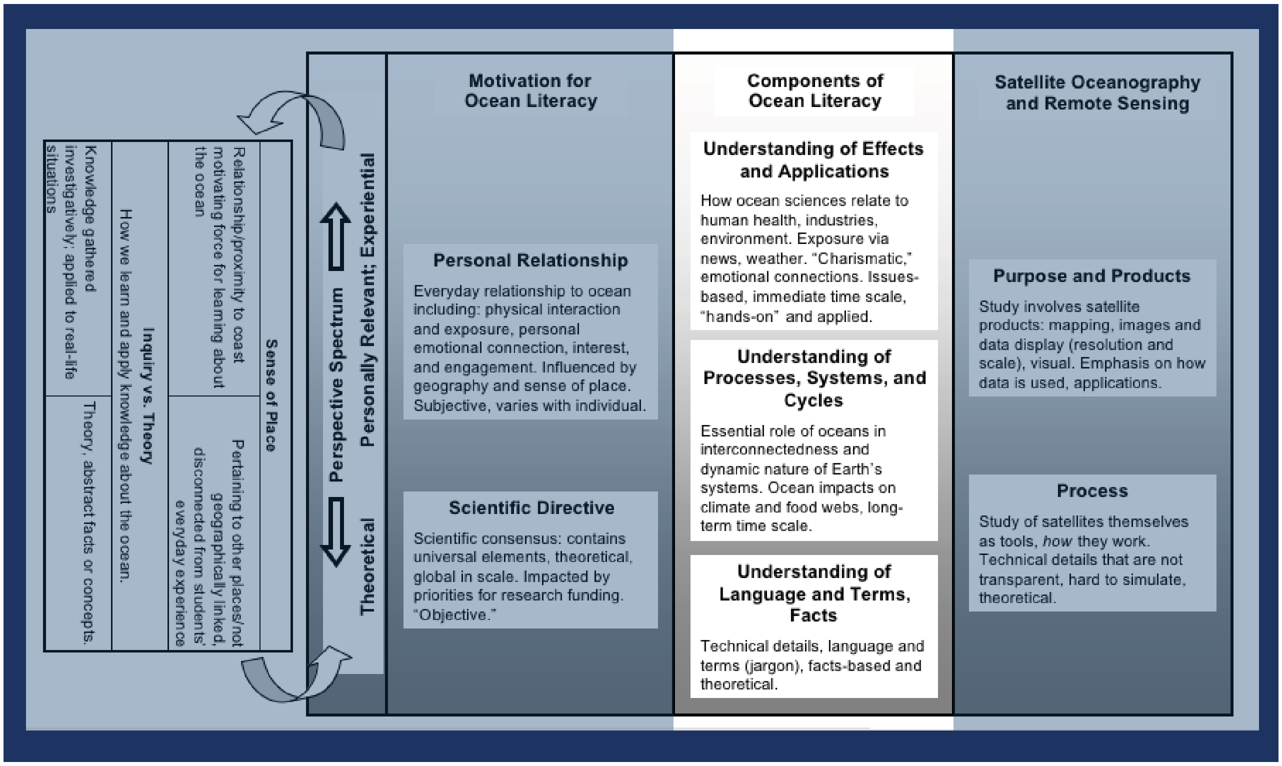
In attempting to define "ocean literacy," people often alluded to their opinions about the origin of this term. The category *Motivation for Ocean Literacy* includes responses that indicated interviewees' perceptions about who was responsible for the term, both in defining it and encouraging its promulgation. In essence, it addresses interviewees' perceptions about why one would want to be or "should" be ocean literate. This manifested itself in two general themes: the idea that one's own personal relationship to the ocean does/should motivate one to be literate, and the idea that ocean literacy and its definitions and goals are passed down as a scientific directive.

Personal Relationship

Responses falling into this theme had to do with an "everyday" relationship to the ocean, including physical interaction and exposure as well as personal emotional connection, interest, and engagement. As a former SMILE employee said: "I think if you can ground things in things that might be interesting and important to people, then that is a way to help motivate people to learn." (SMILE GA) Teachers contributed comments like: "Living on the coast more people understand about the ocean because it's where we get our weather" (T8), and "I've seen things on OPB and I was amazed" (T18). This perspective is heavily influenced by geography and sense of place: "Some of them have never seen the ocean" (T6). It was also viewed as subjective, believed to vary with individual: "It will mean different things to different types of people" (T8). The current SMILE staff member I interviewed said the following: "As human beings we've walked around on the moon more than we've walked around in the [deep] ocean. We tend to think of coastal margins because that's where we live and interact" (SMILE Staff).

Scientific Directive

In contrast to the view of motivation for ocean literacy as originating in personal relationship to the ocean is the idea that it stems primarily from a scientific directive. This theme expresses the view that ocean literacy, as a goal, arises out of scientific consensus, contains universal elements, and is global in scale. "It's part of our world. They should probably have an understanding of it" (T14). "Learning as much as we can about the ocean. And there are certain things that all of us should know. I don't know what oceanographers think we ought to know" (T10). The former SMILE graduate student noted that "some things are universal, things about the ocean people should know if they want to have a good understanding of how the world works" (SMILE GA). Though this may seem like a more "objective" interpretation, this person also acknowledged that it could be impacted by research funding priorities: "…wanting people to know about their science so that they'll fund their research more… The funding agencies are saying 'You're going to do it'" (SMILE GA).



Ocean Literacy Components

The next category addresses the Components of Ocean Literacy: the elements people discussed as composing a definition of the term. It is represented in three themes: Understanding of Effects and Applications; Understanding of Language, Terms, and Facts; and Understanding of Processes, Systems, and Cycles. Generally these themes were not discussed as alternative, mutually exclusive definitions, but as different aspects of one comprehensive definition.

<u>Understanding of Effects and Applications</u>

Many people described an understanding of how ocean sciences relate to human health, industries, and the environment as an essential piece of ocean literacy.

> Understanding, explaining, apply ocean concepts to real life events. So some of the things such as the density and the little things ... the salt water, and they can somehow relate that to one or two things with upwelling that might take place, or you know, latitude and longitude, some of the map reading skills. (T4)

"Why would you need to know this? We really have to focus on why this is important" (T2). "Being able to speak intelligently about what's going on in the oceans and how it affects the planet" (T3). In this sense it also requires critical thinking, to be able to speak intelligently and think logically about impacts. "That's all part of literacy, being able to ask the questions and go out there and research it and find the answer" (T12). Information about this component of ocean literacy was easily accessible via the news or local weather. “Weather, that affects everybody, even if you don’t live on the coast” (T5). “I can watch the news, watch the weather, and realize: ‘jet stream, water cold/hot,” I get the idea” (T8). It also included “charismatic,” emotional connections: “Everybody likes mammals” (T5). “The sharks and sea turtles are going to be the things that immediately come to mind and grab students” (T15). It was also issues-based, “hands-on” and applied. “Apply ocean concepts to real life events” (T4). One teacher summarized this perspective with the following anecdote:

> I think of the language that I use, like if I go home and I talk to my mom and she’s explaining something, and she kind of gets the grasp of it. She might not know the terms “upwelling” or “el Niño” or something like that, but she kind of gets how it works and she lives close enough to the coast to know that in the summer the water gets cold, and if the water gets too warm that could be a bad thing, and you know, maybe something might happen with global warming if we do enough. But it’s kind of just being aware as opposed to not having any idea what that is. I’m not talking ocean literacy like you know all the vocabulary, but you have a general ideal of how it all fits. Is what I think of ocean literacy. (T3)

Understanding of Language and Terms, Facts

At the opposite end of the perspective spectrum was the opinion that technical details, language and terms (jargon) are components of what it means to be ocean literate. “They should know a basic vocabulary” (T8). “I see it as a list of definitions” (T17). “Don’t bog people down in terms, but sometimes terms are what you need” (SMILE GA). Generally, this view was that ocean literacy is more facts-based and theoretical: “Trying to understand all the properties of the ocean” (T13). “Buoy. A four letter word my kids don’t know! There’s a lot of vocabulary you really have to go through” (T17).

Understanding of Processes, Systems, and Cycles

At the interface between the fundamental facts and concrete applications, people discussed the need to understand the essential role of oceans in the interconnectedness and dynamic nature of Earth’s systems. These “big picture” concepts involved both fundamental terminology and content knowledge and applications and effects. For example, ocean impacts on climate and food webs. “It’s a big, complicated picture. You don’t just get that on a bumper sticker” (T5). “I would look at ocean literacy as being able to understand the processes throughout the ocean” (T19). SMILE staff and research partners in particular emphasized this aspect, likely due to their roles facilitating outreach and awareness of both the background and applied elements required to understand these issues.

> Ocean literacy for me is really about these big systems pictures. And its just an understanding that there are big, complicated, interconnected systems in the world that 1) are really

> fascinating, that 2) are really, really hard to understand, and 3) are going to play out, and have played out, and will continue to play out huge, for huge implications in the world. (SMILE Staff)

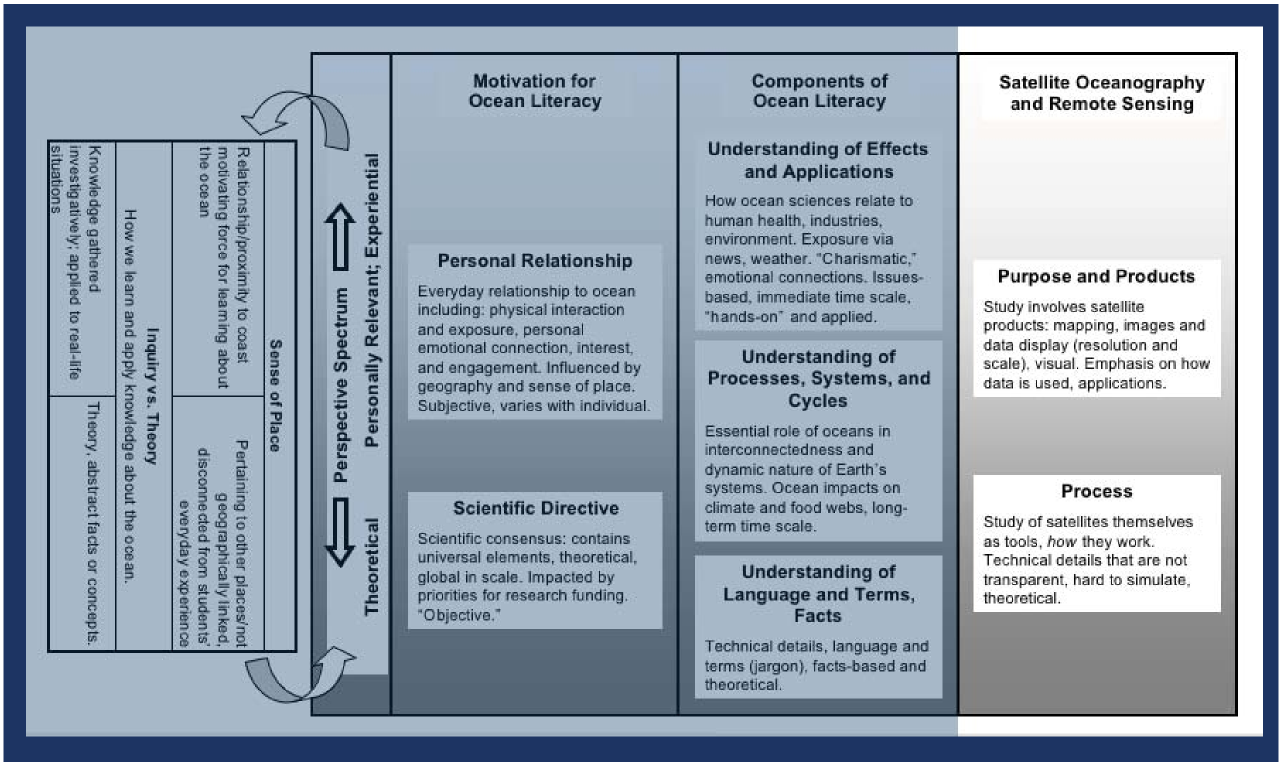
Ocean Illiteracy

Though not a “component” of ocean literacy, the concept of “ocean illiteracy” was discussed in several of the interviews. The term was not part of the question prompt, but several interviewees ‘coined’ it independently. “Just because of where they are our kids are even more ocean illiterate because they don’t even hear the terminology, like El Nino, because it doesn’t affect them” (T2). Most often references to this term reflected feelings of inadequacy with regard to the terminology component of the ocean literacy definition produced by the study participants. “I hardly know anything about any of the terminology that deals with any part of the ocean. It’s like being totally illiterate” (T16). This idea of “ocean illiteracy” may have been appealing to interviewees because the complex definition of ocean literacy makes it easier to say what it is *not*, rather than what it *is*.

In addition to the teachers the former SMILE graduate student said this:

> Personally I think when you start talking about science literacy or ocean literacy you get in a slippery slope situation where it sort of becomes one of those deficit models where you say “You, public or non-scientists, need to get yourself literate in my field of science,” oceanography or whatever it is, and that you really place the burden on the person who has the deficit, or you view people has having a deficit. Like “Oh you people in Burns, Oregon are ocean illiterate. And you need to become literate and understand what I’m talking about.” (SMILE GA)

This perspective indicates that use of “ocean illiteracy” may also result from this “deficit model,” and the value judgment teachers may feel it to impose.



Satellite Oceanography and Remote Sensing

The final category that emerged from my interview responses focuses on *satellite oceanography* and *remote sensing*, which could be viewed as an application of ocean literacy. The interviewees approached the topic in two general ways. Discussion focused primarily on the *purpose and products* of satellite oceanography research, and the *process* through which data is actually collected.

<u>Purpose and Products</u>

From this perspective, satellite oceanography is the study of satellite products, mapping, image interpretation and data display, including resolution and scale. "We've always asked the students to look at the data and not focus so much on how that data was collected" (T15). It is highly visual: "They just looked at maps and kind of answered and discussed" (T6). Emphasis is placed on how data is used, applications: "We looked at temperature and algae on maps and talked about what you saw and why… what kind of effects it might imply" (T11).

> The satellite stuff has been ok because the kids do get some, watching the weather forecast they do get some idea what satellites do so we can tie it in to that. You know the idea that you can use it over the ocean is… It's not as effective with them. They do understand that satellites can receive images and can pick up data… But mainly we have to relate it back to weather, something they see on a nightly basis. (T2)

> We looked at the temperature and, I think it was algae. On maps. And we talked about what

> you saw and why you might see that and what kinds of effects it might imply. Not necessarily that they would know for sure what was going on. We looked at different days; we did this some last year too. We went online and we looked at real time satellite imagery. And they could pick out differences and talk about what they saw. And it was more observational. Because they don't have a sense of what it's like to be on the ocean. (T11)

Process

Interviewees also discussed the study of satellites themselves as tools, including the technical details about how they work. "We talked about the different information they collect. It's always been kind of a preliminary to what the students would then be doing. That's the part of the lesson you don't really expect to soak in" (T15). These details are not transparent, are hard to simulate, and highly theoretical. "As far as my kids are concerned, if I don't show them the tool, physically show them an axe, they're not going to know what that is" (T17). "We're going: 'isn't this satellite imagery cool?' You don't necessarily know how it works. We're kinda going to put little dots on a paper, we're gonna talk about it, and I think that's something, I don't know" (T3). "Even for just for my own knowledge and wanting to increase the education of the students I don't feel like I get enough of a grasp of what exactly we're modeling. To be able to explain it" (T18).

> We've always asked the students to look at the data and "What were some general conclusions?" and not focus so much, not have their activity turn on how that data is collected. So it's more been: we'll give it a little story about where that data came from and then let's get into the data and look at the patterns and things like that. (T15)

Difficulty with the material was attributed to the theoretical nature of satellite studies. As the former SMILE graduate assistant said: "Satellite oceanography is fairly specific… I wouldn't go so far as to say esoteric, but its not something that you can pick up in 10 classroom lessons" (SMILE GA). The wealth of background material and new terminology involved in the subject could prove intimidating to some teachers.

The current SMILE staff member also expressed this challenge of the satellite material. "How satellites work, how they see, how they orbit, mechanics of it is not very transparent to very many people. We're talking about something that's about as little hands-on as we can get" (SMILE Staff).

Use of Satellite Terminology

The teachers seemed hesitant to use the terms *satellite* and *remote sensing*, even after they were introduced, and several probes were often needed to generate discussion on the subject. Some teachers were confused about what types of data could be collected by satellite. "We talked about how each color with the salinity maps and stuff, we talked about how each color represented a different concentration or a different temperature or whatever you wanted it to represent" (T6). Others had difficulty identifying with satellites as "tools in oceanography," as illustrated by this exchange:

> T18: But what *tools* do you talk about that oceanographers use to collect the data? I don't remember talking about tools?
>
> T20: Well that is a tool. The tool is the satellite. Just understanding how it works is understanding the tool.

In addition, the teachers seemed to rely on concrete examples of specific club activities, with little discussion of abstract concepts. "We pictured the different colors and we made those 3-D glasses and stuff but we didn't really connect it back very well" (T11). "We did the mapping the sea floor via remote sensing stuff too. Based on activities in the past" (T12). "We used the GNOME project web site last year" (T14). The few references to satellites in general terms were vague. "'This is a satellite in orbit.' Then they can sort of think 'Well ok, what does a satellite do? Well, can we program it to do this? Do that?" (T17).

General references to *remote sensing* often drew on technology other than satellites. "... The tracking devices that were placed on some of the different creatures that would be tracked so we could see how they matched with salinity or temperature" (T5).

> The little submarine-type thing that goes down and takes samples, and brings them back up. And you know talked about the kind of data it is capable of collecting, kind of like satellites… We send these submarines down to take different samples at different levels to see what's happening at the different layers in the ocean… We took them out on the boats and we actually had them sampling kind of in a rudimentary way, the way that a submarine does it. You know, you take this little container and you drop it in the water and it does its thing and you pull it back up and you've got a clean water sample that you can then go and test. And you can drag the bottom of the bay at different levels and you can see what's there. And you can look at the salinity and the difference and stuff. So. Those are the things that we have done. (T10)

Only one of the teachers I interviewed used the term "satellite" during the discussion of ocean literacy, before being prompted by the third interview question. Few talked about the material with any sense of authority, often bringing in their colleagues or qualifying their own knowledge. "[Another teacher] and I were talking earlier about the remote sensing activity, which neither of us have yet done. So it's a little tough" (T15). "This is my first year in SMILE, and I don't feel like I've taught that much of it so far" (T20). "Well I modified the glasses one. I don't know if I didn't read it very well…" (T17)

> I think part of it is partly my fault because I don't feel like I have as strong of an understanding as maybe I could with those concepts and so I automatically think that they wouldn't be as interested or wouldn't get it or might not understand the depth that we want them to. (T6)

Some of this discomfort may have been due to teachers' perceptions of the interview environment and my role with SMILE, feeling they were being quizzed. Even taking this into consideration however, it is clear that the teachers did not have an authoritative relationship to the subject.

Discussion

Several of the themes that emerged from interviews with SMILE teachers, staff and research partners highlight areas that could represent the source of some of the challenges involved in marine education in general, and The SMILE program more specifically.

Ocean Illiteracy

In 1995 national organizations including The National Geographic Society, National Oceanic and Atmospheric Administration (NOAA), COSEE, and the National Marine Educators' Association (NMEA) collaborated on a report detailing Essential Principles and subsidiary Fundamental Concepts that serve to define ocean science literacy (see Appendix II) (COSEE, 2006; Cava *et al*., 2005). This collaboration involved discussions among 100 scientists and educators and the standards were developed after the model of the National Academy of Sciences standards. The resulting standards now serve as the national definition for ocean literacy.

Ocean literacy, with its 7 Essential Principles and 44 Fundamental Concepts is not simply defined. But to COSEE and others, one who is ocean literate can:

- Understand the essential principles and fundamental concepts
- Communicate about the oceans in a meaningful way
- Make informed and responsible decisions regarding the oceans and its resources

The ocean literacy emphasis mirrors that of basic science literacy in that the ocean literate individual should be able to not only understand major concepts of ocean function, but apply those concepts to critical analysis of resource use and communicate that understanding meaningfully.

"Ocean illiteracy," in the context of these interviews, provides a negative definition that emphasizes lack of terminology and factual background. This highlights an interesting discrepancy between teacher perception and NOAA's Ocean literacy campaign. In their promotion materials NOAA and the National Geographic Society highlight the 'big picture' components of ocean literacy, "an understanding of the ocean's influence on you and your influence on the ocean" (National Geographic Society, 2006). Though the essential principles and subsequent fundamental concepts go into more detail, they do so while using a lot of the terminology that some audiences may find intimidating. For example, fundamental concept 5f states:

> Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy." (National Geographic Society, 2006)

While the big picture concepts are essential to engaging and interesting people in the subject, it is competency with the terminology and basic concepts that make them *feel* literate. This may reflect the need for improved national basic *science* literacy.

SMILE Satellite Oceanography: The Process Piece

This pattern also emerged in teacher responses to the satellite oceanography content of the SMILE programming. In general teachers expressed less detail and more hesitancy to talk about the more theoretical and technical process pieces of satellite science. It is likely that without a solid understanding of this piece, teachers don't feel confident or adequately knowledgeable in the subject. A teacher leading an activity exploring satellite data would want to be prepared for a student to ask how that data is produced. No matter how comfortable a teacher is with the *products* of satellite research, an understanding of the *process* of producing those products is necessary for them to feel competent with the subject. As one teacher put it:

> One of the things that I find real hard for myself is I'm not an oceanographer. I teach mathematics. And there's some of this stuff that when I look at it I don't understand it, and then it's really hard for me to explain it to my kids. And if it were a little bit more user-friendly that would be good because then I might be able to figure out how to use it before a kid would... But I can't, there's times when I'm going "I don't know what I'm supposed to be looking at." (T10)

Reflecting on teacher response to the activities the former SMILE graduate assistant said:

> It often depended on the teachers' prior knowledge. And, sort of confidence in their ability to understand biology or chemistry or physics or whatever. It seems like a lot of times the math teachers were less comfortable with the material than some of the science teachers because there is a lot of math involved in oceanography… [but] it's not really that fun. Like "let's do differential equations!" Oh yeah, we love oceanography! (SMILE GA)

SMILE hasn't emphasized the process pieces in the past due to the difficulty of developing engaging club activities to address them, exceptions noted by teachers being the "Shoebox Satellites" activity (simulating altimetry measurements), GNOME computer simulation (showing chlorophyll), and "Satellite Winds" activity (scatterometry). However, if we shift our perspective from the students to the teachers as our audience, we can see how targeting the teachers with some process-oriented professional development may help them feel more comfortable with the subject. This in turn could improve the classroom activities, whether or not they deal specifically with the process of satellite research, as teachers will be better prepared to discuss these aspects of the topic and feel more confident in general. In addition, the teachers themselves acknowledged the importance of learning about and bringing more of this aspect of satellite science to their students:

> I think this is an important piece, that they learn some of the technical side of this as well. This would be great to send some of our students to become researchers for this new system that they're trying to build. (T15)

Multi-faceted Environmental Problems

Another potential challenge highlighted by this research involves the Understanding of Processes, Systems, and Cycles component of ocean literacy. This area is where foundations and applications intersect. As the current SMILE staff member I interviewed said: "It's time we stopped ignoring earth systems. All of this is interconnected. Which in one way we rationally know, but I don't think we emotionally know this at all…Public policy, health, global health, all those pieces are intertwined and at the center of every single one of them is the oceans" (SMILE Staff). The very fact that there are emotional as well as rational dimensions to the issues arising at this interface reflect the personal level of human knowledge about the oceans. Our own experience, daily exposure, and dependence on resources, as well as our emotional connections assure that issues like climate change are viewed as neither purely scientific, nor purely social. This is related to the nature of the science, and specifically our experience living in the "field" of this science. It is hard to picture such divisive and highly politicized issues as climate change and fisheries management coming out of a field like astronomy. The unique nature of earth sciences also manifests in politicization and scientific "credibility" issues, once again reflecting the implicit value judgment inherent in our perception of *scientific* versus *personal* knowledge. A scientist who takes a stand as a concerned citizen with a personal and emotional investment in an issue risks loosing credibility as an 'advocate' for a cause, and therefore no longer 'objective.' This assumption of scientific impartiality is part of the dominant western worldview.

However, the location of these issues at the interface of the emotional and the rational also provides motivation for education. As the CIOSS representative stated: "There seems to be more need to educate the population as we perceive that we are moving toward crises in both climate and ocean resources" (CIOSS). There is hope that our personal investment in the ocean will lead us to a better understanding of it.

Conclusion and Recommendations

Applicability

The teachers in this study are in a unique position to inform this research due to their diverse educational and geographic backgrounds and their experience working with the SMILE oceanography content. Though these teachers represent a particular program and a single state, they may be considered to be representative of rural high school teachers in general, to the extent that any barriers to communication uncovered in this audience might reasonably be expected in any audience of high school educators. The patterns observed in the SMILE audience of high school teachers may also serve to inform others working to achieve the broader goal of improving ocean literacy as it demonstrates some attitudes and preconceived ideas that people may hold about the subject. Though I did not conduct an explicit member check exercise to confirm my conclusions with my interviewees (Patton, 2002), my repetition of the group interviews with six different groups of teachers provides some level of triangulation (the use of multiple methods to "check" results) in my data, as does the use of two types of analysis (coding for emergent themes and close analysis of use of particular terms).

SMILE Oceanography

Though there are many challenges to effective partnerships I believe that this research helps to identify some potential barriers to success in the SMILE oceanography program.

Recommendations for SMILE programming:

- Formalize formative evaluation using interview methods.
- Teachers and students represent two distinct program audiences:
  - Teacher comfort with satellite oceanography and remote sensing may improve with more technical professional development.
  - Students benefit from application, personal connection to material.

As part of a formative assessment of the SMILE oceanography program this study provides information that is being implemented immediately toward the improvement of the program. Compared with summative assessment, which focuses on completed programs, formative assessment is often challenging logistically since it occurs while a program is still ongoing. This means that assessment efforts may draw on resources needed for the programming itself. My role as graduate assistant within the SMILE-CIOSS partnership put me in a position uniquely suited to accomplish this project, though not without constraints. On one hand, a new perspective on the program was valuable. In a half-time position however, I was pressed to accomplish my programming objectives and this project simultaneously. Its successful completion however, demonstrates the utility of the methods I used.

In particular, this study highlights the importance of basic science literacy, terminology and other fundamental pieces, evident in the SMILE teachers' need for *process* pieces to feel confident and literate about the satellite oceanography content. This demonstrates that there is still work to be done toward achieving the program goal of increasing teacher understanding of ocean sciences and use of satellite data to engage students. Recognition of this challenge, however, also presents an area for program improvement through the introduction of technical aspects of satellite oceanography in future professional development.

Ocean Outreach in General

Scientist-teacher partnerships play an important role in science education, and may play an especially important role in promoting ocean sciences, largely overlooked by standard school curricula.

Insights for outreach programs in general, including the broader goal of improving ocean literacy:

- Ethnographic interviews are a potential method for formative assessment of outreach projects.
- Global environmental problems like climate change present opportunities to reach a broad audience on a personal level.
- Innovative, responsive outreach is important in engaging the public and promoting ocean literacy.

The rich qualitative data collected in this study goes beyond a simple accounting of goals met. Qualitative data, by eliciting feedback on teacher's sense of meaning and personal relationship to the material, also provides information that can help make new material more effective and engaging. The repeated reference to climate change and the importance of the ocean in global climate processes is an indication that this subject may provide opportunities to both inform, with regard to complex technical foundations, *and* engage, due to the relevance of climate in everyone's lives.

The methods of this study are presented as a potential way to incorporate audience assessment into the primary/formative needs assessment of any outreach project. This has helped The SMILE Program collect information about content areas that may be problematic for their audience of educators, and therefore the greater audience that the educators will serve, and will allow them to change their content accordingly. Outreach that is responsive to the audience is ultimately more effective.

Outreach is never easy, but attempts to better understand the dynamics of partnerships and the needs of the audience can help make them more successful. As articulated by my SMILE staff interviewee: "The ocean literacy list is fine. The challenge is making it happen. The gulf between that initial statement and the most rudimentary form of delivery is as big as the oceans are" (SMILE Staff).

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The SMILE Program

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Appendix I: Interview Instruments

Mini-focus Group Instrument:

Q1:

I imagine that ocean science material is received differently by students who may have different levels of personal connection to the ocean in different areas of the state. Since SMILE is expecting to continue to receive funding for oceanography content, it would be valuable to know how the past content has been received and how we can continue to keep students interested in the topic. Could you describe what you would consider to be effective strategies for engaging students in ocean science material?

Q2:

Ocean literacy is a term that is being used increasingly by organizations promoting marine education. Could you describe what this term means to you?

Q3:

While using the SMILE oceanography content in your clubs, how do you talk about the tools oceanographers use to collect data?

Follow-up:

[You mentioned the term remote sensing/satellite oceanography.] In developing content SMILE has tried to emphasize remote sensing and satellite oceanography. Could you tell me a bit (more) about how you use these terms/what these terms mean to you?

Individual Interview Instrument:

<u>Representative from CIOSS:</u>

Would you tell me a bit about your background? Educational? Professional?

How long have you been participating with The SMILE/CIOSS partnership?
What role do you play in the partnership?

NSF is increasingly emphasizing 'broader impact and outreach' as a component of their grant funding. What are characteristics of successful outreach programs from your perspective?
What have you observed to be barriers toward achieving this success? Probe institutional.
Given that there are many different ways to approach outreach, what do you think about the

value of partnerships such as SMILE? Probe specific benefits/challenges of the SMILE/CIOSS partnership.

With the focus on broader impact has come increased emphasis on the ultimate goal of an “ocean literate” U.S. population. What does the term “ocean literacy” mean to you?

What is the nature of your involvement in the oceanography content development?
In your experience with the program, what has been the response to the satellite oceanography and remote sensing content?
What specific content/knowledge do you believe/hope/expect teachers take away from their participation in the SMILE/CIOSS partnership?
Probe for opinion on role of research science in traditional education.

Current SMILE staff member and former SMILE graduate assistant:

Would you tell me a bit about your background? Educational? Professional?

How long have you been working (did you work) at The SMILE Program? What role do (did) you play in the oceanography content development?

Based on your experience, what do you believe are some characteristics of successful outreach programs?
What have you observed to be barriers toward achieving this success?
Probe institutional, both research science and school institutions.
Probe specific challenges of the SMILE/CIOSS partnership?

With the increasing national focus on ‘broader impact and outreach’ among science funding agencies and marine policy organizations has come increased emphasis on the ultimate goal of an “ocean literate” U.S. population. What does the term “ocean literacy” mean to you?

In your experience, what has been the response to the satellite oceanography and remote sensing content?
What specific content/knowledge do you believe/hope/expect teachers take away from their participation in the SMILE/CIOSS partnership?
Probe for opinion on role of research science in traditional education.

Appendix II: Fundamental Concepts of Ocean Literacy (Cava *et al*., 2005)

Concepts	Essential Principles
1. The Earth has one big ocean with many features.	a. The ocean is the dominant physical feature on our planet Earth—covering approximately 70% of the planet's surface. There is one ocean with many ocean basins, such as the North Pacific, South Pacific, North Atlantic, South Atlantic, Indian and Arctic.
	b. An ocean basin's size, shape and features (such as islands, trenches, mid-ocean ridges, rift valleys) vary due to the movement of Earth's lithospheric plates. Earth's highest peaks, deepest valleys and flattest vast plains are all in the ocean.
	c. Throughout the ocean there is one interconnected circulation system powered by wind, tides, the force of the Earth's rotation (Coriolis effect), the Sun, and water density differences. The shape of the ocean basins and adjacent land masses influence the path of circulation.
	d. Sea level is the average height of the ocean relative to the land, taking into account the differences caused by tides. Sea level changes as plate tectonics cause the volume of ocean basins and the height of the land to change. It changes as ice caps on land melt or grow. It also changes as sea water expands and contracts when ocean water warms and cools.
	e. Most of Earth's water (97%) is in the ocean. Seawater has unique properties: it is saline, its freezing point is slightly lower than fresh water, its density is slightly higher, its electrical conductivity is much higher, and it is slightly basic. The salt in seawater comes from eroding land, volcanic emissions, reactions at the seafloor, and atmospheric deposition.
	f. The ocean is an integral part of the water cycle and is connected to all of the earth's water reservoirs via evaporation and precipitation processes.
	g. 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.
	h. Although the ocean is large, it is finite and resources are limited.

2. The ocean and life in the ocean shape the features of Earth.	a. Many earth materials and geochemical cycles originate in the ocean. Many of the sedimentary rocks now exposed on land were formed in the ocean. Ocean life laid down the vast volume of siliceous and carbonate rocks.
	b. Sea level changes over time have expanded and contracted continental shelves, created and destroyed inland seas, and shaped the surface of land.
	c. Erosion—the wearing away of rock, soil and other biotic and abiotic earth materials—occurs in coastal areas as wind, waves, and currents in rivers and the ocean move sediments.
	d. Sand consists of tiny bits of animals, plants, rocks and minerals. Most beach sand is eroded from land sources and carried to the coast by rivers, but sand is also eroded from coastal sources by surf. Sand is redistributed by waves and coastal currents seasonally.
	e. Tectonic activity, sea level changes, and force of waves influence the physical structure and landforms of the coast.
3. The ocean is a major influence on weather and climate.	a. The ocean controls weather and climate by dominating the Earth's energy, water and carbon systems.
	b. The ocean absorbs much of the solar radiation reaching Earth. The ocean loses heat by evaporation. This heat loss drives atmospheric circulation when, after it is released into the atmosphere as water vapor, it condenses and forms rain. Condensation of water evaporated from warm seas provides the energy for hurricanes and cyclones.
	c. The El Niño Southern Oscillation causes important changes in global weather patterns because it changes the way heat is released to the atmosphere in the Pacific.
	d. Most rain that falls on land originally evaporated from the tropical ocean.
	e. The ocean dominates the Earth's carbon cycle. Half the primary productivity on Earth takes place in the sunlit layers of the ocean and the ocean absorbs roughly half of all carbon dioxide added to the atmosphere.
	f. The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon and water.
	g. Changes in the ocean's circulation have produced large, abrupt changes in climate during the last 50,000 years.
4. The ocean makes the Earth habitable.	a. Most of the oxygen in the atmosphere originally came from the activities of photosynthetic organisms in the ocean.
	b. The first life is thought to have started in the ocean. The earliest evidence of life is found in the ocean.

5. The ocean supports a great diversity of life and ecosystems.	a. Ocean life ranges in size from the smallest virus to the largest animal that has lived on Earth, the blue whale.
	b. Most life in the ocean exists as microbes. Microbes are the most important primary producers in the ocean. Not only are they the most abundant life form in the ocean, they have extremely fast growth rates and life cycles.
	c. Some major groups are found exclusively in the ocean. The diversity of major groups of organisms is much greater in the ocean than on land.
	d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.
	e. The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.
	f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is “patchy”. Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.
	g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, methane cold seeps, and whale falls rely only on chemical energy and chemosynthetic organisms to support life.
	h. Tides, waves and predation cause vertical zonation patterns along the shore, influencing the distribution and diversity of organisms.
	i. Estuaries provide important and productive nursery areas for many marine and aquatic species.

6. The ocean and humans are inextricably interconnected.	a. The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and over half of Earth's oxygen. It moderates the Earth's climate, influences our weather, and affects human health.
	b. 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.
	c. The ocean is a source of inspiration, recreation, rejuvenation and discovery. It is also an important element in the heritage of many cultures.
	d. Much of the world's population lives in coastal areas.
	e. 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 (such as point source, non-point source, and noise pollution) and physical modifications (such as changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.
	f. Coastal regions are susceptible to natural hazards (such as tsunamis, hurricanes, cyclones, sea level change, and storm surges).
	g. 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.
7. The ocean is largely unexplored.	a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.
	b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.
	c. Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.
	d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.
	e. Use of mathematical models is now an essential part of ocean sciences. Models help us understand the complexity of the ocean and of its interaction with Earth's climate. They process observations and help describe the interactions among systems.
	f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Appendix III: Summary of Applications of SMILE Project Results

At the Summer Teachers' Workshop on August 8th, 2007 I presented the project emerging themes back to the teachers (N=12, 9 were participants in the original interview project) and conducted a group discussion feedback exercise. Based on this feedback and the data from the original interviews, I compiled this list of recommendations for SMILE content targeted to both students and teachers. I have also included teacher response and recommendations for the use of this methodology in future evaluation.

Considerations for Students:

<u>Improving Student Engagement Through Sense of Place</u>

Sense of place repeatedly emerged as an important element in determining the level of student engagement in club and challenge activities. It presents a challenge to SMILE programming since the location of SMILE communities means that some students may have more or less direct personal connection to the ocean than others. These points represent ways that awareness of students' sense of place can be taken into account to improve their experience of SMILE programming. Teachers may also benefit from these considerations in their role as learners through SMILE professional development (see **Considerations for Teachers** below).

- Make activities as local as possible.
- Place may be incorporated throughout. For example, provide maps that show locations in relation to students' own communities.
- Provide opportunities for students to travel to the ocean (see **The Role of Field Trips** below).
- Where field visits are not feasible, enable students to engage in "real" virtual or very close simulation of the ocean through multimedia resources (see **Use of Technology** below).
- Personal connection can be developed by emphasizing practical goals and objectives. For example, present a problem to solve that relates to a real world event or other popular topic or trend, such as a local resource management issue.
- Students are particularly interested in "charismatic megafauna," whales and other mammals, turtles. Tying oceanography concepts in to popular marine topics/sources of information and exposure is helpful (the "Nemo effect").
- Catastrophic events are fascinating, of high interest and include a human connection.
- Whenever possible, make connections with students' daily lives. Examples include economics of resource use, cultural aspects, fish and food sources, environmental quality, potential career paths, and alternative energy sources.
- Highlight ocean science history, the "people" pieces and discovery/invention.
- Include local cultural/mythological connections to science and the ocean.
- Topics should relate to career opportunities that are or will be available.

- Bring in the "big picture," global climate, national and international connections.
- Authentic learning- what does it mean to me? Why should I care?

Balancing Inquiry and Theory in an After-School Setting

Another theme that was frequently emphasized in discussion with the teachers focused on the appropriate balance of theory and background or lecture information with the hands-on, inquiry based elements. While the teachers agreed nearly unanimously that hands-on activities were better received by students, the technical nature of the oceanography content area means that some background is essential. Below I have summarized teacher feedback on how these issues impact their students.

- The best activities are hands-on with a story or purpose that leads the students through, gets them excited and gives them a reason to go through the activity and find out an answer.
- Club activities should make a big distinction between club and school.
- Make sure any lecture is at an appropriate level for the students.
- Ask for student input before "teaching" anything. Ask- what do you know about… or what would you like to know about…
- When it comes to worksheet/pencil and paper work, less is more.
- Activities should not be reading intensive.
- Students (and teachers) are more enthusiastic for new topics.
- Involve the students in data collection and making observations, e.g. water quality testing.
- Use technology and new media to enhance student experience (see **Use of Technology** below).
- Having a goal/solving a problem using "real" methods, modeling scientific techniques, using real data/equipment/situations (See **Use of Technology** below).
- Build/create something (e.g. shoot a projectile by… float a boat made from…)
- Role play can be an engaging way to present material.
- Maps, pictures and other visual aids make background material more interactive.
- Working with live organisms and animals is highly engaging.
- Students benefit from enthusiastic guest lecturers, such as college students.
- Highly technical topics are not off-limits, but may need more steps to get to the goal.

Considerations for Teachers:

SMILE Teacher Professional Development

For the teachers, the results from the interview study emphasized the importance of treating them as an audience of learners separate and distinct from the students in their clubs. In the workshops and other professional development settings the teachers are very much learners, and their needs and goals are different than that of their students. The following points describe teachers' perspectives on the workshop setting as a learning environment for them and their comments about the nature (type and content) of SMILE Oceanography professional development programming.

- At workshops less is more, do fewer things in more depth, go through/do club activities in their entirety.
- Provide complete handouts for each teacher at the workshops so that they can make notes.
- Make sure the different activities and speakers fit together in general theme.
- Themes should reinforce how pieces fit into a "big picture."
- Seeing facilities at OSU in person gets teachers excited and gives them an experience to share with students, e.g. visits to labs and other facilities (see **The Role of Field Trips** below).
- New topics are good! New = interesting.
- Web resources are useful (see **Use of Technology** below), but teachers shouldn't have to hunt for them. Provide specific and relevant resources.
- Content can be simple/basic to start with, with more in-depth information to refer back to if teachers have questions later or if it is an area they are unfamiliar with (e.g. provide a handout for reference during club).
- Teachers appreciate guest speakers who are excited/enthusiastic, knowledgeable, and know their audience (present information at an appropriate level).
- Handouts with "take-home points" based on guest speakers or field trips would be helpful in order to jog teachers' memory and help them explain concepts to students when they do the activity months later.
- Teachers also benefit from personal connection, sense of place in the content of workshop professional development.

The Role of Field Trips in SMILE Programming for Both Students and Teachers

Field trips were repeatedly stressed by the teachers as one of the best ways to provide their students with engaging and personally relevant material. They also indicated that field trips were one of the most beneficial types of professional development they receive at SMILE workshops. Suggestions include:

- Provide or help facilitate a trip to the coast for students as part of the yearly Challenge event.
- Potential Oregon coast field trip sites are:
    - Hatfield Marine Science Center
    - Oregon Coast Aquarium
    - Tide pools
    - Fishing boats

    - Marine Discovery Tours, whalewatching
    - Yaquina Bay estuary
- When on campus, facilitate student and teacher visits to labs like the O.H. Hinsdale Wave Research building and COAS Core Lab.

Use of Technology in SMILE Clubs and Professional Development

While not discussed explicitly, technology clearly plays an important role in the development of engaging activities and supporting teacher professional development. Examples discussed by teachers include:

- Showing videos, pictures and other media. Many SMILE students have had little direct exposure to the ocean. Multimedia materials help them visualize the topic and make it more real to them.
- Computer interactive web sites allow students to manipulate and observe processes they may not be able to examine first hand at school, e.g. online wave simulator.
- Incorporating computer models into club and challenge activities allows students to conduct virtual "experiments" that model the type of large-scale science projects conducted by professional scientists. This helps students build their understanding by working with systems and analytic tools that they don't have access to at their schools, as well as teaching them about the nature of scientific research.
- Internet resources are good technical background support for teachers.

Interview Methodology as Part of Continued Evaluation

Teacher response to the interview methods was positive. Conclusions were perceived to be valid and there were tangible benefits to the structure of the project. Teachers also offered suggestions for improvement.

<u>Suggestions for Improvement/Modification</u>

- Some teachers felt that the 20-30 minute interview timeframe was too short.
- Potential of a written "reflection" piece as part of data?
- Teachers would welcome opportunity for feedback on the process sooner.
- Having the questions beforehand would allow the teachers to think and reflect on them before the data collection.

<u>Benefits of the Small-Group Interview Methodology</u>

- Teachers felt the method gave them a good opportunity to discuss the things they think about over the course of the year with SMILE and their colleagues.
- Smaller groups allow more voices to be heard than would be possible working with the whole group at once.
- Verbal feedback allows for more detail than a written evaluation form.
- Teachers enjoyed the small-group setting, it allowed them to feed off each other's ideas.