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Ocean Literacy and Reasoning About Ocean Issues: The Influence of Content, Experience and Morality

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The Influence of Content, Experience and Morality

by

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DEDICATION

It is with great delight that I dedicate this work to my marine science mentor, Dr. Peter Betzer. He has steadfastly provided the example and support to grow professionally as an ocean educator. I thank you, Peter for inspiring me to soar higher.

Finally, my ultimate dedication is to my Lord and Savior, Jesus the Christ. You are my life mentor. May this gift of a higher education be used to honor and glorify you, and to inspire those with whom I am privileged to meet along the journey. Thank you for the work you have done in me.

Being confident of this very thing, that he which hath begun a good work in you will perform it until the day of Jesus Christ (Philippians 1:6)

Rejoice evermore, pray without ceasing and in everything give thanks: for this is the will of God in Jesus Christ concerning you (I Thessalonians 1:16-18)

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ABSTRACT

Ocean issues with conceptual ties to science and a global society have captured the attention, imagination, and concern of an international audience. Climate change, over fishing, marine pollution, freshwater shortages and alternative energy sources are a few ocean issues highlighted in our media and casual conversations. From the life-giving rain that nourishes crops and our bodies, to life-saving medicines; from the fish that come from the ocean, to the goods that are transported on the sea's surface—the ocean plays a role in our life in some way every day (NOAA, 1998). However, a disconnect exists between what scientists know and the public understands about the ocean. Although standards for science teaching and literacy are established, the fundamental role of the ocean is not emphasized.

This was an exploratory study of 30 females, 13-14 years old, during an extended ocean learning experience, the Oceanography Camp for Girls, which included direct experiences in natural environments. Teens were engaged in a series of ocean learning and stewardship activities. A mixed-methods approach was used to develop three quantitative instruments: the Survey of Ocean Literacy and Engagement (SOLE), Survey of Ocean Stewardship (SOS) and Scenarios of Ocean Environmental Morality (SOEM). Three ocean socioscientific issues (OSSI) case studies were analyzed qualitatively.

Participants reasoned and expressed positions in writing and verbally following OSSI embedded activities.

Research questions examined what understanding teen girls currently hold about the ocean (content), how they feel (environmental attitudes and morality) toward the ocean environment, and how these feelings and understanding are organized when reasoning about ocean issues. Results from SOLE and SOS revealed that content knowledge and environmental attitudes significantly contribute to ocean literacy. Analysis of SOEM demonstrated that biocentric environmental reasoning was most important to teens in solving specific ocean dilemmas. Analysis of OSSI from interview responses revealed three patterns of informal reasoning (rationalistic, emotive and intuitive).

Findings support the critical need to globally advance ocean literacy, especially amongst youth and adults. An overarching outcome was that the Oceanography Camp for Girls program is multimodal and goes beyond cognitive understanding to include social and emotive aspects of learning.

CHAPTER ONE: THE PROBLEM

Introduction

Ocean issues with conceptual ties to science and a global society have captured the attention, imagination, and concern of an international audience. Global climate change, natural disasters, over fishing, marine pollution, freshwater shortages, groundwater contamination, economic trade and commerce, marine mammal stranding, and decreased biodiversity are just a few of the ocean issues highlighted in our media and conversations. The ocean shapes our weather, links us to other nations, and is crucial to our national security. From the life-giving rain that nourishes crops and our bodies, to life-saving medicines; from the fish that come from the ocean, to the goods that are transported on the sea's surface--- the ocean plays a role in our lives in some way everyday (NOAA, 1998). The American public values the ocean and considers protecting it to be a fundamental responsibility, but its understanding of why we need the ocean is superficial (Belden, Russonello & Stewart, 1999). However, a broad disconnect exists between what scientist know and the public understands about the ocean. The ocean, more than any other single ecosystem, has social and personal relevance to all persons. In the 21st century we will look increasingly to the ocean to meet our everyday needs and future sustainability. Thus, there is a critical need to advance ocean literacy within our nation, especially among youth and young adults.

It has been estimated that less than 2% of all American adults are environmentally literate (NEETF, 2005). Results from a series of ocean and coastal literacy surveys

(AAAS, 2004; Belden, et al., 1999; Steel, Smith, Opsommer, Curiel & Warner-Steel, 2005) of American adults reveal similar findings. Surveys demonstrated that in the 1990's the public valued the ocean and expressed emotional and recreational connections, however, awareness about ocean health was low. A decade later Americans had an increased sense of urgency about ocean issues and were willing to support actions to protect the oceans even when the tradeoffs of higher prices at the supermarket, fewer recreational choices, and increased government spending were presented (AAAS, 2004). While most Americans surveyed agree that humans are impacting the health of the ocean more than one-third felt that they cannot make a difference. In contrast, a survey of youth reveals strong feelings about environmental issues and the confidence that they can make a difference (AZA, 2003). Collectively, these studies reveal that the public is not well equipped with knowledge about ocean issues. This implies that the public needs access to better ocean information delivered in the most effective manner. The component lacking for both adults and youth is a baseline of ocean knowledge--- literacy about the oceans to balance the emotive factors exhibited through care, concern and connection with the ocean.

The interdependence between humans and the ocean is at the heart of ocean literacy. Cudaback (2006) believes that given the declining quality of the marine environment (Pew Ocean Commission, 2003), ocean educators have the responsibility to teach not only the science of the ocean, but also the interdependence with humans. Ocean literacy is especially significant, as we implement a first-ever national ocean policy to halt the steady decline of our nation's ocean and coasts via the Ocean Blueprint for the 21st Century (U.S. Commission on Ocean Policy, 2004). The need for ocean education and literacy that goes beyond emotive factors is critical and relevant towards preparing our students, teachers, and citizens to regularly contribute to ocean decisions and socioscientific issues that impact their health and well being on Earth. “The biggest barriers to increasing commitment to ocean protection are Americans’ lack of awareness of the condition of the oceans and of their own role in damaging the oceans,” (Belden, et al., 1999). The challenge for ocean educators is to explicitly state the connections between the ocean and daily decisions and actions of people.

People enjoy the beauty of the ocean and the bounty of its waters, but may not understand that their everyday actions such as boating, construction, improper waste disposal, or ignoring protected areas, can impact the ocean and its resources. More than one-half of the US population lives within 200 miles of the ocean. Long-term planning for growth, development and use of coastal areas is key to the continued productivity of the ocean (NOAA, 1998). Because the ocean is inextricably interconnected to students’ lives it provides a significant context for socioscientific issues that foster decision making, human interactions, and environmental stewardship.

Ocean literacy encompasses the tenets of scientific literacy which is defined by national standards, as the ability to make informed decisions regarding scientific issues of particular social importance (AAAS, 1993; NRC, 1996, 2000). As such, scientific literacy encompasses both cognitive (e.g. knowledge skills) and affective (e.g., emotions, values, morals, culture) processes. Science standards were designed to guide our nation toward a scientifically literate society and provide criteria to judge progress toward a national vision of science literacy (NRC, 1996). Although standards for science teaching and literacy are established, the fundamental and critical role of the ocean is not emphasized.

Recently the definition of scientific literacy has been more broadly conceptualized to include dealing sensibly with moral reasoning and ethical issues, and understanding connections inherent in socioscientific issues (Zeidler, 2001; Zeidler & Keefer, 2003). Even more recently, the Centers for Ocean Sciences Education Excellence (COSEE) established a definition of ocean literacy as understanding how the ocean affects you and how you affect the ocean. An ocean-literate person understands the science of the ocean, can communicate about the oceans, and can make informed decisions about ocean policy. Table 1 identifies the seven content principles that guide the scope of ocean literacy. Appendix A provides a description of the COSEE centers and their contribution to ocean literacy. Now that a definition, characteristics and essential principles exist to describe ocean literacy, there is a critical need to operationalize the concepts and assess the success and shortfalls of current ocean education programs using the tenets of ocean literacy. The present study sought to test the concept of ocean literacy within the context of an ocean education program, the Oceanography Camp for Girls. Appendix B provides a description of the Oceanography Camp for Girls education program.

Understanding the role of science in relation to other areas of life rather than an isolated subject is an important goal of many educators and scientists (Cudaback, 2006; Kolsto, 2001; Schroedinger, Cava, Strang & Tuddenham, 2006; Zeidler & Keefer, 2003). Evident from Table 1 is that ocean literacy encompasses both social and scientific factors. Socially, humans are consumers of ocean recreation, transported goods, and products from the sea. One of every six US jobs is marine-related, and one-third of the nation’s gross domestic product is produced in coastal areas through fishing, transportation,

Table 1. Ocean Literacy and Seven Essential Principles of Ocean Sciences (COSEE, 2005)

Ocean Literacy Definition	Seven Essential Principles
An ocean-literate person: understands the science of the oceans, can communicate about the oceans, and can make informed decisions about ocean policy	1. Earth has one big ocean with many features 2. The ocean and life in the ocean shape the features of 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 linked 7. The ocean is largely unexplored

recreation and other industries dependent on healthy waters and marine habitats. Scientifically, the oceans make Earth habitable, cycle our freshwater, and drive weather patterns. A major outcome of scientific literacy is the ability to negotiate complex issues that involve scientific knowledge and social influences (Sadler & Zeidler, 2004). The socioscientific movement aims to empower students to functionally handle science-based issues that shape their current world and those which will determine their future world (Driver, Newton & Osborne, 2000; Kolsto, 2001; Sadler, 2004). It may be that socioscientific issues and discourse can provide the kinetic energy to set in motion a wave of ocean literacy.

The goal to advance ocean literacy is synchronous with the goals of most science educators and research councils (AAAS, 1993; NRC, 1996, 2000), that is to progress toward a national vision of functional scientific literacy for decision making. Science literacy research has focused in three primary areas: attitudes, knowledge, and processes. My study examined the role of content knowledge specifically conceptual understanding and attitudes about the ocean were analyzed as mediating factors contributing to ocean literacy. Socioscientific decision-making is a significant aspect of scientific literacy and responsible citizenship (Berkowitz & Simmons, 2003; Driver et al., 2000; Kolsto, 2001; Zeidler, 1984). The socioscientific movement has gained substantial momentum over the past several years; consequently, the number of empirical studies to support socioscientific issues has expanded. The significance of content (Lambert, 2005; Sadler, 2004; Sadler & Zeidler, 2004), context (e.g. culture, individual beliefs, experience, place/time in life; McGinnis, 2003; Persing, 2006; Sadler, 2004; Semken, 2005), morality (Abd-El-Khalick, 2003; Persing, 2006; Sadler & Zeidler, 2004; Zeidler, & Keefer, 2003), critical thinking skills (Ault, 1998; Keefer, 2003; Zeidler, Lederman & Taylor, 1992), and the nature of science (Sadler, 2004; Zeidler & Keefer, 2003) are cited as components to attend to when engaged in discourse about socioscientific issues. Decision making is further influenced by personal experiences, emotive factors, and social considerations. It is reasonable therefore to consider that many of these same processes will contribute to the resolution of ocean socioscientific issues.

Because the ocean is inextricably interconnected to students' lives it provides a significant context for socioscientific issues that foster decision making, classroom discussions, human interactions, and environmental stewardship. Ocean literacy and reasoning most closely align with the international definition of scientific literacy which is "the capacity to use scientific knowledge, to identify questions and draw evidence-based conclusions in order to understand the natural world and the changes made to it through human activity" (OECD/PISA, 2001, p. 76). The present study sought to support the science education community's understanding of reasoning and resolution of socioscientific issues by expanding the research to include the influence of ocean conceptual understanding (e.g. content), environmental experiences (e.g., context) and environmental morality on reasoning about the ocean. The remainder of this chapter will introduce issues and concepts central to the research: scientific literacy, socioscientific issues and reasoning, content knowledge, experience, and environmental morality. A framework for investigating ocean literacy and reasoning will be provided, and the research questions presented. The chapter will conclude with the study's significance for science education practitioners and researchers.

Research Issues

Scientific and Ocean Literacy

The need to advance a scientifically literate citizenry is a widely accepted U.S. educational goal (AAAS, 1993; Laugksch, 2000; NRC, 1996, 2000; Rutherford & Ahlgren, 1994; Zeidler, 1984, 2003; Zeidler, Sadler, Simmons, & Howes, 2005). Two sequential works have served as a catalyst and vision for science education reform in the U.S. These are Science for All Americans (Rutherford & Ahlgren, 1989; AAAS, 1994) and Benchmarks for Science Literacy: Project 2061 (AAAS, 1993). Science for All Americans provides the societal wake-up call, relevance, and viability of science literacy for citizens. It answers the question of what constitutes adult science literacy, recommending what all students should know and be able to do in science, mathematics, and technology by the time they graduate from high school (Rutherford & Ahlgren, 1989; AAAS, 1993). The Benchmarks for Science Literacy provides a framework for obtaining life-long science literacy. However, the question of what constitutes scientific literacy, or what a literate person should know or be able to do, remains controversial (AAAS, 1993; Durant, 1994; Kolsto, 2001; NRC, 1996; Ramsey, 1993; Sadler, 2004; Zeidler & Lewis, 2003).

Two central foci have emerged from a review of scientific literacy research, a knowledge-centered perspective and a sociocultural-centered perspective (Brown, Reveles, & Kelly, 2005). A knowledge-centered perspective is evident in the major reform documents. Brown et al. (2005) argue that this perspective is abstracted from experience, ultimately disconnected from the lives of people engaged in their worlds. In contrast, a sociocultural-centered perspective considers how literacy is relevant to particular tasks at hand in some relevant social contexts. This perspective situates scientific literacy in the action of accomplishing everyday life.

From an international perspective ocean literacy is a global issue and necessary to sustain environmental, economic and human health. UNESCO (1977) provided a tool to accomplish environmental and economic vitality and sustainability via the Environmental Education (EE) process. EE is a process that includes at least five components most relevant to the present study:

1. <u>Awareness</u> to help social groups and individuals acquire an awareness and sensitivity to the total environment and its allied problems.

2. <u>Knowledge</u> to help social groups and individuals gain a variety of experiences in, and acquire a basic understanding of, the environment and its associated problems.

3. Attitudes to help social groups and individuals acquire a set of values and feelings of concern for the environment and motivation for actively participating in environmental improvement and protection.

4. Skills to help social groups and individuals acquire a set of skills for identifying and solving environmental problems.

5. Participation to help provide social groups and individuals with opportunities to be actively involved at all levels in working toward resolution of environmental problems (UNESCO, 1977)

Participation may include environmental stewardship of which one component is environmental literacy. Literacy denotes knowledge. Without the integration of an ocean environmental knowledge base, individuals could be drawn to poor environmental decision making and/or counterproductive actions, thus jeopardizing productive and sustainable initiatives within a nation. Ocean environmental knowledge is one manageable, goal-driven step that can be applied in the context of the commonwealth's environment, economy, human health, and sustainability. My study proposed to expand the baseline data currently available about ocean literacy (Brody & Koch, 1990; Brody, 1996; Fortner & Mayer, 1983, 1991) to include a cross-section of youth using a standardized multi-item instrument aligned with the three tenets of an ocean literate person and the seven essential principles of ocean literacy.

If the goal was for the future citizen not only to be able to possess and use scientific knowledge, but also to take part in decision-making with regard to the application of science to everyday life, today's students must be taught not only what science can do, but also how science is done (Hurd, 1998). Teaching science should therefore be consistent with the nature of scientific inquiry (AAAS, 1993; NRC, 1996). This includes starting with questions about phenomena rather than with answers to be learned (AAAS, 1993). The ocean is the largest unexplored environment on Earth. This frontier invites exploration and inquiry essential to understanding ocean systems, processes, potential resources and limitations. Sustaining a healthy and vibrant lifestyle on planet Earth requires a citizenry with a broad understanding of major ocean science concepts and the ability to engage critically with cultural and moral decisions which involve scientific ocean knowledge. My study utilized the essential content principles of ocean literacy defined by COSEE (2005) to examine the development of conceptual understanding towards ocean literacy. This was accomplished by assessing the degree of ocean literacy amongst youth using a multi-item ocean environmental knowledge scale to establish a baseline of what is presently understood about the ocean.

Socioscientific Issues and Ocean Literacy

Socioscientific issues occupy a central role in the promotion of scientific literacy, and are based on scientific concepts or problems controversial in nature, discussed in public arenas, and frequently subject to political and ethical influences (e.g. global climate change; Sadler, 2004). A major outcome of scientific literacy is the ability to negotiate complex issues that involve scientific knowledge and social influences (Sadler & Zeidler, 2004). Both cognitive and affective processes contribute to the resolution of complex issues via informal reasoning. The ocean sciences may provide developmentally appropriate ocean environmental dilemmas relevant to youth grades 5-9.

One way to provide opportunities to practice and experience connections between the science students are learning and the issues they are likely to confront in their daily lives is through reasoning and discourse with socioscientific issues. The socioscientific issues (SSI) movement emphasizes empowering students to consider how science-based issues and the decisions made concerning them reflect, in part, the moral principles and qualities of virtue that encompass their own lives, as well as the physical and social world around them (Brown et al., 2005; Kolsto, 2001; Kozoll & Osborne, 2004; Lemke, 2001; Sadler, 2004; Zeidler & Lewis, 2003). This movement provides a conceptual framework that unifies the development of moral and epistemological orientations of students and the role of emotions and character as key components of science education (Sadler, 2004; Sadler, 2005; Zeidler & Keefer, 2003; Zeidler et al., 2005).

While the infancy of ocean science literacy precludes an in-depth discussion of mediating factors, a compelling case can be put forth to illustrate how ocean science concepts, questions, and research closely parallel the central components of functional scientific literacy. The ocean is an environment that is inextricably interconnected to students' lives and provides a significant context for socioscientific issues that foster decision making, social discourse, human interactions, and action via environmental stewardship. The ocean not only is the dominant feature on our blue planet but throughout the course of our everyday activities we are exposed to multiple social and emotive issues related to the oceans (e.g., recreation, hurricane predictions and relief efforts, freshwater supplies, import of consumer products, flooding and droughts, cosmetics and pharmaceuticals). Zeidler et al. (2005) provide a coherent conceptual framework to achieve a 'functional' view of scientific literacy. Although this framework is a tentative model, it is flexible enough to allow for multiple perspectives. For the present study the assumptions of the Zeidler et al. model of functional scientific literacy were examined via the use of case-based ocean socioscientific issues (OSSI) to provide empirical evidence towards the use of OSSI to advance ocean literacy.

Framework for Examining Ocean Literacy and Reasoning

Zeidler and others (Zeidler & Keefer, 2003; Zeidler et al., 2005) framework may help to identify key components that likely influence ocean literacy and reasoning about ocean issues. Derived from a cognitive-moral reasoning perspective, this framework identifies four pedagogical areas that are central to the teaching of socioscientific issues. The relationship between these areas and cognitive and moral development are visualized in Figure 1. It is reasonable to think that these same pedagogical areas will be central to ocean literacy and reasoning. However, to date few ocean-based socioscientific case studies have been reported in the literature (Rebich & Gautier, 2005; Schweizer & Kelly, 2005).

The present study sought to identify the mediating factors contributing to ocean literacy and reasoning by examining the relationships between ocean literacy outlined in Table 1, and the socioscientific elements of functional scientific literacy outlined in Figure 1. Possible relationships between ocean literacy and the socioscientific elements of scientific literacy are suggested in Table 2.

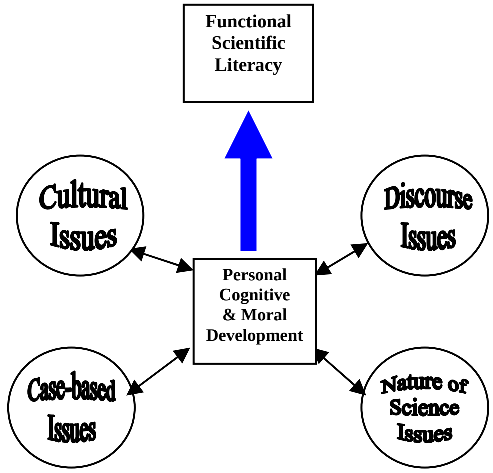

Figure 1. Socioscientific Elements of Functional Scientific Literacy

Current socioscientific issues (SSI) that have been addressed in primarily high school and college classrooms include: cloning, stem cells, genetically modified foods, global climate change, land-use decisions, the introduction of exotic species, dietary decisions, smoking, hazards of meteors, and ozone depletion (Abd-El-Khalick , 2003; Sadler & Zeidler, 2005). Specific OSSI I considered included coastal development, offshore drilling (e.g. fuel to drive our cars), global climate change, fisheries and harvesting, marine mammal rescue and rehabilitation, marine debris and pollution (e.g. impacts on recreation and tourism economy), habitat restoration (e.g., maintain healthy waterways), drinking water via precipitation (e.g., for health and survival), transportation and shipping (e.g., consumers of MP3 players, other electronics, computers, automobiles, crude oil, cell phones), beach re-nourishment (tourism economy) and sea turtle nesting. I sought to expand the current SSI to include ocean socioscientific issues (OSSI). This was

Table 2. Possible relationships between components of ocean literacy and the socioscientific elements of functional scientific literacy

Ocean Literacy Definition	An Ocean Literate Person:	Functional Scientific Literacy Element	Mediating Factors
Understanding how the ocean affects you and how you affect the ocean	➢ Understands the science of the ocean	Content knowledge & nature of science	Content & experience (nature context)
	➢ Can communicate about the oceans	Classroom discourse issues & cultural issues	Environmental morality, content & informal reasoning
	➢ Can make informed decisions about ocean policy	Case-based issues, classroom discourse & cultural issues	Content, morality & behavioral commitment (action)

accomplished by developing and piloting several case-based ocean environmental dilemmas.

Content Knowledge and Ocean Literacy

Kolsto (2001) addresses three challenges when dealing with socioscientific issues: “the need for specificity, the need for relevance, and the need to adjust the amount of content knowledge to be emphasized in order to put it within reach of most students” (p. 293). Sadler & Zeidler (2004) emphasize the significance of content knowledge for informal reasoning regarding socioscientific issues that used case studies of applied genetics knowledge to genetic engineering issues. There is a need to develop an epistemology of ocean literacy to effectively engage ocean socioscientific issues (OSSI).

Ocean science issues are relevant to our everyday needs and decision-making in contexts that impact multiple levels of human development (e.g., K-adult).

To advance an ocean knowledge base requires development of ocean science content that utilizes the criteria put forth in Project 2061 (AAAS, 1993)—utility, social responsibility, the intrinsic value of knowledge, and philosophical value. These criteria provide a basis for addressing the social aspects of ocean science as a way of knowing while embedding the tenets of the nature of science and socioscientific issues. Ocean education resources and experiences do not exist in a collective, standardized format to teach or assess the essential content principles for ocean literacy (COSEE, 2005) outlined in Table 1. It is hoped that the establishment of ocean literacy standards will help to realize the next step. Assuming acceptance of these standards, the next step is to develop measurable and appropriate ocean science curriculum, instruction, and experiences.

The concerns are similar in developing the competency of the learner to integrate what is being learned with the actions that are required to contribute to community and everyday socioscientific issues in life. A progressive approach to science education incorporates a social dimension based on an interdisciplinary curriculum (Zeidler & Shafer, 1984). Ocean science literacy naturally encompasses interdisciplinary topics, thus reducing traditional content, and provide context meaningful to a wider range of students in terms of applying the scientific process (including moral and ethical components) to societal problems. The future of ocean health relates directly to personal, individual decisions about its management or exploitation. There is a critical need to provide the public with the scientific knowledge and societal issues relevant to our ocean and people. Equipped with ocean-based knowledge, processes, and issues, students beginning at early ages can make scientifically informed decisions inclusive of evidence, evaluation, and personal commitment. I examined the impact of building ocean content knowledge from the point of personal relevance towards scientific understanding by engaging youth in direct sustained experiences with nature (e.g. local ocean environments).

Experience and Ocean Literacy

Experience and Nature (as Context)

Kellert (1996, 2002) suggests that within contemporary society, children experience nature in one of three ways: direct, indirect, and symbolic. Direct experiences require the individual to be physically involved and interacting with the natural world, indirect experiences are those in which physical contact occurs but in a structured context (e.g., zoos, aquaria), and symbolic experiences take place without any physical contact with the natural world (e.g., television program, books, computer program). While all three types of experience may impact a child's cognitive, affective, and/or evaluative maturation, studies suggest that direct experiences have the greatest potential for positive youth development (Kals et al., 1999; Taylor et al., 2001; Wells, 2000). However, among many youth today, opportunities for direct experiences in nature have been usurped by increases in symbolic experiences through representations of nature in television, film, and computer technologies (Naban & Trimble, 1994; Orr, 1994, 2002).

Rop (2004) provides a review from 1980-present of learning in schoolyards and nearby natural settings. The research literature clearly supports that field studies and environmental education programs that take students outside to learn in nature have significant impact on the NSES category—student perspectives; their attitudes, individual ethic and concern for the environment. Research also provides evidence that students improve cognitively, by improving their scientific content knowledge and learn science more efficiently as a result of study in natural settings. However, there is a critical lack of research that connects field studies with inquiry, a major tenant of the current national standards for scientific literacy. Crompton and Sellar (1981) in a review of whether outdoor educational experiences contribute to positive development in the affective domain conclude that evaluative research in this area is sparse and generally of poor quality. Rop (2004) concludes from his 20-year review of the literature that the potential of science education in outdoor settings for improving student understanding about the nature of science and doing scientific inquiries is enhanced. However, the quality of comparative research in this area is lacking. With this in mind, much more research is needed to find clear connections and empirical evidence about whether or not field studies actually result in improvements in scientific literacy.

The evidence for a relationship between nature experiences and a child's cognitive functioning is only just emerging. In a longitudinal study, Wells (2000) measured the cognitive functioning of youth while they were living in low rent housing complexes and after they had moved to a single family home in a residential neighborhood funded through a self-help housing program. Objective measures of the naturalness of the living environment were taken pre and post move. Results suggest that youth whose homes improved the most in terms of natural surroundings had the highest levels of cognitive functioning after the move. A growing body of empirical literature has emerged that focuses on nature as a context for human development and the ways children may benefit. These studies have primarily focused on affective and evaluative domains of human development. Findings suggest that exposure to aspects of nature can positively influence development in children and adolescents but the effect is largely contingent upon the types of experiences the youth have had with nature.

It is reasonable to expect experiences in nature to carry an emotional component as well. Studies suggest that the affective domain is believed to precede cognition in the production of knowledge (Iozzi, 1989). The natural world provides opportunities for youth to experience such emotions as curiosity and indifference, attraction and repulsion, courage and fear, like and dislike. It has been suggested that the intensity of these emotions significantly affects how strongly one interprets, perceives, and remembers the experience (Milton, 2002). Childhood experiences with the natural world are frequently cited by adults as some of the most powerful and formative memories they can recall (Kals et al., 1999; Milton, 2002; Sebba, 1991). In all of these studies, adults' current feelings, values, and behavior towards nature were substantially attributed to their experience with nature as a child.

My study examined the impact of an outdoor education program, to determine if the learning experience results in improvements in ocean literacy. The goal was to produce empirical evidence that connects field studies with improvements in scientific literacy, especially at it relates to reasoning and socioscientific issues.

Experience and Socioscientific Issues

Kolsto (2001) suggests that only through experience will students develop the attitudes and skills necessary to examine and effectively reason about socioscientific issues. Zeidler and others (Zeidler, 1984; Zeidler, Walker, Ackett, & Simmons, 2002) argue that students must be provided experiences that allow them to practice and apply rational, informed decisions about their society via individual and collective decision making. Learners therefore should be provided with experiences that will have direct impact and relevance to their present and future social experiences (Zeidler & Keefer, 2003). In Sadler's (2004) review of reasoning and socioscientific issues, the role of personal experience was pervasive in all research categories. "Personal experiences of the decision makers emerged as a consistent influence on informal reasoning related to socioscientific issues, but its effect differed across contexts" (Sadler, 2004; p. 531). The role of personal experiences was examined from the perspective of direct outdoor learning experiences. The relationship between emotion and reasoning was also examined, specifically attitudes and behaviors about ocean concepts and the ocean environment.

Environmental Morality and Development

The limitations of conceptualizing moral development as a singular process, i.e. principles, have been clearly argued in the literature (Sadler, 2004). The essential role of affect, specifically emotive factors, has emerged more frequently in the literature (Eisenberg, 1982; Gilligan, 1977; Hoffman, 1981; Sadler & Zeidler, 2005). Persing & Britner (2002) examined middle school students' responses to environmental dilemmas. Students elicited moral responses that were strongly care-oriented and suggest that youth conceive of environmental dilemmas from both a justice and care perspective.

The framework adopted for the present study was the four-component model of moral development proposed by Rest and colleagues (Rest, 1986; Rest et al, 1999; Rest et al., 2000) to explore morality as it relates to reasoning about ocean issues. A key strength of this model is that it addresses the interconnectedness of cognition and affect, thus addressing the limitations of conceptualizing moral development as a singular process, i.e. principles (Kohlberg, 1984). Persing (2006) summarizes the Rest model as follows:

> The Four Component model is intended to organize the various psychological processes that result in the execution of a moral act and presents these processes as distinct functions that are nevertheless interactive with, and influenced by, the other processes. It addresses the obvious and complex question of what happens psychologically when a person behaves morally (Rest, 1986). The four components follow a logical sequence but do not necessarily have to occur in this order for moral behavior to occur. (p. 33)

The components of the model are moral sensitivity, moral judgment, moral motivation, and moral character. These components and the intersection of cognition and affect are summarized in Table 3.

By attempting to synthesize the diverse approaches and phenomena associated with the study of morality, the Four Component Model possesses multiple processes and constructs that are appropriate both as a framework for constructing important theoretical questions that may advance the understanding of the totality of morality as well as structuring specific goals and outcomes when applied to specific moral education programs (Persing, 2006; p. 34). My study applied the four component model to evaluate how and under what circumstances youth think morally about ocean environmental dilemmas.

Table 3. Summary of the Four Component Model of Moral Development (Rest, 1986; Rest et al., 1999; Rest et al., 2000)

Component	**Definition**	**Cognitive & Affective Processes**
moral sensitivity	Requires the individual to be able to interpret the situation by role taking how various actions may affect the parties involved and thinking in terms of cause and effect	Grounded in the research on empathy in which an individual, even at a very early age is able to recognize distress in others as a primary affective response (Hoffman, 1981)
moral judgment	Involves the individual's ability to judge which action is most justifiable from a moral perspective	Concepts of justice, fairness, and care
moral motivation	The degree of commitment an individual has in taking the moral course of action; competing non-moral values may play a role in whether the individual is able to redirect these alternatives and persist in the moral course	Entails the imagining of a desired goal and implies both cognition (the imagining) and affect (the desiring)
moral character	Involves the execution of a particular action; requires an individual to persevere and overcome the temptation of competing values and goals to achieve the moral task	Manipulation of self-regulatory processes has suggested that how an individual feels while in the course of helping someone else may influence the level of persistence and effort in that action (Rest, 1986)

Two distinct moral orientations towards nature have been identified by researchers who have attempted to understand reasoning, values, or motives underlying an individual's environmental ethic. An anthropocentric environmental orientation views nature as having value and deserving to be protected in so far as it affects human well being, while a biocentric orientation toward the environment perceives nature as worthy of rights and protection because of its intrinsic value (Kahn 1999; Kortenkamp & Moore, 2001). As we progress in the 21st century ocean issues may be a benefit or detriment to human well being and/or the ocean environment. There is an emerging societal need to understand ocean socioscientific issues which may be influenced by environmental morality. Although both orientations may engender concern and interest for the ocean environment, and even result in similar actions toward the ocean, the reasons and motives for doing so are quite different. The significance in understanding these orientations has potential implications for decisions about natural resource management and in designing more effective ocean education programs. Socioscientific issues in science classrooms are beginning to play a central role in the development of a responsible citizenry capable of applying scientific knowledge and habits of mind in making decisions (Bingle & Gaskell, 1994; Driver et al., 2000; Kolsto, 2001; Zeidler, 1984). It is reasonable to think that ocean socioscientific issues may help to advance ocean literacy and reasoning about ocean issues. These are issues that encompass environmental ethics and morality.

Informal Reasoning and Ocean Literacy

During social interaction and discourse (e.g. written or oral) students are engaged in informal reasoning as they negotiate and resolve complex problems that lack clear solutions. Characteristics that are manifested when learners are reasoning about socioscientific issues are: 1) process of inquiry, 2) negotiation, 3) discourse, 4) argumentation, 5) compromise, 6) conflict, 7) decision making, and 8) commitment

(Zeidler & Keefer, 2003). Findings from Sadler & Zeidler (2005) reveal that college students using informal reasoning might relate to socioscientific issues in three ways during discourse: (a) rationalistically, which encompasses reason based considerations, (b) emotively, which encompass care based considerations, and (c) intuitively which encompasses considerations based on immediate reactions to the context of the scenario or dilemma presented. Middle school students have elicited moral responses that were strongly care oriented suggesting youth conceive of environmental dilemmas with a justice and care perspective (Persing & Britner, 2002).

In Sadler's (2004) literature review of reasoning and socioscientific issues, the key research areas that influence informal reasoning are a) argumentation skills, b) nature of science conceptualization, c) evaluation of information, and d) development of conceptual understanding of science content. Further research from Sadler and colleagues (Sadler & Zeidler, 2004; Zeidler et al., 2005) suggests that the degree of personal relevance of an issue is associated with increased validation of knowledge claims. For the present study ocean socioscientific issues were introduced after students engaged in a content-embedded role playing (e.g. Fish Banks) or stewardship activity (e.g. Coastal Clean-up). Building upon the research of Sadler & Zeidler (2004) and Persing (2006), the present research study examined the reasoning patterns and environmental morality of rising 9th graders while engaged in ocean socioscientific issues. It is beyond the scope of this study to assess argument structure however, argumentation is useful as a means of assessing an individual's informal reasoning.

Problem Statement

The overarching goal of my study was to test the construct of ocean literacy within the context of an ocean education program. The practical purpose was to provide baseline data to describe what youth understood about the ocean and how youth reason about ocean environmental issues. These data were then analyzed to assess the degree of ocean literacy demonstrated in individuals with varying levels of content knowledge and social development, and how they used these factors to make decisions about the ocean. The major education needs at the heart of ocean science literacy are to provide (a) ocean science content and experiences as part of a 21^{st} century integrated science curriculum, and (b) opportunities to engage in ocean socioscientific issues (OSSI) meaningful to the life experiences of most citizens. I pursued the first need by examining ocean content and attitudes that emerged during an informal ocean education program. The second need was addressed by engaging students' ages 13-14 years in a series of ocean environmental dilemmas. While present methods preclude direct empirical access to an individual's ocean literacy, the analysis of conceptual understanding and attitudes about the ocean may reveal underlying patterns of ocean literacy and mediating factors of ocean-related decision making. The working hypothesis for the present research was that both the acquisition of content knowledge (understanding, experiences) and social considerations (e.g., emotions, morality) contribute to ocean literacy and to reasoning about ocean socioscientific issues. The present study explored the validity of this hypothesis by analyzing the degree of ocean literacy demonstrated in individuals with varying levels of content knowledge and social development, and how they used these factors to reason and make decisions about the ocean. To accomplish this goal four research questions were pursued.

Research Questions

Question 1

How do content and environmental context mediate the development of conceptual understanding about the ocean during an ocean education program, the Oceanography Camp for Girls, an experience for rising 9^{th} graders focused on direct experiences in natural environments?

Rationale. I utilized the seven essential content principles of what constitutes ocean literacy as defined by COSEE (2005) to examine the development of conceptual understanding towards ocean literacy. In the present study participants were engaged in a 3-week primarily outdoor ocean education program to determine if the learning experience results in improved ocean literacy. This was accomplished via pre and post-program scaled instruments, learning essays, and interviews. I sought to discover the effectiveness of the Oceanography Camp for Girls (OCG) program to increase conceptual understanding about the ocean based on essential principles of ocean literacy. A detailed description of the OCG can be found in Appendix B. Although it is understood that these variables do not function independently, my study addressed the influence of content knowledge and context via direct environmental experiences on conceptual understanding about the oceans. A series of two sub-questions were formulated to address this broader question.

Sub-Question 1a.

To what extent does content knowledge contribute to conceptual understanding about the ocean?

Rationale. I examined the impact of building ocean content knowledge from the point of personal relevance towards scientific understanding by engaging youth in direct sustained experiences with nature (e.g., local ocean environments). There is a need to develop an epistemology of ocean literacy to effectively engage ocean socioscientific issues (OSSI). Ocean environmental knowledge is a manageable, goal-driven step that can be applied in the context of the environment, economy, human health, and sustainability. In this study the baseline data currently available about ocean literacy (Brody, 1996; Brody & Koch, 1990; Fortner & Mayer, 1983, 1991) was expanded to include a cross-section of youth from an informal learning setting. This was accomplished by assessing the degree of ocean literacy among youth using a multi-item ocean environmental knowledge scale to establish a current baseline of what is presently understood about the ocean, nearly 20 years later. This instrument was called a Survey of Ocean Literacy and Experience (SOLE).

Sub-Question 1b.

To what extent do direct environmental experiences (e.g. context) contribute to conceptual understanding about the ocean?

Rationale. The evidence for a relationship between nature experiences and a cognitive functioning are only just emerging. Kellert (1996, 2002) suggests that within contemporary society, children experience nature in one of three ways: direct, indirect, and symbolic. While all three types of experience may impact a child's cognitive, affective, and/or evaluative maturation, studies suggest that direct experiences have the greatest potential for positive youth development (Kals et al., 1999; Taylor et al., 2001; Wells, 2000). Direct experiences require the individual to be physically involved and interacting with the natural world. In my study, participants were engaged in ocean learning through physical interactions with multiple natural environments in the Tampa Bay region. I examined the extent to which an outdoor ocean education program contributes to improved ocean literacy amongst youth. Participants were asked how the Oceanography Camp for Girls environmental experiences impacted their learning of science. A 500 word learning essay was written by each participant titled, ‘Compare and contrast learning science during OCG with learning science in school.’

Question 2

How do environmental attitudes (e.g. care, concern and connection) contribute to conceptual understanding about the ocean?

Rationale. In as much as content knowledge has been shown to contribute significantly to scientific literacy, the present study sought also to investigate the extent to which it contributes to more favorable ocean environmental attitudes amongst youth. I postulated that experiences in nature to carry an emotional component as well. Iozzi (1989) concluded that the affective domain precedes cognition in the production of knowledge (Iozzi, 1989). The natural world provides opportunities for youth to experience such emotions as curiosity and indifference, attraction and repulsion, courage and fear, like and dislike. Milton (2002) suggested that the intensity of these emotions significantly affects how strongly one interprets, perceives, and remembers the experience. Numerous ocean surveys of adults in the U.S. consistently reveal that emotive factors play a significant role in participant responses. Indeed social considerations had greater significance than knowledge as evidenced in a critical lack of ocean conceptual understanding. However, the specific moral emotions and extent of impact is unclear from the literature. I investigated the extent to which environmental attitudes contributed to youth's understanding about science, the ocean environment, and stewardship by asking participants to express their attitudes via pre/post measurements. The Survey of Ocean Stewardship (SOS) was used to examine if the OCG experience contributed to more favorable ocean environmental attitudes. A multi-item scale was constructed to assess general environmental attitudes toward science, oceanography, care and connections to the ocean. After camp, participants were asked how the OCG learning experiences had impacted their feelings and attitudes about the ocean environment, stewardship, products and services.

Question 3

What types of environmental moral reasoning are important to youth in resolving ocean dilemmas and how likely are they to act in an environmentally-sensitive way?

Rationale. I sought to expand understanding of scientific literacy to include a functional aspect of action via stewardship as a consumer and/or citizen of the ocean environment. Research suggests that direct experiences have the greatest potential for positive youth development (Kals et al., 1999; Taylor et al., 2001; Wells, 2000). Participants in this study were engaged in ocean stewardship as part of the Oceanography Camp for Girls program design, which includes coastal clean-ups and habitat restoration activities. I investigated the type of environmental moral reasoning (e.g., biocentric, anthropocentric) most important in ocean decision-making and if reasoning type was predictive of one acting in an environmentally sensitive manner (e.g. ocean stewardship). Persing (2006) identified the types of reasoning important to young adults in solving environmental moral dilemmas experienced during common outdoor recreation activities. Rest and colleagues model of moral action (Rest, 1986; Rest et al., 1999; Rest et al., 2000) was adapted to evaluate how and under what circumstances youth think morally about ocean environmental dilemmas. This was accomplished by developing and piloting four familiar ocean environmental dilemmas adapted from the research of Persing (2006). The Scenarios of Ocean Environmental Morality (SOEM) instrument was used to measure moral motivation and likelihood to act. Moral motivation refers to the degree to which one chooses a moral course of action, valuing moral values over other values, and taking responsibility for a moral resolution to the problem at hand (Rest et al., 1999). Likelihood to act refers to the execution and implementation of one's moral plan (Shields & Bredemeier, 1995).

Question 4

How do youth informally reason about ocean socioscientific issues in the context of direct experiences in ocean environments?

Rationale. I examined the influence of informal learning experiences on reasoning about ocean socioscientific issues. This was accomplished by directly engaging participants in ocean socioscientific role-playing and stewardship activities, followed by open dialogue discussions, written responses and interviews. Building on the work of Sadler & Zeidler (2004, 2005) my study sought to gather insight about how individuals reason informally about ocean environmental socioscientific issues. It is beyond the scope of this study to assess argument structure, however argumentation was used as a means of assessing an individual's informal reasoning. The present study expanded current SSI to include ocean socioscientific issues (OSSI).

Significance of Study

This research emerged from a wave of recent interest in promoting ocean literacy on a national level (AAAS, 2004; COSEE, 2005; National Geographic Society, 2006; Pew Ocean Commission, 2003; Schroedinger et al., 2006; US Commission on Ocean Policy, 2004). I constructed an operational meaning of the term ocean literacy. Currently, K-12 students and our citizenry at large are under-prepared to contribute individual or societal decisions about our oceans, due to limited ocean knowledge from which to make socioscientific decisions. Any conversation about scientific literacy for our citizenry that does not include ocean literacy as a pivotal focus will fall short of literacy goals for all students by neglecting the planet's largest environment.

The ocean environment is bountiful with opportunities to engage in ocean-related socioscientific issues (OSSI) meaningful to the life experiences of most citizens. By providing ocean content, learning experiences, and socioscientific case studies students and citizens can contribute to the social, economic, and cultural development of an ocean literate society permeated with global implications. The ocean sustains life on Earth and everyone is responsible for caring for the ocean. Individual and collective actions are needed to effectively manage ocean resources for all (National Geographic Society, 2006).

I examined the influence of an informal learning experience to advance ocean literacy and reasoning about ocean socioscientific issues. Specifically, my research described what understanding youth currently hold about the ocean (content), how they feel toward the ocean environment (environmental attitudes), and how these feelings and understanding are organized when reasoning about ocean issues (environmental morality). It is hoped that this baseline study will provide standardized measures where possible that can be replicated by other researchers. As others conduct similar ocean literacy empirical research, a set of studies that build on each other will be established. This investigation adopts the following position on ocean literacy. *An ocean literate person is an individual equipped to use ocean knowledge, to engage in oral or written discussion about the oceans (e.g., support a position), to understand the changes made to the ocean through human activity, and to apply ocean knowledge through actions as citizen, steward or consumer*.

In as much as educational research supports one's knowledge as a significant component of scientific literacy and reasoning, the significance as relates to ocean literacy is not known. On a theoretical level it is reasonable to propose that acquisition of content knowledge and social considerations will contribute to ocean literacy and reasoning about ocean socioscientific issues. I propose that the development of ocean literacy may advance functional scientific literacy through an integrated knowledge base, practice doing and reasoning about science, and opportunities for social action. Ocean socioscientific issues (OSSI) may have relevance to a broader audience of learners than current socioscientific issues reported in the literature. Finally, ocean literacy may advance science literacy by lessening the gap between public knowledge and the frontiers of scientific inquiry.

While there is a paucity of educational research regarding ocean literacy and reasoning, my findings contribute more generally to the pedagogy of classroom practice and curriculum. Specifically, my research identified current ocean content that advances ocean literacy based on the formal and informal ocean learning experiences examined. In addition, a preliminary metric to evaluate conceptual understanding was developed. Classroom practice and curriculum will be further enriched with the addition of developmentally appropriate ocean socioscientific issues via case studies implemented during my study. Ultimately, ocean literacy research provides (a) ocean science content and experiences as part of a 21st century integrated science curriculum, and (b) opportunities to engage in ocean socioscientific issues (OSSI) meaningful to the life experiences of most citizens.

CHAPTER TWO: LITERATURE REVIEW

Introduction

My study is primarily concerned with what youth know about the ocean, how they feel and might act toward the ocean, and how they reason about ocean issues of interest. While the need to advance a scientifically literate citizenry is a widely accepted educational goal (AAAS, 1993; Laugksch, 2000; NRC, 1996; Rutherford & Ahlgren, 1989; Zeidler, 1984; Zeidler & Keefer, 2003; Zeidler, Sadler, Simmons & Howes, 2005), the role of ocean literacy as a part of this goal is not evident.

Ocean education and literacy that goes beyond emotive factors (e.g., care, concern and connection with the ocean) is critical and relevant towards preparing our students, teachers, and citizens to contribute to ocean decisions and socioscientific issues that impact their health and well being on Earth. It has been estimated that less than 2% of all American adults are environmentally literate (NEETF, 2005). This implies that the public needs access to better ocean information delivered in the most effective manner. In the 21^{st} century we will look increasingly to the ocean to meet our everyday needs and future sustainability. Thus, there is a critical call for ocean literacy within our nation, especially amongst youth and young adults.

For the present study, I analyzed the role of content knowledge specifically conceptual understanding and attitudes about the ocean as mediating factors contributing to ocean literacy. The significance of content (Lambert, 2005; Sadler, 2004; Sadler &

Zeidler, 2004), context, (e.g. culture, individual beliefs, experience, place/time in life; McGinnis, 2003; Persing, 2006; Sadler, 2004; Semken, 2005), morality (Abd-El-Khalick, 2003; Persing, 2006; Sadler & Zeidler, 2004; Zeidler & Keefer, 2003), critical thinking skills (Ault, 1998; Keefer, 2003; Zeidler, Lederman & Taylor, 1992), and the nature of science (Sadler, 2004; Zeidler & Keefer, 2003) are often cited as components to attend to when engaged in discourse about socioscientific issues. Decision making is further influenced by personal experiences, emotive factors, and social considerations. Therefore, I consider that many of these same processes contribute to the resolution of ocean socioscientific issues. In particular, content knowledge construction as it relates to the ocean, context as relates to nature experiences, and morality as relates to the environment are examined in this study.

Because the ocean is inextricably interconnected to students' lives, it provided a significant context for socioscientific issues that foster decision making, social discussions, human interactions, and environmental stewardship. I sought to support the science education community's understanding of reasoning and resolution of socioscientific issues by expanding the research to include the influence of ocean conceptual understanding (e.g., content), environmental experiences (e.g., context) and environmental morality and attitudes.

Figure 2 presents a graphic organizer of the general themes to be covered in this review. The ensuing literature review will address issues and concepts central to ocean literacy and emerging research. Past research reviewed included scientific literacy and citizenship, socioscientific issues and reasoning, content knowledge, experience, and environmental morality.

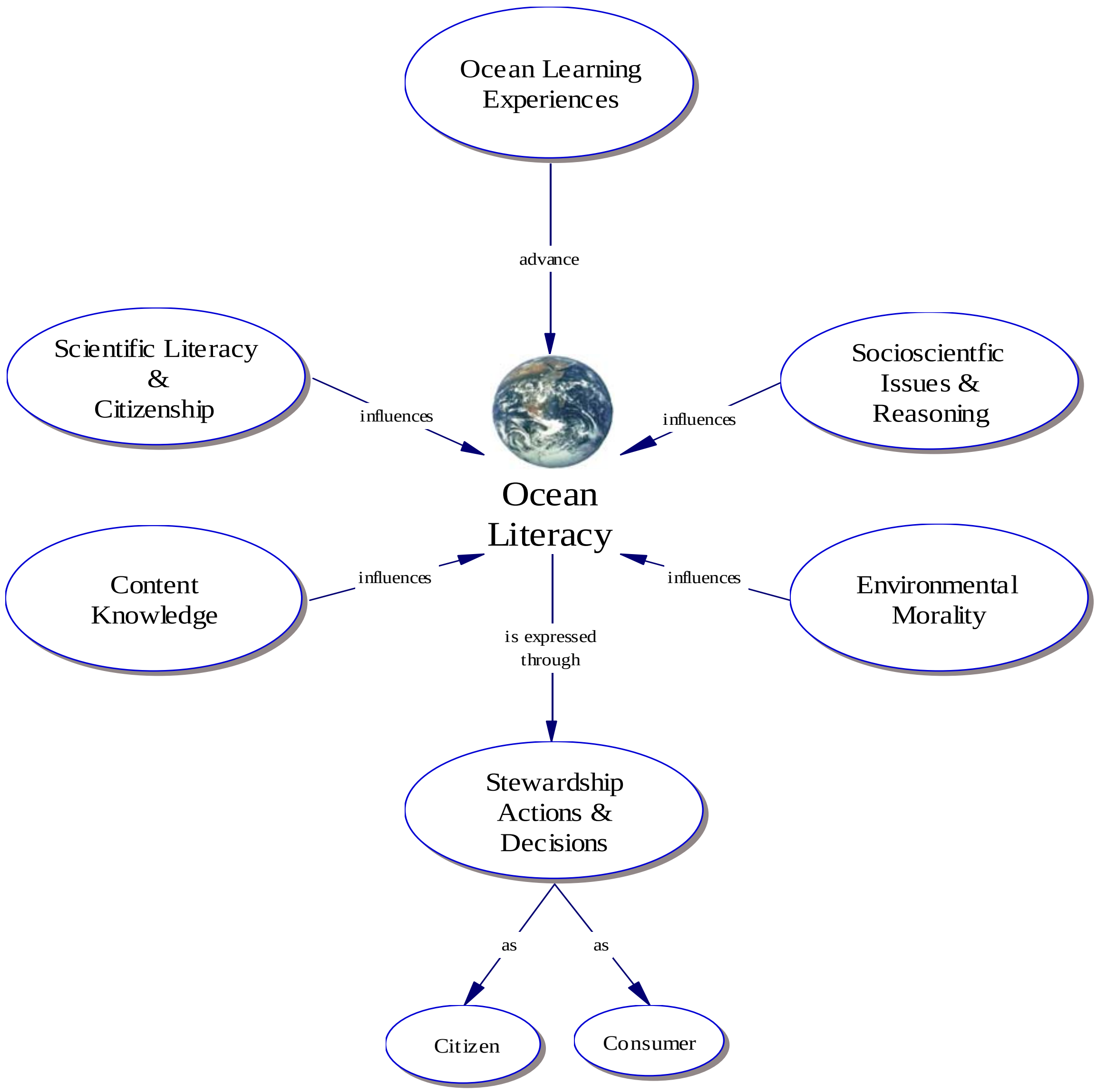

Figure 2. Graphic Outline of the Topics Addressed in Literature Review

Scientific Literacy and Citizenry

The goal to advance ocean literacy is synchronous with the goals of most science educators and research councils (AAAS, 1993; NRC, 1996, 2000), that is, to progress toward a national vision of functional scientific literacy for decision making. *Science for*

All Americans described the scientifically literate person as one who knows that science, mathematics, and technology are interdependent enterprises with strengths and limitations; who understands key concepts and principles of science; recognizes both the diversity and unity of the natural world; and uses scientific knowledge and scientific ways of thinking for personal and social purposes (Rutherford & Ahlgren, 1989). The *National Science Education Standards* defined scientific literacy as the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity (NRC, 1996). However, the question of what constitutes scientific literacy, or what a literate person should know or be able to do, remain controversial (Durant, 1994; Kolsto, 2001; Ramsey, 1993; Sadler, 2004; Yores & Treagust, 2006; Zeidler, 2001).

Factors that have influenced interpretations of scientific literacy are 1) the number of interest groups, 2) different conceptual definitions, 3) the relative or absolute nature of scientific literacy as a concept, 4) different purposes (i.e., benefits) for advocating scientific literacy, and 5) different ways of measuring it. Three common reasons to advocate scientific literacy are 1) economic well being of the nation to compete in international markets, 2) greater literacy translates into greater support for science, and 3) promotion of the public's expectations of science by knowing more about how science is accomplished. Laugksch (2000) concluded that the most advanced scientifically literate person therefore uses science in performing a function in society. Table 4 outlines the parallel relationships between the tenets of scientific literacy and ocean literacy. The following is a review of relevant definitions and specific factors to be considered towards implementation of scientific literacy as relates to the advancement of ocean literacy.

Table 4. Outline of the Parallel Relationships between the Tenets of Scientific Literacy and Ocean Literacy; CKC = Content Knowledge Construction, SSI = Socioscientific Issues and Reasoning

Scientific literacy as defined by Science for All Americans (Rutherford & Ahlgren, 1994)	Scientific literacy as defined Internationally (OECD/PISA, 2001)	Key area addressed as relates to this study; CKC or SSI	Ocean essential principles content as defined by COSEE stakeholders (Schroedinger, et al., 2006)
1. science, mathematics, & technology are interdependent enterprises with strengths & limitations		CKC SSI (e.g. nature of science)	1. earth has one big ocean with many features 6. ocean & humans are inextricably linked 7. ocean is largely unexplored
2. understands key concepts & principles of science	1. capacity to use scientific knowledge	CKC	2. ocean & life in the ocean shape the features of the earth 3. ocean is a major influence on weather & climate 4. ocean makes earth habitable 5. ocean supports a great diversity of life & ecosystems
3. recognizes both the diversity & unity of the natural world	2. identify questions & draw evidence- based conclusions	CKC	1. earth has one big ocean with many features 4. ocean makes earth habitable 5. ocean supports a great diversity of life & ecosystems
4. uses scientific knowledge & scientific ways of thinking for personal and social purposes	3. understand the natural world & the changes made to it through human activity	SSI (functional literacy); consumer, citizen, or steward	4. ocean makes earth habitable 6. the ocean & humans are inextricably linked 7. the ocean is largely unexplored

Laugksch (2000) provided a review of the contemporary literature about scientific literacy. He noted that the term scientific literacy was coined in the late 1950's and has evoked a plethora of meanings. It is noteworthy that this is also the time when modern oceanography emerged as a field of science. Laugksch classified scientific literacy based on three implied interpretations of the word literate. The literate categories are learned, competent, and able to function minimally as consumers and citizens. The emphasis when moving from "learned" to able to "function in society" is an increasing ability to carry out a task with the acquired scientific literacy and use these attributes to cope in everyday life. The learned literate category is proposed only for intellectual value with no associated purpose for obtaining this ability (Branscomb, 1981; Shamos, 1995). Literacy advances to competent when the learned attributes of scientific literacy are extended to an ability to carry out a task (AAAS, 1993; Layton, Davey & Jenkins, 1986). The functionally literate person is required to play a role in society, as citizen or consumer, and to use the knowledge in a variety of social contexts (AAAS, 1993; Miller, 1983). From this literacy continuum it can be concluded that a person can know about the ocean (learned); know about the oceans and participate in a coastal clean up event (competent); or know about the ocean and participate in a petition drive about offshore oil drilling in the Gulf of Mexico, and/or purchase only dolphin-safe tuna (functional). Laugksch (2000) concluded that to be functionally literate requires an individual to use science in performing a function in society in a variety of contexts (i.e. citizen or consumer) that affect their personal or economic well-being.

Ryder (2001) provided a review of published case studies of adult individuals interacting with science to identify the knowledge needed for functional scientific literacy. Drawing from the work of Miller et al. (Miller, 1983; Miller & Osborne, 1998) he outlined five specific knowledge areas that argue for functional scientific literacy. The relationship between levels of science education and the economic wealth of a nation is the ‘economic’ argument (e.g., science graduates needed to occupy science professions). An understanding of science is practically useful in everyday contexts within a technologically advanced society. For example, an individual drawing upon knowledge of human nutrition in following a balanced diet describes the ‘utility’ argument. In contexts featuring scientific information, science knowledge enables people to engage in debate and decision-making as part of the ‘democratic’ argument. The importance of maintaining links between science and the wider culture (e.g., less alienated from science, sympathetic with the aims of science) supports a ‘social’ argument. Finally, individuals should know something of science because it is a major accomplishment of human “cultures”, such as history, music and art.

Shamos (1995) asserted that a functionally literate person lacks an understanding of the fundamental role played by theories in the practice of science and of the unique processes that characterize it. He thus introduces the concept of ‘true’ scientific literacy. ‘True’ scientific literacy is characterized by all the scientific habits of mind such as logical reasoning, the role of experiments, reliance on evidence, the ability to think critically and other elements of scientific investigation. True scientific literacy is also characterized by “the ability to converse read and write coherently in a non-technical but meaningful context” (p. 88). Finally, a true-scientifically literate person is able to use scientific ways of thinking for individual and social purposes (AAAS, 1993; Hurd, 1998; NRC, 1996; Shamos, 1995). Even Shamos (1995) conceded that this level of literacy is likely out of reach for most members of society. It thus lacks meaningful application to current research. The remainder of this section reviews research related to scientific literacy and the influence of contextual values on social knowledge construction. Figure 3 summarizes these findings.

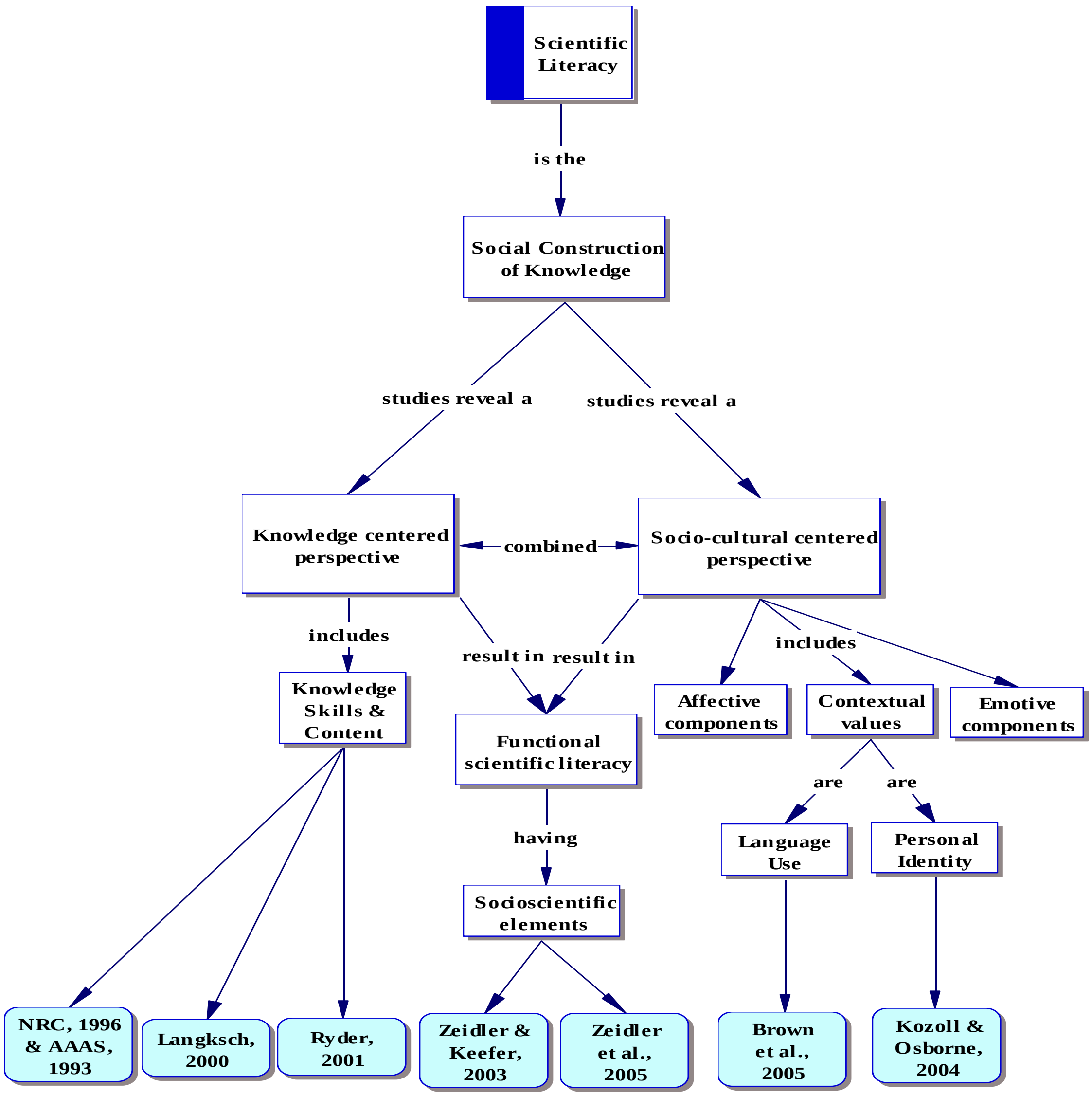

Figure 3. Graphic Summary of Research Related to Scientific Literacy and the Influence of Contextual Values on Social Knowledge Construction

Brown et al. (Brown, Reveles & Kelly, 2005) identified two central perspectives of scientific literacy, a knowledge-centered perspective and a sociocultural-centered perspective. A knowledge-centered perspective is evident in the major reform documents (AAAS, 1993; NRC 1996, 2000). This perspective may be appropriate if a generalized view of knowledge is required, for example, when setting national standards. However, Brown et al. (2005) argued that a knowledge-centered perspective is abstract from experience, ultimately disconnected from the lives of people engaged in their worlds. In contrast, a sociocultural-centered perspective considers how literacy is relevant to particular tasks at hand in some social context. This perspective situates scientific literacy in the action of accomplishing everyday life.

One view (knowledge-based perspective) proposes the acquisition of knowledge as preparation to engage in social events; the other (sociocultural perspective) proposes to engage students in social activities that employ knowledge (Brown et al., p. 780). For example, students spend hours and hours solving math problems or memorizing the body's chemical cycles (e.g. Kreb's cycle), yet seldom does the subject matter connect in a way to inspire or promote sustained interest in science. Scientific understanding of any type must occur within a culturally specific context for participants to make sound use of the new scientific knowledge. Thus, sociocultural perspectives highlight the affective and emotive components of scientific literacy. Factors identified as relevant from a sociocultural-centered perspective included issues of language use (Brown et al., 2005), student identity (Kozoll & Osborne, 2004), and articulating communities (Lemke, 2001; Yerrick & Roth, 2005).

In a study of a fifth-grade classroom of African American students, Brown et al. (2005) examined the use of discursive identity as an analytical framework for understanding student discourse (e.g. attainment of scientific literacy). Results revealed a co-construction of student identity and science literacy through specific language use. The sociocultural context of language was particularly important in considering whether students embrace or resist scientific dialogue (e.g. science learning). This study "provides insight into how students' discursive interactions continually transform new forms of cultural knowledge and understanding of and about science" (p.800).

Kozoll & Osborne (2004) argued that science teaching and learning should include students' understandings of self in relation to others and how science may provide experiences that contribute toward personal growth. Results from four case studies of migrant students revealed perceptions of science that relate to what science is, who it is that does science, and who needs science. The ultimate literacy goal was to achieve a union between science and self to fully realize the potential science has to contribute to citizens' everyday lives. From these findings Kozoll & Osborne (2004) posit the importance of students finding meaning in science as a part of their personal identity and lives lived in the world. However, too often science learning has been abstract and distant from the personal experience.

Zeidler et al. (2005) concluded that many of the previous definitions of science literacy are too narrow and fall short in not attending to "the role of personal epistemological and intellectual development in the context of varied cultural settings" (p. 362). Their definition of functional scientific literacy is "informed decision making; the ability to analyze, synthesize, and evaluate information; dealing sensibly with moral reasoning and ethical issues; and understanding connections inherent among socioscientific issues (SSI)" (Zeidler et al., 2005; p. 358). Two key abilities characterize this literacy: a) understanding the epistemology of scientific knowledge, and b) the processes and methods used to develop such knowledge. In addition, a functional degree of scientific literacy includes evaluation of scientific claims by discerning connections among evidence, inferences and conclusions. The seminal contribution of Zeidler et al. (2003, 2005) offered a coherent conceptual framework to achieve a 'functional' view of scientific literacy. Derived from a cognitive-moral reasoning perspective, this framework identified four pedagogical areas that are central to the teaching of socioscientific issues. These areas are 1) nature of science issues, 2) cultural issues, 3) classroom discourse issues, and 4) case-based issues. These four issues are potential entry points in the science curriculum (see Figure 1, chapter one). Although this framework is a tentative model, it is flexible enough to allow for multiple perspectives. The two perspectives of scientific literacy outlined above are therefore aggregated in the framework proposed by Zeidler et al. (Zeidler & Keefer, 2003; Zeidler et al., 2005) to include both cognitive (e.g., knowledge skills) and affective (e.g., culture, emotions, values) processes, as well as, socioscientific elements and moral reasoning.

The factors outlined in this section related to scientific literacy are significant in evaluating and establishing what constitutes ocean literacy and what an ocean literate person should know and be able to do. For the present study, advancing ocean literacy focused upon the sociocultural-centered perspective of literacy described by Brown et al. (2005) and examined the socioscientific elements of reasoning provided by Zeidler et al. (Zeider & Keefer, 2003; Zeidler et al., 2005). Through this perspective, students will be engaged in social activities that will employ ocean knowledge. Argument structure is beyond the scope of my study, however, I included documentation of how youth learn to talk and write about the ocean, as fundamental components of ocean literacy as defined for this study.

For the present study, I adopted the following definition of ocean literacy. *An individual equipped to use ocean knowledge, to engage in oral or written discussion about the oceans (e.g., support a position), to understand the changes made to the ocean through human activity, and to apply ocean knowledge through actions as citizen, steward or consumer.* This operational definition of ocean literacy most closely parallels the international definition of science literacy which is, “The capacity to use scientific knowledge, to identify questions, and draw evidenced-based conclusions in order to understand the natural world and the changes made to it through human activity” (OECD/PISA, 2001; p. 76).

Ocean Literacy Defined

Ocean literacy was defined in 2005 by consensus of over 100 ocean educators and scientists, including members of the National Marine Educators Association (NMEA) and the Centers for Ocean Sciences Education and Excellence (COSEE). Ocean literacy is an understanding of how the ocean affects you and how you affect the ocean. An ocean-literate person understands the science of the ocean, can communicate about the oceans, and can make informed decisions about ocean policy (COSEE, 2005; Schroedinger, Cava, Strang & Tuddenham, 2006). Seven essential principles guide the scope of ocean literacy. These essential principles are: 1) Earth has one big ocean with many features; 2) the ocean and life in the ocean shape the features of 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 linked; and, 7) the ocean is largely unexplored.

Equipped with a definition, characteristics and essential principles that describe ocean literacy, there is now a critical need to assess the success and shortfalls of current ocean education programs using the tenets of ocean literacy as criteria. Evident from the definition and principles of ocean literacy is that it encompasses both social and scientific factors. Socially, humans are consumers of ocean recreation, transported goods, and products from the sea. Scientifically, humans are dependent upon the ocean to maintain the comfortable climate we live in, for 50% of the oxygen in the atmosphere and similar amounts of carbon dioxide removed from the atmosphere, as well as regulating the freshwater resources on the planet.

As a discipline, oceanography has rarely been examined by social scientists (Goodin, 1995; Mukerji, 1998). Further, the ocean and geological (i.e., Earth) sciences have been under researched in science education (Ault, 1998; Bezzi, 1999; Libarkin, et al. 2005). Research contributed from the ocean sciences education community was primarily from the broader discipline of geosciences education. This research included several examples and applications of teaching strategies such as place-based courses (Kean, Posnanski, Wisniewski, & Lundberg, 2004; Semken, 2005), role playing (Abolins, 2004), and debates (Rebich & Gautier; Schweizer & Kelly, 2005). There is a plethora of articles on ocean teaching materials, programs, government reports, and career guides. However, these materials and reports are not equivalent to educational research. The following is a summary of the research available about ocean literacy.

Personal experience has emerged as a key influence on ocean science literacy. Multiple surveys of adults' literacy about the ocean and coastal environments revealed that the public values the ocean and have emotional (e.g., care and concern) and recreational connections to the ocean but lack ocean content knowledge (Belden, et al., 1999; AAAS, 2004; Steel, et al., 2005). Indeed, although American adults surveyed demonstrated a critical lack of awareness about ocean health and issues (conceptual understanding), these same adults consistently cited personal experiences and emotive connections to the ocean to express value about the ocean. In general these surveys of 1000's of adults via telephone interviews revealed a high level of concern about the ocean but not the understanding needed to act on that concern. Similar findings were reported by Cudaback (2006) from her survey of college students. Personal experience (45% of respondents) with and connection (43%) to the ocean is what most interested respondents about the ocean. The number one ocean content interest of students was to learn about ocean life and ecosystems. These results support the well established role of prior knowledge and personal experiences in learning (Berk, 2000; Bransford, Brown & Cocking, 1999; Flavel, Miller & Miller, 2002).

Cudaback's (2006) research on ocean literacy provided a summary of the ocean topics of interest to college students and affective factors to consider towards advancing ocean literacy. Results from surveys of 119 college students entering an introductory oceanography course revealed that students feel a strong personal, emotional connection with and curiosity about the ocean. Students' prior knowledge about the ocean came from formal courses (56%), personal experience (45%), and media (26%) namely science and exploration television stations. Only a few students (7%) mentioned informal experiences such as aquaria and camps as sources of ocean information. This suggested that either students did not learn or retain ocean knowledge from informal experiences, or that few of the students surveyed had had these informal experiences. Findings related to attitudes about how individual actions affect the ocean identified pollution (88%) and fishing (20%) as the most frequent actions affecting the ocean. Results from Cudaback's survey were encouraging in that students are gaining ocean knowledge from a variety of sources, feel strongly connected to the ocean, and are curious about the oceans and desire to learn more. These results further emphasized the critical need for a baseline of ocean content knowledge at earlier ages to advance a general understanding about the ocean beyond emotive factors.

Content Knowledge

Rest et al. (2000) and Zeidler & Keefer (2003) share the perspective that the primacy of content knowledge in the process of making individual and socially constructed decisions was a pivotal factor in terms of scientific literacy. Without a science knowledge base the social aspect prevailed and allowed for decisions that are made based on psychological processes drawing on the role of affect and emotions in moral decision making. Moral development occurred in tandem but distinct from cognitive development. Cognitive development was necessary but not sufficient for moral development likewise, content knowledge was necessary but not all sufficient for socioscientific decision making. Furthermore, it was not sufficient for students to master the content if they did not understand how to apply it to the world in which they live by reasoning and actions. Teaching must provide more opportunities for students to interact with the subject matter, the environment, other students, and societal issues (Itin, 1999).

The role of content knowledge and scientific literacy was well established and formed the basis of the national science standards. Science content standards described the knowledge and abilities students need to develop to become scientifically literate. Bransford et al. (1999) provided succinct relationships in the construction of knowledge and organization of content knowledge when advancing from novice to expert about any subject matter or skill level. Conceptual understanding of content was strongly influenced by prior knowledge and personal experiences (Berks, 2000; Bransford et al., 1999; Flavel et al., 2002). The remainder of this section reviews what is known about ocean content knowledge and the link between content knowledge and reasoning about socioscientific issues.

Role of Content Knowledge for Understanding about the Ocean

Six studies have been published about marine science knowledge of students at various grade levels (Brody & Koch, 1990, 1996; Fortner & Mayer, 1983, 1991; Fortner & Teates, 1980; Lambert, 2005). These studies focused on students' understanding of specific ocean science concepts. Fortner & Mayer's (1983) conducted a baseline study in 1979 to determine the knowledge and attitudes of Ohio students about the ocean and Great Lakes. The study revealed a low level of knowledge, with 5th graders answering 37.6% and 9th graders 48.3% of questions correctly. Attitudes about the ocean and Great Lakes were related to knowledge, with high scorers having more positive attitudes. Students indicated that most of their information on the content knowledge was obtained through movies and television. The Oceanic and Great Lakes Awareness Survey was repeated in 1983 and 1987, offering a longitudinal study of awareness changes amongst students using comparison groups.

Fortner & Mayer's (1991) cohort comparisons showed that over a four year period, from 5^{th} grade to 9^{th} grade, the students gained substantial amounts of knowledge, increasing their scores on average of over ten percentage points. Both science and social studies subject matter reflected gains, while humanity scores remained constant. Amongst ninth graders, science scores ranged from 49.9 to 54.3. While Ohio students were learning a significant amount about the ocean and Great Lakes in middle years, the slow rise in knowledge levels was indicative of little progress in increasing general awareness of the water world over the eight year test period. Subject matter trends showed improved scores on nearly all biology items, while items related to earth sciences declined or remained at low scores. This finding supported the need to increase basic understanding of Earth (e.g., ocean features and processes) systems and how they relate to people. Media trends demonstrated that students' source of information shifted from television to classes in school, as most influential in teaching students about the ocean.

Brody (1996) assessed the marine environmental science knowledge of 4^{th}, 8^{th}, and 11^{th} grade students in Oregon. Researchers interviewed 159 students on a variety of ocean concept principles in geology, physical and chemical characteristics, ecology, and natural resources. Brody specifically sought to establish the extent of students' knowledge about the nature and use of marine resources. Findings revealed that students learn a few basic science and natural resource concepts in elementary grades, and that overall, the level of understanding of basic concepts and principles related to marine ecosystem dynamics, resource use, management, and decision making processes was low. From 8^{th} to 11^{th} grade students demonstrated an increased understanding of geological processes and structures. Persistent knowledge gains about beaches, sand, and rock shorelines likely reflected personal experiences of students. Little or no difference between grades was found for physical and chemical concepts. Ecological concepts, such as food chain and habitat, showed some elaboration as did natural resource concepts. Overall, older students' understanding did not progress beyond the early grades as evidenced by a lack of elaboration or differentiation of basic concepts, especially physical and chemical concepts.

Two critical points were emphasized in Brody's (1996) conclusions. First, the significance of the misconceptions held by at least half of the students interviewed. These included: 1) no one owns the ocean and there are no political boundaries; 2) animals breathe oxygen in the water by breaking up the water molecule; 3) coral reefs exist throughout the oceans; 4) water temperature changes with seasons and gets colder in winter; 5) salinity is the same throughout the ocean; 6) some plants like seaweed at the bottom of the ocean do not need sunlight to live, they must grow in soil to live. These misconceptions influenced the meanings students attached to concepts and conceptual relationships in the major ocean content principles that were addressed in the Brody's study. Second, the critical need to assess prior knowledge was emphasized. As science education moves toward an interdisciplinary teaching strategy, such as ocean or environmental sciences, the increase in possible misconceptions rises because of the multiple relationships of various concepts from the disciplines.

Fortner & Mayer (1983, 1991) utilized the Oceanic and Great Lakes Awareness Survey to assess student knowledge, while Brody (1996) utilized modified clinical interviews. Overall knowledge progression findings were similar for all authors, however, the details about conceptual understanding varied. The written assessment provided insights about subject matter and attitude trends, while interviews identified misconceptions that would not likely emerge from the awareness survey. The assessment of student knowledge through interviews provided a more comprehensive picture of student understanding of concepts and conceptual relationships than other more frequently used assessment techniques, such as multiple-choice tests (Novak & Gowin, 1984). I used both assessment techniques in an effort to maximize research findings and begin development of a quantitative metric for ocean literacy that can be more broadly distributed. Figure 4 is a graphic summary of research related to what individuals know about the ocean from content scales.

Two studies that provide a more significant research perspective are Lambert (2005, 2006). Lambert provided empirical data from a science content assessment of students before and after their participation in a high school marine science course. This study determined that for at least two of the nine classes studied that marine science could serve as a model for teaching integrated science if curricula and instructional activities are aligned with National Science Education Standards (NSES). Overall, this research found significant science content gains from pre and post camp assessment of high school students completing a marine science course. The most significant content gains seem to be found in the properties of water and ocean and atmospheric interactions. This finding suggests that students in an integrated marine science course improved understanding of physical and chemical concepts. This was not the case in either Brody (1996) or Fortner and Mayer (1991) studies, which showed no appreciable gains in the physical or chemical subject areas.

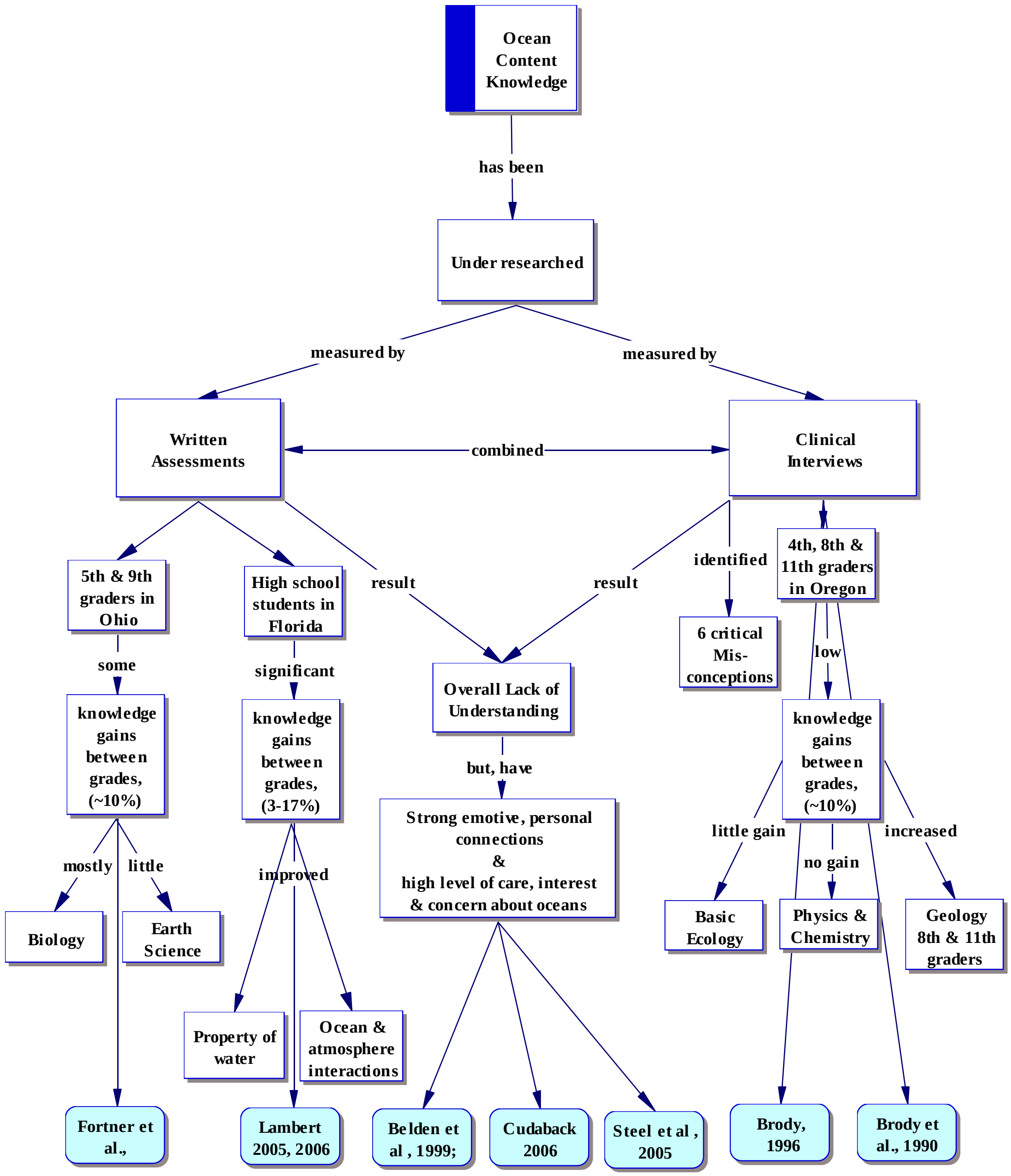

Figure 4. Graphic Summary of Research Related to What Individuals Know about the Ocean from Content Scales

Lambert argued that single-discipline science instruction is outdated for the demands of contemporary science. Students participating in integrated science courses are more completely exposed to the true nature of science than single discipline courses (McComas & Wang, 1998). Integrated science provides a context-rich teaching method that helps students better apply science to their daily lives (McComas & Wang, 1998). Marine science concepts were taught using the context of a system for connecting the disciplines to realistically reflect the relationships in nature. Lambert recommended that more integrated courses be taught and assessed, that course-taking patterns be changed to include integrated science as a core-course option, and to provide professional development for teachers to practice an integrated, system context for teaching and learning. These conclusions supported the case for changes in course design to include integrated content-embedded socioscientific issues (Zeidler & Keefer, 2003; Zeidler et al., 2002). Most prevalent from the research on ocean content knowledge is the overall shortfall of conceptual understanding. The need to provide more opportunities to construct knowledge about the ocean through formal and informal learning experiences and quality media programs is critical to advance ocean literacy.

Role of Content Knowledge for Reasoning about Socioscientific Issues

Sadler & Zeidler (2004) research findings positively supported the significance of content knowledge for informal reasoning of socioscientific issues. The context for their study was reasoning about genetic engineering issues. Findings from a quantitative content measure and multiple interviews revealed that 30 college students' genetics understanding was related to the quality of informal reasoning in response to gene therapy and cloning. Those individuals with a higher level of content knowledge demonstrated fewer reasoning flaws and incorporated genetics content as part of their arguments, consequently improving the quality of their arguments. Individuals who did not possess a strong understanding of genetics frequently cited a lack of content knowledge as a direct reason why they were unable to answer some interview questions. In contrast, findings did not support that individuals with different levels of content knowledge relied on different modes of informal reasoning patterns. For example, 'Understanding the science behind a controversial issue does not necessarily imply that an individual will base his/her decisions on that science content' (p. 89). Findings from this research support a positive relationship between the variables of content knowledge and quality of informal reasoning about socioscientific issues (Hogan, 2002; Zeidler & Shafer, 1984).

Zeidler & Shafer (1984) empirically demonstrated that mastery of content knowledge resulted in improved moral reasoning for college students reasoning about environmental dilemmas. Researchers selected two groups of college students, 86 environmental science majors and 105 non-science majors, to identify the mediating factors contributing to moral reasoning. As expected the environmental content knowledge of science majors was significantly higher than non-majors as well as overall measures of environmental attitudes. However, the groups were not significantly different in terms of affect defined as emotive feelings toward the environment. Both groups exhibited significantly higher levels of moral reasoning on environmental issues (EIT) than on general social issues (DIT), although science majors outperformed non-science majors on both reasoning scales and content measures. Hogan (2002) reported that 8^{th} grade students with the greatest understanding of content knowledge displayed the highest quality of argumentation and informal reasoning in the context of environmental management dilemmas. Figure 5 provides a graphic summary of the influence of content knowledge on reasoning about socioscientific issues (SSI).

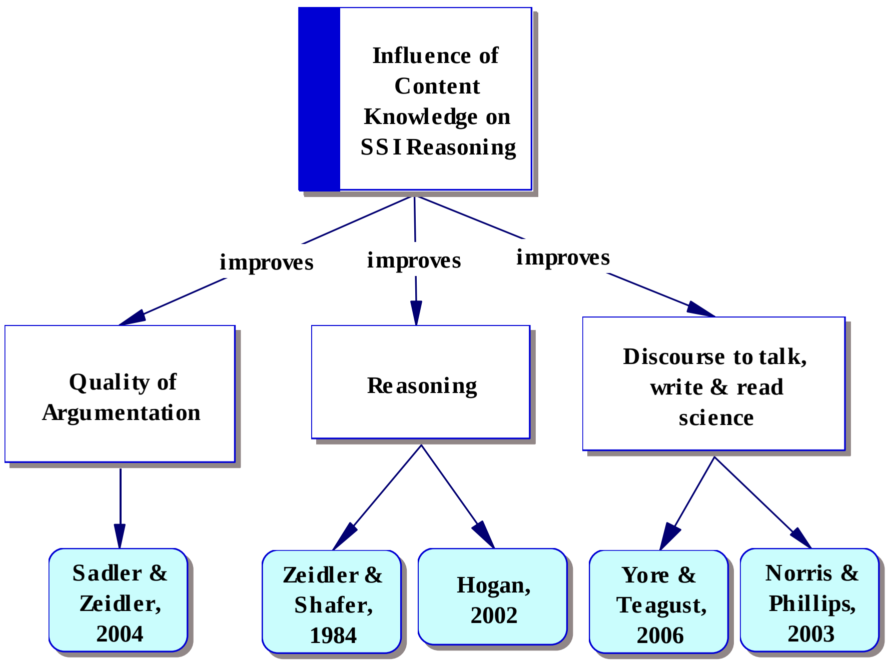

Figure 5. Graphic Summary of Influence of Content Knowledge on Reasoning about SSI

Kolsto (2001) addresses three challenges when dealing with socioscientific issues: "the need for specificity, the need for relevance, and the need to adjust the amount of content knowledge to be emphasized in order to put it within reach of most students" (p. 293). Kolsto provides a framework of eight specific content transcending topics as tools to deal with the science content dimension of socioscientific issues (Table 5). These topics are intended to serve as focal points when developing curriculum materials and provide contexts of application for the science issue.

Table 5. Summary of Kolsto (2001) Content-transcending Topics

I. SCIENCE AS A SOCIAL PROCESS	1. Science-in-the-making & the role of consensus in science
II. LIMITATIONS OF SCIENCE	2. Science as one of several social domains 3. Descriptive & normative statements 4. Demands for underpinning evidence 5. Scientific models as context-bound
III. VALUES IN SCIENCE	6. Scientific evidence 7. Suspension of belief
IV. CRITICAL ATTITUDE	8. Scrutinize science-related knowledge claims

It takes practice to gain competence in using the suggested tools and concepts to examine the science dimension of issues. The ultimate goal was to empower students with tools to gain insights and knowledge that prepared them for doing their own evaluations as to the relative relevance and trustworthiness of different knowledge claims with a science dimension. The present study proposed that understanding of ocean content knowledge supports an individual's ability to reason and contribute positively toward environmental decisions and activities, e.g., stewardship content and attitudes.

Yore and Treagust (2006) emphasized how language shaped and influenced knowledge construction. The authors proposed that a central consideration in facilitating scientific literacy was consideration of "the three-language problem encountered as people move from their home language to an instructional language on their way to acquiring scientific language" (p. 299). Learning how to talk, write, and read science frequently requires the embedding of explicit language tasks and instruction into science inquiry that can be used to enhance the desired sense of scientific literacy---talking, writing, and reading to learn science (Yore, 2000). Science learning and discourse (e.g., oral or written) in classrooms connect classroom talk, informal personal experiences, everyday terms and concrete experiences.

The specific science discourse functions generally employed are argumentation (oral), reading, and writing. Argumentation research often drawing on Toulmin's (1958) model has linked teachers' practice and discourse to students' discourse, identified taxonomies, and criteria for evaluation (Driver, Newton, & Osborne, 2000; Niaz, Aguilera, Maza, & Liedo, 2002; Zohar & Nemet, 2002). However, this line of research needs to link students' argumentative discourse and quality using established means of science achievement (Yore & Treagust, 2006). Norris and Phillips (2003) argue that oral discourse is necessary, but not sufficient to learn and do science. A written record is required to document ownership of claims, reveal patterns of events and arguments, and to connect claims inter-textually. For the present study both oral and written discourse were examined via classroom talk, written records, and guided interviews.

Socioscientific Issues and Reasoning

One way to provide opportunities to practice and experience connections between what the science students are learning and the issues they are likely to confront in their daily lives is through reasoning and discussions about socioscientific issues. The socioscientific issues (SSI) movement emphasizes empowering students to consider how science-based issues and the decisions made concerning them reflect, in part, the moral principles and qualities of virtue that encompass their own lives, as well as the physical and social world around them (Brown et al., 2005; Kolsto, 2001; Kozoll & Osborne, 2004; Lemke, 2001; Sadler, 2004; Zeidler, 2003). This movement provides a conceptual framework that unifies the development of moral and epistemological orientations of students and the role of emotions and character as key components of science education (Sadler, 2004; Sadler, 2005; Zeidler & Keefer, 2003; Zeidler et al., 2005). Socioscientific issues are based on science concepts or problems controversial in nature, discussed in public arenas, and frequently are subject to political and ethical influences. From a theoretical context, socioscientific issues differ from other issues in science in being characterized as open ended, ill structured, debatable problems, subject to multiple perspectives and solutions, and involve the process of negotiation and resolution via informal reasoning (Sadler, 2004; Kolsto, 2001).

One rationale for the use of socioscientific issues to advance scientific literacy is that the processes students are engaged in when making decisions regarding socioscientific issues is similar to the one scientists engage in when making decisions regarding the justification of scientific knowledge (e.g., choosing between two competing theories). While the literature base of socioscientific issues and research is expanding (Abd-El-Khalick, 2003; Sadler, 2004; Zeidler, 2003; Zeidler & Keefer, 2003; Zeidler et al., 2005), there remains a paucity of research about ocean issues (Kelly & Takao, 2002; Rebich & Gautier, 2005; Schweizer & Kelly, 2005) contributing to scientific literacy. As our scientific knowledge and the processes used to develop knowledge about the oceans has expanded, so too has our awareness of the significant impacts of personal, ethical, moral and societal decision-making. In particular, ocean research is increasingly revealing our direct and critical dependence on the ocean as a global, human society. As such, the ocean can contribute powerfully to the current reform initiatives that require scientific literacy that includes moral and ethical aspects, and relevancy. Figure 6 is a graphic summary of research related to socioscientific issues and informal reasoning.

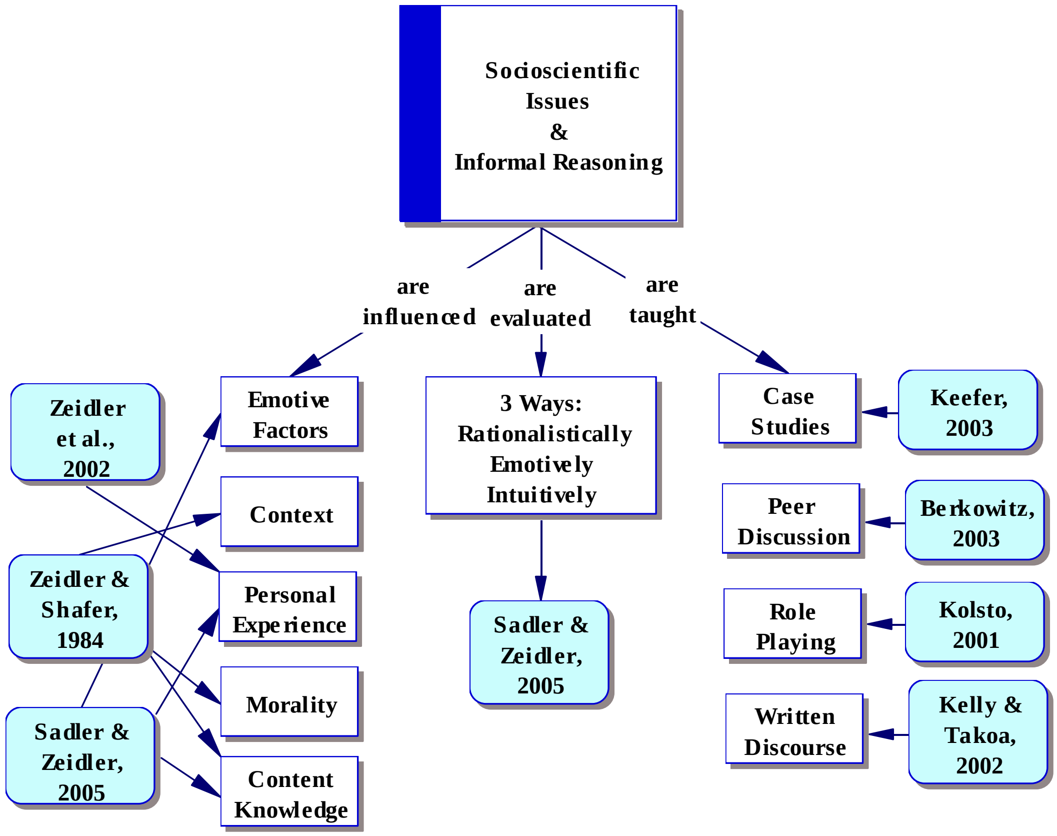

Figure 6. A Graphic Summary of Research Related to Socioscientific Issues and Informal Reasoning

During classroom discussions of SSI students are engaged in informal reasoning as they negotiate and resolve complex problems that lack clear solutions. Findings from Sadler & Zeidler (2005) reveal that students using informal reasoning might relate to socioscientific issues in three ways during discussions: (a) rationalistically, which encompasses reason and logic based considerations, (b) emotively, which encompasses care and empathy based considerations, and (c) intuitively, which encompasses considerations based on immediate reactions to the context of the scenario or dilemmas presented. These results were gleaned from interviews of 30 college students about the topic of genetic engineering. Decision making of college students was further influenced by morality, personal experiences, emotive factors, and social considerations. Thus, both cognitive and affective processes contributed to the resolution of these complex issues via informal reasoning. Sadler's (2004) critical review of informal reasoning and socioscientific issues literature identified a) argumentation skills, b) nature of science conceptualization, c) evaluation of information, and d) development of conceptual understanding of science content as mediating factors. The mediating factors I examined for the present study were conceptual understanding of ocean science content and discourse via talking and writing about ocean issues.

Zeidler and Shafer's (1984) pivotal study with college students substantiated a link between content knowledge and informal reasoning. Researchers selected two groups of college students, 86 environmental science majors and 105 non-science majors, to identify the mediating factors contributing to the moral reasoning. Students completed the Defining Issues Test (DIT), a general measure of reasoning about social issues, the Environmental Issues Test (EIT), a measure of reasoning about environmental problems, the Test of Ecology Comprehension (TEC), a conceptual test of environmental understanding, and the Ecology Attitudes Inventory (EAI), a measure of verbal and actual commitment and affect related to the environment. Results from ANOVA and multiple regression analysis indicated that moral reasoning is influenced by context, content, and attitudes toward the content. The environmental content knowledge of science majors was significantly higher than non-majors, as were overall measures of environmental attitudes. Content knowledge was a significant factor in the resolution of environmental dilemmas. Science majors had greater commitment to and comprehension of ecology than non-science majors.

However, the groups were not significantly different in terms of affect defined as emotive feelings toward the environment. Affect accounted for the most variation in moral reasoning. Both groups, science and non-science majors, exhibited significantly higher levels of moral reasoning on environmental issues (EIT) than on general social issues (DIT), although science majors outperformed non-science majors. The environmental context of this study resonated highly for both groups, thus supporting a relationship between context and moral reasoning. These findings challenged previous work that suggests moral reasoning was independent of context (Iozzi, 1978). The findings of Zeidler & Shafer (1984) also provided evidence that content understanding may be an important variable for informal reasoning. This finding was further substantiated by Sadler and Zeidler (2004), see previous content knowledge section.

Kelly & Takoa (2002) examined university students' use of evidence in writing (i.e. discourse) assignments as part of an oceanography course. Kelly & Takoa provided examples of reasoning skills related to discipline specific constructs (i.e., epistemic levels in argument) and a working model for additional applications and assessments. The hierarchy of epistemic levels presented moved from observation, such as simple data representations and the identification of topographical structures, to interpretive statements including context specific theory and general geological theory.

Personal experience emerged as a consistent influence on reasoning about socioscientific issues. In some studies personal experience seemed to mediate scientific knowledge (Tytler et al., 2001; Zeidler & Shafer, 1984), while other studies suggested personal experience was used to the exclusion of scientific knowledge (Sadler et al., 2002; Zeidler et al., 2002). Kolsto (2001) suggested that only through experience will students develop the attitudes and skills necessary to examine and effectively reason about socioscientific issues. Zeidler and Keefer (2003) posit that learners should be provided with experiences that will have direct impact and relevance to their present and future social experiences.

> The central argument [for teaching and learning] is that if citizens are expected to make reasoned, informed decisions about their science and technology embedded society then as students they ought to be provided with necessary experiences in which to practice and apply this kind of decision making. (p. 11)

In my study, I sought to demonstrate that the ocean can provide relevant science connections to life experience, decisions, and actions impacting individuals and the ocean environment.

Socioscientific Issues and Teaching Strategies

Several recommendations were put forth in the literature for how to teach using socioscientific issues. Socioscientific issues provided a useful mechanism for teachers to stimulate the intellectual and social growth of their students (Sadler, 2004). Among the more common instructional approaches for attending to socioscientific issues were case studies (Keefer, 2003), peer discussion (Berkowitz & Simmons, 2003), role playing (Kolsto, 2001), and explicit nature of science instruction (Abd-El-Khalick, Bell & Lederman, 1998; Khishfe & Lederman, 2006).

Keefer (2003) provided a compelling perspective for the development and implementation of case-based approaches to ethical instruction in science and science education. Keefer recommended a classical approach to moral reasoning because it taught "ethics using analyses of moral decision-making in practical contexts, usually in the form of realistic case examples" (e.g., engineering, medicine; p. 253). Moral decision-making was analyzed using a seven-component model that established if one could: 1) identify the moral issue at stake, 2) identify the relevant knowledge and unknown facts in a problem, 3) offer a resolution, 4) provide a justification, 5) consider alternative scenarios that argue for different conclusions, 6) identify and evaluate moral consequences, and 7) offer alternative resolutions. By specifically outlining these components, the relevance of moral decision-making and its necessity in thinking about and engaging in socioscientific issues was immediately clear. This perspective helped to develop sensitivity to context and the importance of professional knowledge. For practical application of case-based approaches Keefer recommended using realistic cases and case analyses, and infusing inquiry based science and instructional programs with realistic and informed case-based ethical instruction.

Berkowitz & Simmons (2003) posited that teaching and learning must include an understanding of civic character and moral reasoning as integral parts of science inquiry. This research demonstrated how transactive peer discussion not only nurtured the development of moral reasoning and social skills, but also increased science learning and experiences that prepared students to participate in a democratic society. By definition, "transactive discussion occurs when one discussant demonstrates clear discursive evidence of reasoning about another discussant's reasoning" (p. 129). Transactive discussion was likely when students collaboratively explored scientific issues and solved scientific problems. The emphasis on collaborative inquiry-based education closely paralleled the nature of ocean science as nearly every research project was multidisciplinary and multi-collaborative (IOOS, NMS, IODP). Problem solving, reasoning, transactive discussion, and reaching agreement or consensus, each enhanced the science learning and ‘research’ experience. The role and value of the inclusion of peer collaborative scientific and ethical problem-solving and inquiry in the science classroom included learning to solve scientific and mathematical problems more effectively and being more capable of active, thoughtful engagement and understanding in public debates. Results from research in this area clearly demonstrated that more transactive discussion in social interactions was significantly related to both the development of reasoning capacities and the solution to scientific problems. Overlapping science and character education promoted future “ethical scientists and reflective, responsible citizens who are scientifically literate.” (p. 128).

Environmental Morality

The emergence of global environmental problems as major policy issues symbolizes the growing awareness of the problematic relationship between modern industrialized societies and the physical environments on which they depend (Stern, Young & Druckman, 1992). Recognition that human activities are altering the ecosystems on which the existence of all living species are dependent and the growing acknowledgment of the necessity of achieving more sustainable forms of development give credence to suggestions that we are in the midst of a fundamental reevaluation of the underlying worldview that has guided our relationship to the physical environment (Milbrath, 1984). Suggestions that a more ecologically sound worldview is emerging have gained credibility in the past decade (Olsen, Lodwick, & Dunlap, 1992). In this context, it is not surprising to see that traditional measures of "environmental concern" are being replaced by instruments seeking to measure "ecological consciousness" (Ellis & Thompson, 1997), "anthropocentrism" (Chandler & Dreger, 1993), and "anthropocentrism versus ecocentrism" (Thompson & Barton, 1994).

Environmental and outdoor education programs have sought to increase an awareness and understanding of the natural world through an experiential process of engagement with the immediate physical environment. This process of direct experience and primary interaction with the natural environment is intended to influence the learner’s attitudes and behaviors towards the natural world. In turn, these attitudes and behaviors, what may be construed as environmental ethic, often manifest as civic action in the form of particular duties performed for the sake of both the health of the environment and its residents, both humans and animals.

The emphasis on environmental attitudes and values as a primary objective of environmental and outdoor education is well intended and successful (Orr, 2002; Pooley & O’Conner, 2000). Indeed, in terms of effectiveness, outdoor education programs have demonstrated significant change in the student’s pro environmental attitudes. However, environmental attitudes have confounded researchers who have attempted to argue for a strong corollary between one’s attitudes and corresponding behavior. While attitudes provided a means of knowing an individual’s position or preference regarding a specific behavior, object, or organism, they did not contribute to understanding the underlying processes that conspired in the formation of the particular environmental attitude.

Recently, researchers have become interested in the potential role that outdoor environmental education programs can play in promoting moral development (Beringer, 1990; Caduto, 1998; Garvey, 1999; Palmberg & Kuru, 2000). Garvey (1999) and others suggested that outdoor education is inherently suited to present moral dilemmas and facilitate moral reasoning through its emphasis on group problem solving. In this context, moral judgment is understood to be a process through which the decision of what is morally right in the particular situation is determined by deciding what is in the best interest of the group. This is an approach to moral education that subscribes much more to ethics of care and responsibility than ethics of rights and justice. This approach is similar to Kohlberg's (1984) notion of the 'just community' in which the individual's membership within a group of just and caring individuals instills a sense of moral commitment to the group.

The content, setting, and structure of outdoor education programs are unique to facilitate opportunities for moral development. If morality in the conventional sense is a basis for social cooperation and coordination, it is easy to discern the compatibility of outdoor education and moral development. But does the same potential exist for outdoor education in promoting moral reasoning about the environment? Thomashow (2002) suggested that children and adolescents are capable of possessing an ecological identity that has 'the potential to shift the way we conceptualize the world and how it works, shaping an ecologically minded sense of purpose and responsibility in the way we behave' (p. 265-266). Her research attempted to link ecological awareness to identity formation through educational experience that 'integrates the essential character of teens into a study of the local environmental issues' (p. 267). This approach closely parallels the mission of the Oceanography Camp for Girls in advancing a positive sense of self, science, and the environment.

More recently research on environmental attitudes and ethics has moved beyond mere description of who and how much of a given population support environmental conservation efforts, to a deeper understanding of why they hold these beliefs and attitudes (Kahn, 1997; Kortenkamp & Moore, 2001; Thompson & Barton, 1994). One way to achieve answers was by framing one's relationship with the natural environment from a moral reasoning perspective. By extending moral consideration to the natural world, one acknowledges a responsibility for protecting nature and perhaps a recognition of the inherent and intrinsic rights of nature. Moral orientations towards nature are typically categorized as anthropocentric (i.e., nature has value and deserves to be protected as it affects human well-being) or biocentric (i.e., nature is perceived as worthy of rights and protection because of its intrinsic value).

Kortnekamp & Moore (2001) studied university undergraduates' moral reasoning about environmental dilemmas and found variation in biocentric and anthropocentric reasoning that was contingent upon several situational variables. Specifically, the authors determined that when a social conflict was present in the dilemma (i.e., the needs and effects on humans was emphasized), students tended to reason anthropocentrically. Conversely, when a land-use conflict was emphasized (i.e., the impact of an act on the environment was emphasized), more biocentric reasoning was used. These contextual influences highlighted the shortfall of past research on moral reasoning based on principles only, suggesting that moral reasoning was independent of context. The significance of context has also been reported by Zeidler & Shafer (1984). Current research has moved toward a more constructivist approach to understanding moral reasoning by considering salient situational and contextual variables.

The research of Kahn and colleagues (1995, 1997, 1999) involved interviews to determine children’s environmental moral reasoning in response to specific ecological moral dilemmas. The results of these studies provided evidence for the ability of 8th, 5th, 3rd, and even 1st graders to morally reason about the environment, and a systematic analysis of their responses confirmed the existence of both anthropocentric and biocentric orientations in their reasoning. These results represented moral reasoning of a cross section of youth including African American youth living in an inner-urban setting (Kahn & Friedman, 1995), a mixed-ethnic population of children of varying economic levels (Kahn, 1997), and a population of both urban and rural Brazillian youth and Portuguese students (Kahn, 1999). As a cross-cultural representation, Kahn’s studies found commonality among these different groups in both environmental knowledge and environmental moral reasoning.

Kahn and his colleagues discovered that the majority of children interviewed provided justifications for their responses to environmental dilemmas that were prescriptive, generalizable, not contingent on rules, and utilized principles of rights, justice, and welfare. Thus, children reasoning about the environment consistently revealed a type of obligatory moral judgment. For example, Kahn & Friedman (1995) conducted a study among African-American youth living in inner-city Houston. When asked whether it was acceptable to throw garbage into a local bayou that ran through their community, 97% of youth responded that this action was unacceptable, would not be acceptable even if a law allowed for it (97%), and would not be acceptable even if it occurred in a another city where a law allowed for it (86%). These responses supported the assertion that children are not only capable of recognizing issues or moral import, but that they also recognize aspects of nature as morally significant.

Outdoor education programs vary widely in the types of activities and learning that occurs. Zelezny (1999) conducted a meta-analysis of educational tactics intended to improve environmental behavior. The author concluded that educational programs that actively involved the learner were most successful in creating the intended outcomes. Often, these programs used the outdoors as a context for learning and deriving meaning about environmental processes (Caduto, 1998). Direct experiences with nature are thought to increase not only the participant's environmental knowledge but also his or her positive attitudes towards nature. Palmberg & Kuru (2000) in a study of outdoor experiences among 11-12 year old youth, found that those students more experienced in outdoor activities had a stronger emotional relationship with nature, exhibited better social behavior, and had higher moral judgments. Pooley & O'Conner (2000) investigations found that both affect and cognition formed the basis for environmental attitudes. They posited that environmental education programs should balance the emphasis on cognitive-based learning with an emphasis on affective learning. They concluded that attitudes formed through direct experience with objects of nature (e.g., examining aquatic life in a stream in a forest) tended to be affectively based and attitudes formed through indirect experience with objects of nature (e.g., seeing an instructional video on aquatic life) were typically cognitively based. The Oceanography Camp for Girls program used the outdoors as a context for learning and deriving meaning about environmental processes, concurrently providing direct experiences with nature that strive to advance both cognitive and affective-based learning. Within this context I sought to examine how youth think morally about ocean-based environmental dilemmas.

Environmental Attitudes

Environmental attitudes are conceptualized in terms of attitude theory as being composed of beliefs and affect toward an object. The environment as an object is difficult to define. People experience an aspect of the environment (e.g., a beach, a park, a river) not the environment as a whole. To measure environmental attitude, it must be operationalized it or defined to describe what one thinks an individual's environmental attitude might be. Following an extensive literature search on environmental attitude, the work of Dunlap et al. (Dunlap & Van Liere, 1978; Dunlap, Van Liere, Mertlig & Jones, 2000) operationalized environmental attitude and developed a scale to measure it. At the time of its development, people were becoming disenchanted with the so-called "Dominant Social Paradigm," (DSP; Pirages & Ehrlich, 1974), which emphasized human ability to control and manage the environment, limitless natural resources, private property rights, and unlimited industrial growth. In response, Dunlap & Van Liere (1978) developed the New Environmental Paradigm (NEP) scale that emphasized environmental protection, limited industrial growth, and population control. Since its development, the scale has been used in many other studies that have replicated as well as modified the scale. The NEP has established internal validity (coefficient alpha of 0.81), construct validity (predictive validity and face validity), and content validity. Several studies conducted since NEP development, have questioned the validity of the instrument especially since it was not grounded in social-psychological theories of attitude structure.

Twenty years later, Dunlap et al. (2000) conducted an extensive revision of the original NEP to develop the New Ecological Paradigm. This revised ecological instrument improved on the original design as follows: 1) it tapped a wider range of facets of an ecological worldview; 2) it offered a balanced set of pro- and anti-NEP items; and 3) it avoided outmoded terminology. The New Ecological Paradigm Scale consisted of 15 items (Appendix C). Cudaback (2006) used the New Ecological Paradigm instrument with college students in her Oceanography courses, along with modified versions of the AAAS Public Opinion Survey (AAAS, 2004), Ocean Project Public Opinion Survey (Belden et al., 1999a), and CLASS-Geosciences (Libarkin et al., 2005). I used a combination of questions from the NEP and Cudaback’s Attitude Surveys to compose the Survey of Ocean Stewardship (SOS).

Kempton, Boster & Hartley (1995) conducted in-depth, ethnographic interviews in an attempt to sort out the environmental perspectives of Americans. Kempton et al. (1995) concluded that three general sets of environmental beliefs played crucial roles in the "cultural models" by which Americans attempt to make sense of environmental issues. Environmental belief sets were: 1) nature is a limited resource, upon which humans rely; 2) nature is balanced, highly interdependent and complex, and therefore susceptible to human interference; and 3) materialism and lack of contact with nature have led our society to devalue nature. Interestingly, Kempton et al. found three nearly identical beliefs to those that formed the major facets of the NEP Scale; balance of nature, limits of growth, and human domination over nature, further confirming the scales content validity. In the context my study measuring attitudes about the ocean and ocean stewardship, these belief sets were important to consider in development of the Survey of

Ocean Stewardship (SOS) instrument and Survey of Ocean Environmental Morality (SOEM). These instruments strived to access general environmental attitudes, value-based environmental attitudes, and pro-environmental behavior (e.g., stewardship).

The following is a brief review of several key studies examining youth's environmental attitudes and awareness, specifically within the context of experiential, outdoor education programs. Crompton & Sellar (1981) reviewed over 30 empirical studies to determine if outdoor education experiences contributed to positive development in the affective domain. Cumulative findings were generally supportive of claims that outdoor education experiences facilitate positive affective development, if the subject area of concern was closely associated with the outdoors and the outdoor education experience was of sufficient duration (e.g. five or more days). However, these general conclusions remained very tentative for two reasons: 1) the cumulative body of evaluative literature was sparse and the majority was not found in scientific or professional journals; and 2) weaknesses in the quality of research designs, including inadequate control or randomization procedures, small and unrepresentative samples, and untested reliability and validity of instruments. Figure 7 is a graphic summary of research related to environmental morality and the influence of environmental outdoor programs including links to behaviors and attitudes.

In contrast, in more recent studies, researchers have reported a positive connection between attitude and behavior in natural environments (Dressner & Gill, 1994; Leeming, Dwyer, Porter & Colbern, 1993; Palmer & Neal, 1994; Ryan, 1991; Shepard & Speelman, 1985). Mittelstaedt et al. (Mittelstaedt, Sanker & VanderVeer,

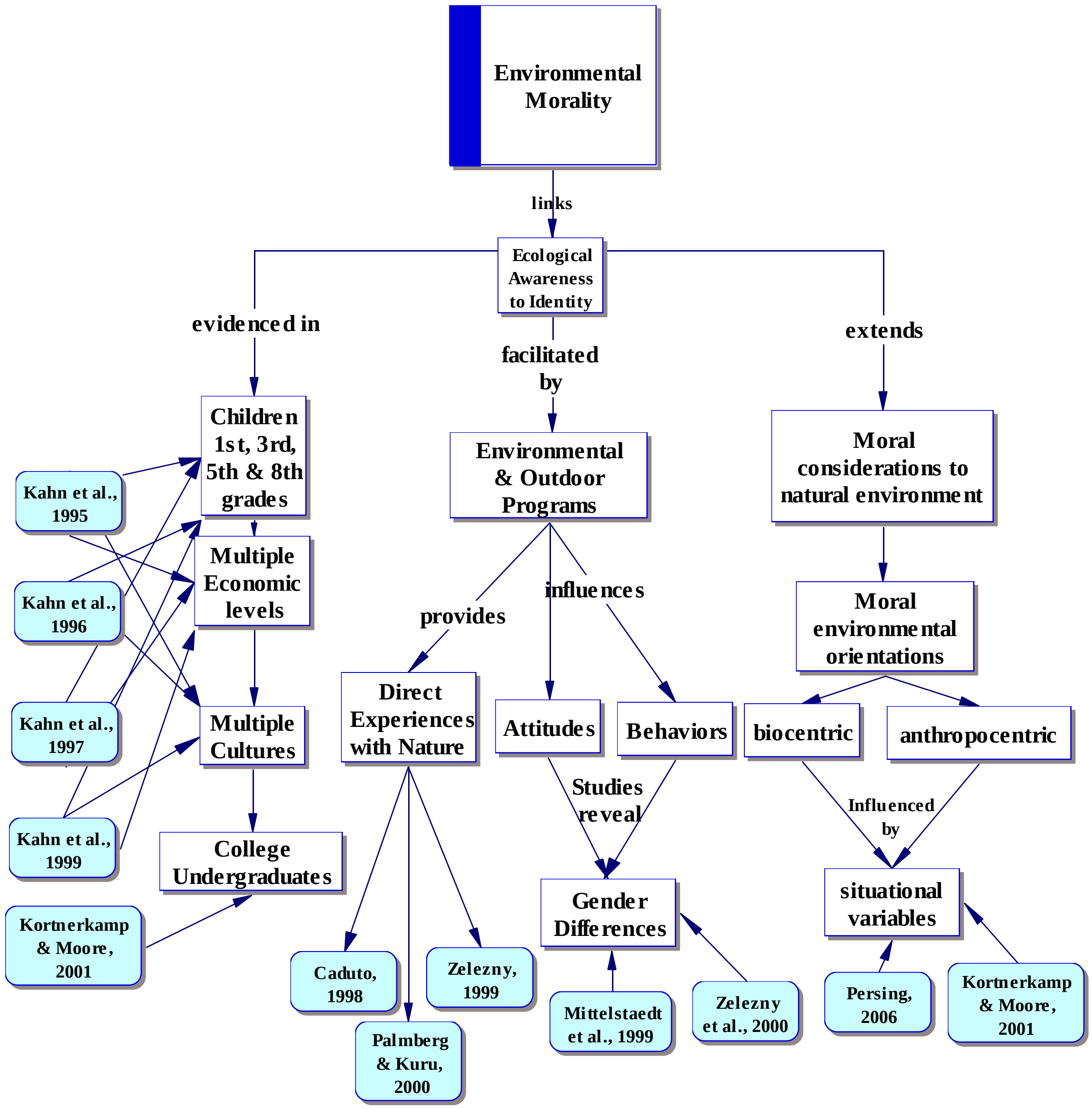

Figure 7. A Graphic Summary of Research Related to Environmental Morality and the Influence of Environmental Outdoor Programs Including Links to Behaviors and Attitudes

1999) evaluated the impact of a week-long summer science camp on 46 youth, ages 9-12 years on their attitudes and behaviors toward the environment. A pre-post research design was utilized using the Millward-Ginter Outdoor Attitude Inventory (MGOAI). This instrument was designed for 9-14 year olds, applicable to camp experiences, included four subcategories (environment, education, pollution, and socialization), and had reliability coefficients that exceed 0.80. Results of the matched t-test analysis comparing pre-post attitude scores indicated significant improvements in all four categories, Girls scored significantly higher on both pre-post attitude scores however, regardless of gender on average, all participants had a positive attitude toward the environment. Both groups had positive attitudes at the outset and these attitudes significantly improved at the end of the week-long program. The most interesting findings from this study were the relationships between intentions related to activity in and for the natural environment and self-reported involvement in those activities.

A content analysis of qualitative data which asked students, 'Is there anything you will do differently in your life after attending camp this summer? If so, what are the three most important things you believe you will do to help the environment? Analysis revealed five key categories of intended behaviors. These were educational action, physical action, persuasive action, acts of omission or preservation, and acts of environmental appreciation and awareness. The largest number of intended behaviors (93% of campers) represented acts of omission (e.g., to not litter or harm nature) or preservation of the environment, indicating a heightened sensitivity to the natural world around them. Physical actions represented the second largest number of intended behaviors; 21% of responses dealt with preservation of the natural environment by picking up trash, saving energy, and recycling. Most noteworthy was that a subset of over 50% of participants were questioned 12-months later and of the 69 intentions originally reported, 60 resulted in actual behaviors. These behaviors included 38% categorized as environmental appreciation and awareness (e.g., going on hikes, listening to nature, respecting and being more observant of nature), and 25% were educational activities (e.g., reading books about nature, learning names of animals, and studying nature on their own). This study supported the research that an experiential education program can effectively help to produce citizens willing and motivated to take some action (e.g., from intentions to behaviors) on behalf of the planet.

Zelenzy, Pho Pheng & Aldrich (2000) provided data on gender differences in environmentalism among 1293 primary and secondary youth systematically surveyed over a two year period. A 35-item instrument was constructed to assess students' general environmental attitudes, self-reported knowledge, feelings of personal responsibility, specific environmental attitudes, and attitudes about recycling. This instrument incorporated 6-items from the NEP to assess general environmental attitudes. Compared to boys, girls consistently reported stronger pro-environmental responses on all environmental variables in this study. In both years, girls reported stronger overall concern for the environment, general NEP environmental concern, and personal responsibility for improving the environment than boys. Further, girls reported stronger concern about trash, interest in recycling, and interest in school recycling. Finally, girls reported significantly more participation in school recycling. Qualitatively, with regard to specific environmental issues, girls reported in both years that the issue that they cared the most about was animal extinction. Boys, however, reported in year one that their top concern was animal extinction, and in year two, they reported that they were most concerned about water pollution. Girls and boys consistently reported, across both years, that they were least concerned about wasting energy. These findings were consistent with the adult studies. Females, regardless of age (i.e., youth or adult) reported more concern for the environment and pro-environmental behaviors than males. In both adults and youth, the effect of gender (female) was stronger on pro-environmental behaviors than NEP environmental concerns. In a subsequent study of gender differences in environmentalism across 14 countries, females consistently reported higher ratings than males on all variables, including pro environmental behaviors. As a group, females across 14 countries reported significantly stronger NEP environmental attitudes, stronger value-based ecocentric environmental attitudes, and greater participation in pro-environmental behaviors, although gender differences in environmental attitudes and behaviors within countries were less convincing. Although the present study is primarily focused on a single gender, findings about gender differences in environmental attitudes and behaviors are important to recognize as potential mediating factors in analysis of my study. Specifically, will trends emerge within a single gender group or be consistent throughout the group?

A Framework for Investigating Ocean Literacy

Cudaback (2006) used the essential learning principles to examine ocean literacy among undergraduate students in her oceanography courses. My study builds on the framework presented by Cudaback to provide comparative data in developing a continuum of ocean literacy knowledge construction and stewardship attitudes. Cudaback has organized in a simple 2x2 matrix the learning objectives for ocean literacy defined by

COSEE (2005). The quadrants of the ocean literacy matrix are named Science Content, Science Attitudes, Stewardship Content and Stewardship Attitudes. Cudaback is working to establish reliability and validity parameters for the ocean literacy surveys developed and evaluated over the past several years with her undergraduate students. Her hope is that students will understand aspects of the ocean sciences, the human impacts upon the ocean (cognitive domain), and perceive science as a useful tool that can be used to protect the ocean (affective domain). Table 6 provides an outline of Cudaback's survey questions by category within the ocean literacy matrix of learning objectives.

Summary of Literature

Research related to scientific literacy and reasoning about socioscientific issues has focused on the following distinct but related areas: 1) scientific literacy as a functional process, 2) the influence of content knowledge on scientific literacy and reasoning, 3) the characteristics of reasoning about socioscientific issues, and 4) the emerging influence of environmental morality. (For graphical summaries of the research related to each of these variables see Figures 3-7.) By exploring the studies contributing to these areas, a comprehensive picture of what is known thus far and what still needs to be learned appears.

Research on scientific literacy focused on pivotal reviews to identify a perspective to frame ocean literacy. Based on the literature, the transition of scientific literacy from a knowledge- centered perspective to a sociocultural-perspective more realistically reflects the true nature of science and social values about science accessible to others (Brown et al., 2005; Zeidler et al., 2005). Of the studies investigated, several emphasized that

Table 6. Ocean Literacy Survey Instrument Questions by Category Within an Ocean Literacy Matrix of Learning Objectives as Conceptualized by Cudaback (2006)

Science Content	**Stewardship Content**
Quantitative ➢ Size Of The Ocean ➢ Properties Of Water ➢ Life In The Ocean **Qualitative** ➢ Ecosystems: Open-Ended With Rubrics	**Quantitative** ➢ Pollution ➢ Coastal Development ➢ Destruction Of Marine Life ➢ Global Warming (Climate Change) **Qualitative** ➢ Ecosystems: Open-Ended With Rubrics
Science Attitudes	**Stewardship Attitudes**
➢ Attitudes About Oceanography Survey ➢ Where Did You Learn About The Ocean?	➢ Concern, Responsibility And Empowerment ➢ Whose Actions Can Affect The Ocean? ➢ Whom Do You Trust To Provide Information About Human Impacts? ➢ Self-Reported Behaviors

science understanding must take place in a culturally specific context for learning to occur by making use of the new knowledge. Relevant factors are language use (Brown et al., 2005; Yore & Treagust, 2006), student's personal identity (Kozoll & Osborne, 2004), and articulating communities (Lemke, 2001). Zeidler et al.'s (2003, 2005) offered a functional view of scientific literacy derived from a cognitive-moral reasoning perspective. Within this framework four pedagogical areas are central to teaching SSI. These are nature of science issues, cultural issues, classroom discourse issues, and case-based issues. From these findings my study grounds ocean literacy within the sociocultural perspective of scientific literacy and case-based and cultural issues (Zeidler et al., 2005) to advance reasoning about ocean issues. Specifically, I examined if current ocean literacy standards are multimodal and go beyond cognitive understanding to include social and emotive aspects of learning.

The studies that examined the influence of understanding content on cognitive literacy and reasoning suggested some tentative, yet instructive trends. A review of current levels of ocean cognitive literacy revealed a general lack of even a baseline of ocean content knowledge amongst youth (Brody, 1996; Fortner & Mayer, 1983, 1991), high school students (Lambert, 2005), college students (Cudaback, 2006), and adults (Belden et al., 1999; Steel et al., 2005) who participated in survey studies. Research supported the critical need to establish a validated, reliable scale to measure conceptual understanding about the ocean across groups. Of the studies reviewed there is no meaningful comparison or validity established. General trends suggested content gains in early grades with no significant gains in later grades. Students who participated in a marine science course demonstrated significant content gains in some areas of oceanography (Cudaback, 2006; Lambert, 2005). However, these results were tentative and require further investigation with validation of scales. A key finding of Lambert's research (Lambert, 2005, 2006) on high school students' conceptual understanding of science after participation in a marine science course supported an integrated curriculum to advance scientific literacy. Support for an integrated curriculum was also echoed by Zeidler (1984) and others (Zeidler, Walker, Ackett & Simmons, 2002) that included socioscientific issues as part of science classes.

Studies related to the influence of content on reasoning about socioscientific issues provided evidence that increased content knowledge influences the quality of informal reasoning (Sadler & Zeidler, 2004; Zeidler & Sadler, 2005; Zeidler & Shafer, 1984). Sadler & Zeidler (2004) specifically focused on the role of content knowledge and informal reasoning. Results support a link between level of content knowledge and quality of informal reasoning, however, additional work is needed in this area. The present study will address the influence of content knowledge and reasoning from a preliminary perspective. The minimal level of conceptual understanding about the oceans required to reason about ocean issues is not yet known. A goal of the Oceanography Camp for Girls environmental program is to increase conceptual understanding about the oceans and that participants will be able to reasonably engage in socioscientific dilemmas related to the ocean environment.

Research related to the role of socioscientific issues (SSI) and reasoning towards scientific literacy demonstrated an emerging role for SSI, especially when viewed in light of a sociocultural perspective of scientific literacy. Sadler's (2004) review of socioscientific issues provided a number of empirical studies that support socioscientific issues as a mechanism to advance scientific literacy. The following factors should be attended to when examining reasoning about socioscientific issues, content (Sadler & Zeidler, 2004), context (Persing, 2006; Sadler 2004; Semken, 2005), morality (Persing, 2006; Sadler & Zeidler, 2004; Zeidler & Keefer, 2003), critical thinking skills (Ault, 1998; Keefer, 2003), and the nature of science (Sadler, 2004; Zeidler & Keefer, 2003). Several authors provide teaching strategies for implementing SSI; case studies (Keefer, 2003), peer discussion (Berkowitz, 2003), role playing (Kolsto, 2001), and written discourse (Kelly & Takoa, 2002). Sadler & Zeidler (2005) identified three ways that college students reason about SSI; rationally, emotively, and intuitively or a combination thereof. Building upon Sadler & Zeidler (2005) research, I explored if the three informal reasoning patterns evidenced in adult college students were manifest in teen-aged girls when negotiating ocean related socioscientific issues.

Studies related to environmental morality and its facilitation via outdoor, environmental programs showed promise as a new line of research in moral development. The majority of research related to environmental and outdoor education programs demonstrate a significant change in students' pro environmental attitudes, however correlation with corresponding behaviors is only recently emerging (Mittelstaedt et al., 1999). Recent moral environmental research has examined the influence of outdoor programs on moral orientations (Kortnerkamp & Moore, 2001; Persing, 2006), attitudes (Palmberg & Kuru, 2000; Zelezny et al., 2000), behaviors (Mittelstaedt et al., 1999), and direct experiences with nature (Caduto, 1998; Zelezny, 1999). Mittelstaedt et al., (1999) provided a comprehensive study of the impacts of week-long, outdoor, science summer camps on youths' attitudes and behaviors toward the environment. Results clearly demonstrated significant improvements on all levels measured, positive environmental attitudes and intentions. Most striking were the delayed post experience results 12 months after the summer program that revealed 69 originally reported intentions resulted in 60 actual behaviors toward the environment. These findings are particularly relevant to my study which hoped to advance ocean stewardship behavior as a post impact of the three-week, Oceanography Camp for Girls summer science program.

A trend that emerged across all research areas was the pervasive influence on knowledge construction, reasoning about socioscientific issues, and environmental morality associated with outdoor learning programs. Specific to reasoning about socioscientific issues, personal experience in some studies appeared to mediate scientific knowledge (Tytler, 2001; Zeidler & Shafer, 1984), while in other studies personal experience was used to the exclusion of scientific knowledge (Sadler & Zeidler, 2005; Zeidler et al., 2002). Personal experiences emerged consistently in ocean literacy surveys as one of the most influential factors reported by adults and undergraduate students when asked about their interest in the ocean and source of prior knowledge (Belden et al, 1999; Cudaback, 2006; Steel et al., 2005). Studies in environmental morality consistently reported the significant influence of direct personal experiences with nature in developing positive attitudes, values, and behaviors towards the environment (Caduto, 1998; Palmberg & Kuru, 2000; Zelenzy, 1999). Specific to knowledge construction and scientific literacy, the role of prior knowledge and personal experiences have been well-established (Berk, 2000; Bransford et al., 1999; Flavell et al., 2002).

I considered the role of personal experience in the process of ocean knowledge construction and moral environmental reasoning. Recognizing and addressing how personal experiences effect development of ocean literacy, reasoning, and decision making was an explicit focus of my study. The future of ocean health relates directly to personal, individual decisions about its management and exploitation. Perhaps building from the point of personal relevance towards scientific understanding can leverage informed decision making about ocean socioscientific issues.

Two major education needs are at the heart of ocean science literacy. These are the need to provide (a) ocean science content and experiences as part of a 21st century integrated science curriculum, and (b) opportunities to engage in ocean-related socioscientific issues (OSSI) meaningful to the life experiences of most citizens. In this way students and citizens can contribute to the social, economic, and cultural development of an ocean literate society permeated with individual, regional, and global implications. An overarching outcome of my study was to examine if current ocean literacy standards are multimodal to go beyond cognitive understanding to include social and emotive aspects of learning.

CHAPTER THREE: METHODS

Introduction

Science literacy research studies have primarily focused on three main areas as factors contributing to literacy. These are content knowledge, process skills, and attitudes about science and towards science. More recently socioscientific decision-making has emerged as a research area of scientific literacy and has advanced a functional aspect to literacy. Elements of socioscientific decision making that guided this study included informal reasoning, understanding of embedded content, and emotive factors. Although current methodologies preclude direct empirical access to an individual's ocean literacy and informal reasoning about ocean issues, the analysis of learning experiences may reveal underlying factors contributing to ocean literacy and decision-making. Because science literacy encompasses both cognitive (content knowledge and skills) and affective (emotions, values, morals, and culture) processes, it is reasonable to hypothesize that both science content and social components will contribute to ocean literacy.

The purpose of this study was to explore the validity of this hypothesis by analyzing learning experiences of individuals to reveal underlying factors and patterns contributing to ocean literacy and reasoning. The overarching goal of the present study was to test the validity of the construct of ocean literacy within the context of an ocean education program. The broader educational objectives of this study relate to students' understanding of particular ocean science concepts (content acquisition, skills development) and changes in attitudes and long-term behavioral outcomes (Ewell, 1987).

In the case of ocean literacy, the learning objective is to positively impact students' understanding, attitudes toward the ocean, and behaviors that protect the ocean (e.g. stewardship). To the extent possible, the research protocol initiated by Cudaback (2006) and Persing (2006) were adapted for this study. This will lead to comparative studies in the future based on similar research design and methodologies, although certain aspects of instruments and measurements will vary due to developmental differences in populations. The initial work of Cudaback (2006) provides some of the first baseline data associated with ocean literacy in a formal education setting. Her sample population was undergraduate students in college level introductory oceanography courses.

The remainder of this chapter presents the research design, methodology and research questions that guide my investigation. Topics include the selection of appropriate content and attitudinal questions, instrument development, selection of appropriate socioscientific issues about the oceans, data collection, the target population and samples, and data analysis.

Research Questions

RQ1. How do content and environmental context mediate the development of conceptual understanding about the ocean during an ocean education program (Oceanography Camp for Girls) for teen-age youth focused on direct experiences in natural environments?

RQ1a. To what extent does content knowledge contribute to conceptual understanding about the ocean?

RQ1b. To what extent do direct environmental experiences (context) contribute to conceptual understanding about the ocean

RQ2. How do environmental attitudes contribute to conceptual understanding about the ocean?

RQ3. What types of environmental moral reasoning are important to youth in resolving ocean dilemmas and how likely are they to act in an environmentally-sensitive way?

RQ4: How do youth informally reason about the ocean socioscientific issues in the context of direct experiences in ocean environments?

Research Design and Methodology

This study primarily explored and described what youth know about the ocean, how they feel and might act toward the ocean (stewardship), and how they reason about ocean issues of interest. Specifically, this research aimed to provide a systematic study which describes what understanding youth have about the ocean (content), how they feel and might act toward the ocean environment (environmental attitudes), and how these feelings and understandings are organized when reasoning about ocean issues (environmental morality). The investigator used a mixed-methods approach to explore these processes. Content knowledge was evaluated using a quantitative survey instrument named Survey of Ocean Literacy & Experiences (SOLE). Stewardship attitudes were measured using a quantitative instrument named Survey of Ocean Stewardship (SOS). Variables related to reasoning about ocean issues (emotions and content knowledge) were explored through qualitative analysis of classroom discussions/role playing, written responses, and interviews. This was an exploratory study of an intact group of 13-14 year old females during an extended, three-week ocean learning experience, encompassing local and global environmental issues and conceptual science understanding.

Construct modeling was used to develop item response measures for each instrument (Linacre, 2002; Wilson, 2005). Construct modeling provided a framework for developing the instruments and a theoretical model of a person's cognition that is an understanding of a certain set of ocean concepts and their attitude and reasoning toward ocean issues. Four building blocks comprised the instrument development cycle, the construct map, items, item scores and measures. A construct map matrix, referred to as Matrix 1, was constructed to align each essential principle of ocean sciences with an established framework for scientific literacy, attitudes, morality, and reasoning using a Knowledge, Impact, Disposition and Skills (KIDS) organizing structure. Matrix 1 provides a visual representation of the construct, ocean literacy, and can be viewed in Appendix F. A second matrix, an items design matrix, was constructed to show which specific instrument items evaluated each concept level constructed in Matrix 1. The item responses Matrix 2 can be viewed in Appendix G.

A survey research design was implemented to provide descriptive and explanatory aspects of ocean literacy and reasoning. Structured interviews have provided a rich description of the types of environmental reasoning commonly used by youth (Kahn, 1999; 2002). However, there is a need to systematically test previous research in this area. The present study examined the types of environmental moral reasoning preferred by youth and while engaged in ocean environmental dilemmas through direct experience and written responses to familiar recreational scenarios. Specifically, the instrument, Scenarios of Ocean Environmental Morality (SOEM), and a series of ocean socioscientific issues (OSSI) activities were examined. A graphic summary of the research design and methodology is provided in Figure 8.

The role of the researcher in this study was as a participant observer. The researcher is co-director of the ocean education program, the Oceanography Camp for Girls, which was sampled for this study. The researcher facilitated many field and lab-based activities as well as the OSSI activities embedded as part of the program. A second researcher, a member of the interviewer team for this study, was also a co-director of the Oceanography Camp for Girls and served to facilitate teambuilding activities, daily energizers and re-focusers, and open-dialogue group activities.

Methods for Assessing Ocean Literacy and Reasoning

The following is a review of the methodology utilized to develop four assessment instruments designed to measure different aspects of ocean literacy and reasoning. The Survey of Ocean Literacy and Experience (SOLE) quantitatively measured conceptual understanding about general ocean content. The Survey of Ocean Stewardship (SOS) will quantitatively measure stewardship attitudes about ocean environmental issues connecting humans and the ocean. The Scenarios of Ocean Environmental Morality (SOEM) quantitatively analyzed environmental morality in the context of ocean dilemmas and the likelihood of acting sensibly toward the ocean environment. The fourth instrument was a set of Ocean Socioscientific Issues (OSSI) activities, as case studies that analyzed how youths' feelings and understanding about the ocean are organized when reasoning about ocean socioscientific issues.

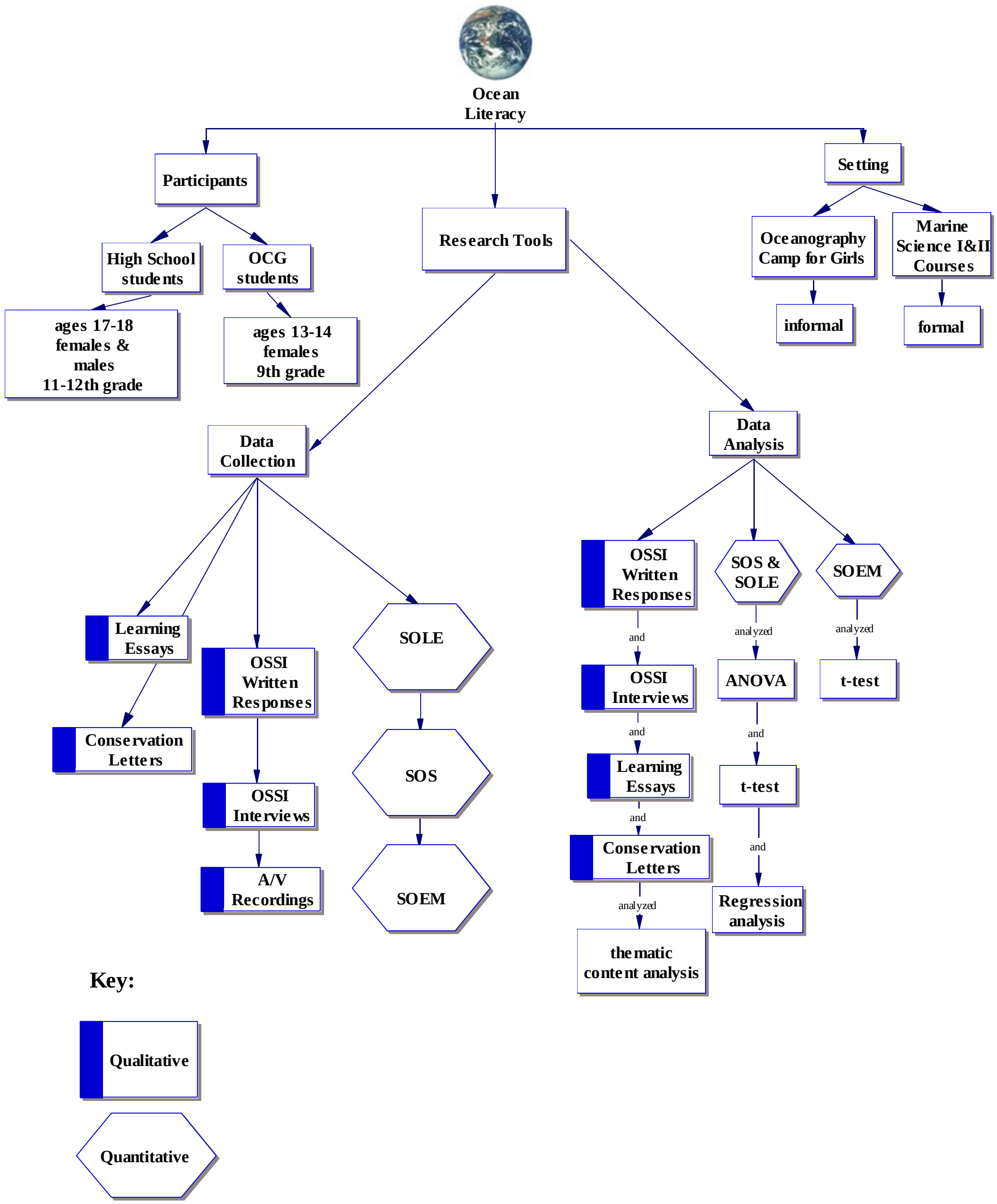

Figure 8. Graphic Summary of Research Design and Methodology

Ocean Sciences Content Selection for SOLE Instrument

For the assessment of literacy of the ocean science content a scale was needed to measure conceptual understanding using the essential principles of ocean sciences (COSEE, 2005), this study requires a measure of ocean conceptual understanding. A review of the literature revealed no preexisting instruments that met the specifications of this study. Therefore, the author developed the Survey of Ocean Literacy and Experience (SOLE). Cudaback (2006) provided some useful survey questions and a framework that had been used to evaluate ocean literacy amongst college undergraduates (Table 7). Cudaback's research design supported research questions 1 and 2 from this investigation.

Table 7. Ocean Literacy Matrix of Learning Objectives as Conceptualized by Cudaback (2006); Italicized Text is Additional Objectives for the Present Study

	Science	**Stewardship**
Content	Ocean Sciences Earth Science *Environmental Sciences*	Human Impacts Suggested Individual Actions
Attitudes	Ocean Sciences Other Sciences *Environmental Sciences*	Cudaback Surveys Public Opinion Surveys *Persing Surveys (2006)* *Kahn semi-structured interviews (1979)*

Content selection for instrument development of the Survey of Ocean Literacy & Engagement (SOLE) was based on general ocean questions from the Essential Principles (EP) and Fundamental Concepts from COSEE (2005) and the 'What I Know Ocean

Survey' based on local ocean content (Tampa Bay and Florida) developed for Oceanography Camp for Girls (Greely, 2004). Specific general ocean questions will focus on EP1 (size of ocean), EP3 (weather and climate), EP4 (habitability), EP5 (biodiversity), and EP6 (human connections). A total of 57 general ocean sciences content questions were constructed (Appendix C). Table 8 is an item content map that provides an overview of the essential principles of ocean sciences used for this study, matrix concept measured (content, attitudes, stewardship, science), instrument choice, and sample group.

Environmental Attitude Content Selection for SOS Instrument

One educational objective for ocean literacy is to positively impact students' attitudes toward the ocean and inspire behaviors that protect the ocean. An instrument was developed to identify emotive factors (attitudes, feelings, experiences) related to ocean literacy. A review of the literature revealed several preexisting instruments that meet the specifications of the present study. Therefore, the author developed the Survey of Stewardship (SOS) by combining questions from other surveys. Cudaback (2006) developed two instruments with 29 items for surveying ocean literacy amongst college undergraduates specifically, attitudes about the ocean and attitudes about ocean stewardship. These same categories comprised the SOS instrument. Content questions for the Survey of Ocean Stewardship (SOS) also utilized 15 questions from the New Ecological Paradigm (NEP) that focused on humans and the environment. The NEP response items have been used with children age 13-15 in United States, Belgium and Zimbabwe (Dunlap et al., 2000). The SOS had a total of 44 items selected from four existing instruments. Items were selected based on reliability estimates for each instrument and use with age groups analogous to my study. It may be that attitudes formed through direct environmental experience such as the Oceanography Camp for Girls are better predictors of behavior (Bixler & Floyd, 1997). Appendix C includes a list of SOS survey items. Rasch analysis provided probabilistic, quantitative estimates of item performance, and model fit statistics which made it possible to assess reliability.

Environmental Morality Reasoning Content Selection for SOEM Instrument

Environmental morality was determined following the protocol of Persing (2006) of the Rest model of moral development. An adaptation of the four-component model of Rest and colleagues (1986, 2000), which describes moral behavior based on four psychological processes, was used to analyze ocean environmental morality (biocentric, anthropocentric) and the likelihood of acting sensibly towards the ocean via ocean environmental stewardship. An instrument, Scenarios of Ocean Environmental Morality (SOEM) was designed to measure ocean environmental moral reasoning rather than collect information by other means, such as interviews (Kohlberg, 1976; Kahn, 1999). The primary reason was pragmatic in choosing a methodology that is time expedient, yet reliable and valid in measuring the important constructs. While much is gained from the interview method including knowledge construction and face validity, limitations exist. For the purpose of this study the reliance on verbal ability (production data) required for successful interviews may not be most effective with youth. Rather a self-administered questionnaire (recognition data) relies less on one’s ability to articulate a response by providing examples of responses which the participant rates and ranks.

Table 8. Content Item Map Using the Essential Principles of Ocean Literacy

Essential Principle	**Number of Questions**	**Concept Measured**	**Instrument Choice**	**Sample Group**
1. Size of ocean	19	14 general ocean content 4 attitudes/stewardship 1 reasoning	SOLE SOS OSSI	OCG & HS OCG & HS OCG
2. Oceans & its life shape Earth	12	6 general ocean content 6 attitudes/stewardship	SOLE SOS	OCG & HS OCG & HS
3. Weather & climate	11	10 general ocean content 1 attitudes/stewardship	SOLE SOS	OCG & HS OCG & HS
4. Habitability	5	1 general ocean content 3 attitudes/stewardship 1 reasoning	SOLE SOS OSSI	OCG & HS OCG & HS OCG
5. Biodiversity	16	13 general ocean content 2 attitudes/stewardship 1 reasoning	SOLE SOS OSSI	OCG & HS OCG & HS OCG
6. Human connections	93	8 general ocean content 23 attitudes/stewardship 62 environmental morality	SOLE SOS SOME	OCG & HS OCG & HS
7. Oceans largely unexplored	6	4 general ocean content 2 attitudes/stewardship	SOLE SOS	OCG & HS OCG & HS
Other questions	*27*	*8 attitudes/stewardship* *19 environmental morality*	*SOS* *SOME*	*OCG & HS* *OCG & HS*
Total essential principles questions	155			

Recognition tasks reduce variability in interpretation, provide clarity about what is being asked, and reduce inherent subjectivity of scoring responses (Rest et al., 1999). There are, of course, limitations with recognition data such as arbitrary ratings and rankings, and overestimation of one's developmental level. The Rest model (1999) uses distinct statements reflective of reasoning from different stages or levels, the researcher then can ask participants to rate or rank these distinct reasons in terms of preference or importance. This method is more flexible and comprehensive because the participant's attention can be focused on specific reasoning types and reactions can be evaluated.

Stephens & Bredemeier (1996) followed the methods of Rest (1979, 1986) by utilizing the technique of recognition data as a way to assess various processes associated with moral reasoning about youth sports, (JAMBYSQ). Persing and Britner (2002) studied middle school students' responses to environmental dilemmas. Persing (2006) minimized the inherent limitations of a paper and pencil instrument by structuring his instrument containing recognition data in a format similar to the DIT (Rest, 1979) and JAMBYSQ (Stephens, Bredemeier & Shields, 1997). Persing's scenarios have been modified for use in the present study by changing scenarios to reflect ocean concepts and settings. It is hoped that these adaptations will allow for comparative studies between researchers.

Ocean Socioscientific Issue Content Selection for Case Studies

It was reasonable to assume that socioscientific reasoning and decision making would be mediated by each quadrant of the Content, Attitudes, Science, and Stewardship matrix. Understanding of ocean content knowledge and attitudes characterized an individual's body of knowledge and feelings regarding a socioscientific issue of interest.

Youth in this study were engaged in a series of ocean stewardship activities including coastal clean-ups and habitat restoration. Embedded in these and other activities were ocean socioscientific issues (OSSI) about which participants reasoned and expressed positions via written and oral discourse, during and following the OSSI embedded activities.

The Ocean Socioscientific Issues (OSSI) activities as case studies were piloted for this study. The first OSSI Case Study was ‘Coastal and offshore fishing’ as it relates to economic and consumer choices (Seafood List) towards conservation of natural resources. The associated activity that addressed this OSSI was *Fish Banks*, a role playing simulation game depicting commercial fishing teams engaged in business and environmental ethics choices. This activity aligned with ocean literacy EP6, EP5 and EP3. A second OSSI Case Study was ‘Biodiversity and protection of endangered species’ as it related to the theme of coastline and habitat protection for endangered species. The associated activity that addressed this OSSI was Turtle Hurdle, a role playing simulation game depicting the life of a sea turtle by engaging students in concepts of predator, prey, life cycles, and identifying natural and anthropogenic impacts on sea turtle survival. This activity aligned with ocean literacy EP6, EP5 and EP4. A third OSSI Case Study was ‘Ocean pollution’ as it related to coastal marine debris. According to adult public opinion surveys, pollution was the most salient threat to the ocean (Belden, et al., 1999b; Cudaback, 2006). The associated activity included a 15-minute NOAA video detailing sources of ocean debris, a 20-minute video (Saving Inky) depicting the rescue and release of a pygmy sperm whale, a coastal clean-up including data collection, and an ocean action letter about how individual teams could contribute to ocean conservation. This activity aligned with ocean literacy EP6, EP4 and EP1.

Analysis of transcripts from A/V recordings of OSSI dialogues, and analysis of written responses, and interviews were used to evaluate reasoning patterns. Descriptive paragraphs of OSSI activities as case study that participants did and questions they responded to in writing are provided in Appendix D. A list of interview questions asked post camp can be found in Appendix E.

After OSSI Cases were presented, participants provided a written response to each issue. Participants completed a higher order task related to ocean stewardship by writing an ocean conservation or issue letter to their congress-person about an issue affecting the ocean. Youth were given free choice about which OSSI Case Study (e.g., coastal pollution, habitat restoration and protection for sea turtles, or conservation of natural resources) concept they addressed in their letter. A thematic analysis of this written form of discourse was conducted independently by two researchers. The goal of the writing activity was to have participants lay out the ocean issues coherently and demonstrate a clear understanding of the relevant science in their ocean conservation letters. A summary of methods used in this study for assessing ocean literacy and reasoning is provided in Table 9.

Table 9. Methods for Assessing Ocean Literacy and Reasoning (SOLE= Survey of Ocean Literacy and Experiences, SOS= Survey of Ocean Stewardship, SOEM= Scenario of Ocean Environmental Morality, OSSI= Ocean Socioscientific Issues, RQ= Research Question Addressed)

	Quantitative Methods	**# Questions**	**Instru-ment**	**RQ #**
Ocean Literacy	General knowledge about the ocean Ocean Attitudes/Stewardship (beliefs, values, feelings) Knowledge related to stewardship activities	47 44 10	SOLE SOS SOLE	1 2 1
Ocean Environmental Morality	Four ocean environmental morality scenarios with a dilemma; walking along the beach, fishing on a bay pier, picnicking in a coastal park, and swimming at the beach/bay	56 questions; 14 for each scenario	SOEM	3
	Qualitative Methods			
Ocean Reasoning	Open-ended written responses to OSSI case study scenarios, follow-up interviews, ocean conservation issue letters	25	OSSI	4
Nature Learning Experience	OCG Comparative learning that asks campers to compare learning in OCG and learning in school	1		1, 2, 3, 4
Other Mediating Factors	Outdoor recreational experiences Standard demographic information Stewardship information about family and friends	25	SOEM	1, 2, 3, 4

Data Collection

Once this study was approved by the University of South Florida's Internal Research Board (IRB), consent forms were distributed to all participants in the present study. Development of the survey instruments, data collection, data analysis and validation of the instruments progressed in a cyclic fashion. Data on a) standard demographics and b) ocean recreational experiences were examined to identify other potential mediating factors contributing to ocean literacy. Responses to open ended questions were used both as qualitative data and to refine questions for sequential drafts of SOLE and SOS until a final version was adopted by consensus of reviewers.

The SOLE and SOS instruments were developed at the high school level. To assess the reliability of the researcher-designed instruments, a pilot study was conducted with a voluntary sample of college and high school level students. The instruments were designed to distinguish between individuals who have a high level of understanding and a level of understanding equivalent to the learning goals of a high school marine science I course. Content validity of the instruments was determined through a review by panel of five content experts (1 high school marine science teacher and 4 marine science professors). Content experts reviewed the proposed concepts for clarity, accuracy, and the extent to which they represent the associated ocean literacy essential principles. After revisions the SOLE and SOS were piloted among a subset of marine science graduate students and a subset of high school students (e.g., enrolled in marine science I and marine science II courses) to provide a larger sample size to calibrate and anchor that instruments by providing a wide range of scores.

From the pilot sample the instrument's internal consistency, reliability, and item analyses were evaluated. Internal consistency analysis estimated test score reliability by examining individual items on the test. Cronbach's coefficient alpha was used for computing test score reliability. Item analysis for SOLE was conducted using p values; in addition, point-biserial correlation coefficients were calculated for each item. The SOLE and SOS were finalized when 4 of the 5 experts approved the appropriateness of a question in addressing the intended concept to be part of the final survey instrument. Each target concept was addressed by at least three questions. The dependent variables included ocean knowledge and environmental attitudes. The resultant surveys were used for the main portion of this investigation. The final versions of each quantitative survey can be seen in Appendix C.

Instrumentation

Survey of Ocean Literacy and Experience (SOLE)

The construct ocean conceptual understanding was measured by 57 items corresponding to the seven essential principles (EP) of ocean literacy (COSEE, 2005). Each EP targeted had a minimum of three corresponding questions related to general ocean knowledge. Items were written as multiple choice questions. The analysis of knowledge was done in two ways: by using separate empirical indicators of each concept and by combining the individual questionnaire items into a summary index. By analyzing each knowledge indicator, it was possible to focus attention on each specific question. By combining several responses into a single index, the goal was to generate a measure that reflected an individual's overall knowledge of the ocean (e.g., ocean literacy index). The value of a summary index can also be used in a regression analysis allowing for statistical controls.

Survey of Ocean Stewardship (SOS)

This study attempted to identify emotive factors (e.g., attitudes, feelings, personal experiences) related to ocean literacy. For the present investigation the 14 item 'Attitudes about Oceanography' survey developed by Cudaback (2006) was distributed to all participants to assess general ocean science attitudes. The 15 item ‘Attitudes about Ocean Stewardship’ survey developed by Cudaback (2006) was distributed to all participants to assess general stewardship attitudes. The 15 item ‘New Ecological Paradigm’ (NEP) survey developed by Dunlop & Van Liere (2000) was distributed to participants to assess relationships between humans and the environment. Post and delayed post surveys asked students to identify specific ocean stewardship activities that they engaged in after the Oceanography Camp for Girls and stewardship activities they may be part of in the future along with a commitment metric. Delayed post SOS provided data on actual behaviors acted upon and compared to the intentions recorded on the post survey. Refer to Appendix C to observe survey items.

A measure of ocean recreation and stewardship participation was constructed to determine the types of environmental service activities each group prefers and enjoys. This measure consisted of 16 items and included an enjoyment scale. Participants were asked how often in the past year they have participated in each activity. Items were measured from 1-5 with 1 indicating never and 5 indicating a few times a week. Participants were also asked how often they planned to participate in each activity in the next five years. Items were measured from 1-5 with 1 indicating never and 5 indicating once every year for five years. This measure provided a level of commitment value. Refer to Appendix C.

Scenarios of Ocean Environmental Morality (SOEM)

To measure the various items associated with ocean environmental moral reasoning four descriptive scenarios were written and contained information about a particular outdoor ocean setting, activity, and moral dilemma. The scenarios reflected outdoor ocean activities that most individuals have directly experienced or are likely familiar with. The first scenario involved walking on an undeveloped beach. The second scenario involved picnicking in a coastal park at an established picnic area. The third scenario entailed fishing from a pier on public land. The fourth scenario described swimming at a public beach.

The goal of a moral reasoning instrument was to design a quantitative instrument to assess several dimensions of moral functioning related to ocean outdoor nature experiences among youth. The framework selected for scenarios was adapted from Persing (2006) and measured several constructs related to youth's moral reasoning about specific ocean environmental dilemmas. One item per scenario measured youth's deontological judgment as a nominal variable and required a yes or no response to commit a specific act that had potential negative environmental consequences. One item was used to measure responsibility judgment as a nominal variable and asked youth whether, based on their deontological judgment, they would or would not engage in the behavior. Moral justification was measured using one item per scenario to provide an indication of whether a moral judgment specific to each scenario was contingent upon specified societal rules or conventions. The construct environmental moral reasoning was measured by nine items corresponding to different types of anthropocentric, biocentric, and egocentric reasoning discussed in chapter two. The anthropocentric items consisted of three categories; welfare, aesthetic, and justice. The biocentric items comprised three categories; intrinsic, justice, and harmony. The egocentric items formed three categories; aesthetic, justice, and personal. Each type of reasoning was measured on a five point Likert-type scale ranging from not at all important to very important. Moral motivation was measured by one item in each scenario in which youth were asked to select the moral reason they most agreed with in guiding their decision to not act in an environmentally harmful way. Likelihood to act was measured by one item asking how likely, based upon the reason they most agree with (e.g., anthropocentric, egocentric or biocentric), they were to act in a morally sensitive way towards the environment based upon the reason. The item was measured on a five point Likert-type scale ranging from not at all likely to very likely (Appendix C).

The measure of ocean outdoor participation consisted of 14 items determined to be the activities most likely engaged in by this age group. Youth were asked how often in the past year they participated in each activity. Items were rated on a scale of 1 to 5 ranging from 1 indicating never to 5 indicating a few times a week. The same items were further rated as to the degree of enjoyment of each activity on a scale of 1 to 5 ranging from 1 indicating do not enjoy to 5 indicating very much enjoy (Appendix C).

A measure of parent and peer environmental attitudes, knowledge, and behavior was included. The influence of parents and peers has been identified as an important factor in the development of youths' environmental values (Bixler & Floyd, 1997; Chawla, 1992; Kals et al., 1999). Questions asked youth how often in the last year 1) the environment was a topic of discussion with family and friends, 2) family and friends recycled items, and 3) family and friends bought environmentally friendly products (e.g., organic produce or all natural cleaning products). The items were measured on a five point Likert-type scale ranging from never to a few times a week (Appendix C).

Interview Structure and Protocol

Participants' informal reasoning of SSI was assessed by guided interviews. Interviews provided a more comprehensive picture of student understanding of concepts and conceptual relationships. Following written responses to OSSI, a subset of participants were interviewed for a deeper understanding of reasoning patterns in the context of ocean socioscientific issues. Conversations were tape recorded and notes were taken by the interviewer. A reading prompt and open-ended questions were similar to those asked in the written surveys, but were presented in ways to encourage a commitment to a position and justification to support one's position. Interviews were guided by a general lead-in reading about the OSSI. Each interview began with a few broad questions to determine the participants' general understanding of the issue. Interview prompts were used to sustain participant interest and to focus attention. The specific probing questions were based on the idiosyncratic response of participants, and interviewers asked them to explain their responses, give examples, or make connections of individual concepts to a specific situation.

The written responses collected through surveys provided insight about the conceptual ideas participants hold about the ocean, while the interviews provided deeper contextual understanding and reasoning patterns. Together, these data allowed for documentation of both the range of ideas held by participants and the perspectives formed about how they view the ocean. Delayed post surveys were conducted to assess longer term impacts, retention of concepts, and provided time to act on intended stewardship behaviors. Delayed post data was gathered three and eight months following the summer program during fall and spring reunions of participants in the Oceanography

Camp for Girls. Finally, demographic questions were asked and include the following categories: age, gender, where live and where grew up (urban, rural, and suburban, near coastline or not), outdoor recreation activities and frequency. Table 10 provides a summary of instrument development and data collection.

Population and Sample

The sample population for this study was an intact group of 30 rising 9th grade students, self-selected to participate in a summer Oceanography Camp for Girls. Participants were teen age girls, ages 13-14. The sample population was a convenience sample. This likely limits the transferability of the research. However, convenience sampling is frequently used when a researcher has access to a particular group of people or solicits participation in a study through voluntary methods (Babbie, 1998). For this study the researcher had access to a particular group of individuals engaged in an informal ocean learning program. This allowed the researcher 1) to survey a population before and after an ocean education learning experience, and 2) to observe the phenomena during implementation in learning environments. All participants voluntarily participated in the data collection for this study. Oceanography Camp participants included first-time campers, alum campers in high school and college age, and marine science graduate students.

The rationale for intentional sampling was to assess mediating factors that contribute to ocean literacy beyond the public attitude surveys previously conducted. Thus, by studying students with an assumed degree of ocean literacy, post and delayed post data can be examined to evaluate mediating factors contributing to ocean literacy

Table 10. A Summary of Ocean Literacy Instrument Development and Data Collection

I. Developed three preliminary instruments

A. Survey of Ocean Literacy & Experience (SOLE) – ocean content knowledge
Survey of Ocean Stewardship (SOS) – stewardship attitudes & content
Survey of Ocean Environmental Morality (SOEM) –environmental morality & reasoning

B. Developed three OSSI activity Case Studies & Questions–reasoning about ocean issues

II. Review instruments for clarity, accuracy and alignment with associated essential principal (EP) of ocean sciences. Modified items as prescribed by experts- content validity.

III. Piloted survey instruments for construct, face validity, item reliability and internal consistency.

A. 50 high school students enrolled in marine science I course (general level)
B. 50 high school students with marine science 2 course (honors level)
C. 12 marine science graduate students and ocean scientists

IV. Rasch analysis of survey items to yield acceptable Cronbach alpha scores that suggest these measures are appropriately constructed

A. Eliminate items not yielding acceptable behavior
B. Final surveys completed

V. Data collection (Convenience sampling)

A. Distribute 3 surveys, SOLE, SOS, SOME
   i. 30 Pre/post/delayed post rising 9th grade girls enrolled 2008 Oceanography Camp (OCG)
   ii. 50 high school students enrolled in marine science I course (general level)
   iii. 50 high school students with marine science 2 course (honors level)

B. Observe reasoning phenomena while engaged in Ocean SSI activities
   i. 30 rising 9th grade girls enrolled in 2008 Oceanography Camp for Girls
   ii. Conduct OSSI Activities (Marine Pollution, Fish Banks, Turtle Hurdle)
   iii. Complete video and audio recordings of post activity discussions

C. Distribute open-ended OSSI questionnaire to gather individual responses
   i. Assign conservation letter writing assignment
   ii. Assign OCG Learning Essay, ‘Learning in OCG compared to learning in school’
   iii. Complete transcripts of recorded post activity dialogues
   iv. Conduct post-treatment guided interviews to assess informal reasoning patterns

and reasoning about ocean dilemmas. A broader focus of this study was to determine 'what is working' with current ocean education programs to advance ocean literacy and identify 'why various strategies are working', as well as 'what is not working'. Therefore, the researcher for the present study acknowledges a level of predisposition towards ocean literacy is expected of participants. Surveys of incoming college students have indicated that students were already gaining ocean knowledge from a wide variety of sources (Cudaback, 2006). This general awareness of ocean sciences was a good basis upon which to build greater understanding and stewardship.

To assess environmental reasoning of sample populations the decision to sample rising 9^{th} graders was based upon previous research in which significant developmental differences in environmental reasoning were revealed. Previous studies have demonstrated significant breaks among fifth graders, eighth graders, and college age students (Kahn, 1999; 2002).

Participation was voluntary. Youth participants in the Oceanography Camp for Girls completed a written application and interview as part of the application process. Finalists were selected based on rankings of two reviewers who have independently reviewed written materials and conducted paired interviews with applicants. Selection and rankings were based on a series of 10 criteria, including social and academic benefits from camp, potential to excel in camp setting, learning ability and exceptionalities, and level of confidence. A total of 30 girls were selected for each camp session. The Oceanography Camp seeks to actively recruit, educate and inspire *all* students. To date, over 800 young women have participated and include minority and non-minority girls inclusive of all learning abilities (e.g., high achieving, average, and high potential).

Participant Characteristics

Initially, 30 of the participants selected for the Oceanography Camp for Girls, during summer 2008 consented to participate in this study. All participants were females who ranged in age from 13-14 with the majority, 90% fourteen years old. They represented 22 schools in Pinellas County including 16 public, 4 private schools, 1 charter school, and 1 home school. The majority of participants were Caucasian, 90% and included 27% high potential (C or lower; at-risk, socially or academically), 33% average (B to C+ students) and 40% high achieving (A to B+) students. Data were analyzed for twenty-nine of the thirty participants in the program, as one camper chose not to complete pre-program surveys and did not attend camp the last day when post-program surveys were distributed.

Context for Treatment

The context analyzed for the purpose of this study was an informal learning setting, the Oceanography Camp for Girls (OCG). The mission of the OCG is to build a positive sense of self, science, and the environment. The Oceanography Camp is a three-week summer educational program for teenaged girls who are poised to enter high school. The primary goals of the program are to retain young women's interests in science and to encourage their pursuit of science careers by sparking their curiosity about the natural world around them. The program provides a multidisciplinary, hands-on, inquiry learning experience in both laboratory and field environments. The camp takes place in an ocean setting at USF marine science laboratories where students actively use the knowledge they acquire to understand local and global environments. Bridging the gap between the real world and the classroom is accomplished by taking students on cruises aboard a research vessel to collect real-time data, taking them on field trips to provide outdoor ecology classrooms, and engaging them in practical laboratory research.

Data Analysis

Rasch Model Analysis

Rasch measurement models were employed to explore the four constructs that guided this study (Rasch, 1980; Wright & Mok, 2004). The Rasch model was selected because it could 1) accommodate different item structures (e.g. surveys, interviews, observations), 2) robustly manage missing data, and 3) provide probalistic, quantitative estimates of both participant and item performance that could be arranged along a single interval scale (e.g., logit scale).

The software, WINSTEPS (Version 3.66) was used to conduct Rasch analyses. Each Rasch estimate included an error term and model fit statistics (e.g., outfit and infit), which made it possible to assess reliability. A Rasch analysis provides a reliability estimate that is equivalent to Cronbach's alpha coefficient. Detailed information about individual performances and item functioning made it possible to simultaneously examine group and individual effects for each instrument. For example, knowledge achievement and ability were analyzed using item location which revealed item difficulty and person location which revealed respondent ability. Rasch outcomes of attitude provided a respondent's attitude toward something via respondent location, and item scale value via item location. Likewise, Rasch outcomes of environmental morality provided a respondent's moral response toward an ocean environmental scenario via respondent location, and item scale value via item location. The distance between logits has a particular probalistic meaning. For this study, an ability estimate for a participant means that the probability of that person performing at a level whose difficulty estimates are at the same level is 100%. The same relationships apply in reverse for levels that are one, two, and three logits harder. The mean item difficulty was set at 50.

Analysis of Ocean Knowledge, Attitudes and Environmental Reasoning

A Rasch analysis was conducted for the following data sets, SOLE, SOS, SOEM and written OSSI responses. All data were coded and entered into a SAS statistical package. The analysis of knowledge, environmental attitudes, and environmental morality and reasoning were accomplished by using separate empirical indicators of each concept and by combining the individual question items into a summary index. Several constructs (e.g. SOS, SOEM) were measured using Likert-type items as integral data and responses were coded on a scale of one to five. Other constructs were measured using continuous data (SOLE) and nominal, ordinal or categorical data (SOME, OSSI written responses).

Rasch analysis calibrated all data to be interval so that multiple data forms are comparable on the same scale. For the present study the constructs of knowledge, attitudes and reasoning were compared to the essential principles of ocean sciences literacy. Thus, all data was evaluated as measured scores not raw data scores. The power of the Rasch model is that it maximizes the available information (e.g., variability) in the data and does not use information that is likely not real. The Rasch analysis uses a conjoint measurement of not only items but also individuals. The Rasch model provides dimensionality and probability. The model was a useful way to look at a complex, multifaceted program. All survey data were analyzed using standard descriptive and inferential statistics. Knowledge data were analyzed using t-tests as appropriate for the data type, as were responses from attitude and reasoning data. Significant differences were reported at the alpha level of $p<0.05$.

Analysis of Informal Reasoning about Ocean Socioscientific Issues

Triangulation involves using multiple methods to collect data. Fraser (1991) recommends the triangulation of qualitative and quantitative methods to enhance the credibility of the results. This study incorporates qualitative data from individual interviews and transcripts of group dialogue to enrich the quantitative datasets. Post treatment interviews were conducted following OSSI group dialogues and written responses performed during OCG. Post treatment interviews were conducted following completion of the SOLE and SOS instruments. Interviews allowed the researcher to include additional data for students' conceptual understanding (SOLE, SOS) and emotive factors (caring, concern, and commitment) that may not have been expressed in the self-report questionnaires. This was also a means of checking students' responses and researchers' interpretations. Interviews were recorded using audio recordings and researcher's written notes of students' responses or comments.

An interview team of one ocean scientist and one social scientist conducted interviews. Following the interview, each interviewer reviewed audiotapes and completed an evaluation rubric for each participant's responses. Each ocean knowledge concept was ranked for basic understanding by designating as complete, incomplete, or missing. Interviewers included notes on specific misconceptions as well as other noteworthy aspects of the interview. Each interviewer also identified patterns and major themes emerging from discussions of reasoning patterns. The interview team shared data as they were collected to provide consistency and corroboration of independent findings, and determine when thematic saturation had occurred. It was hoped that this would protect interviewers from imposing their personal biases on the analysis while providing for the input of various perspectives and expertise that are brought to the investigation by different members of the research team. This resulted in a richer description of student knowledge results and provided a qualitative version of inter-rater agreement.

A framework composed of four of the five criteria, developed by Sadler (2003), was used for analyzing the quality of informal reasoning. Table 11 presents the criteria and descriptive questions for each criterion.

Table 11. Constructs for Assessing the Quality of Informal Reasoning about the OSSI

Criterion	**Description**
Intra-scenario coherence	Does the rationale support the stated position?
Counter-position construction	Can participant construct & explain a counter position?
Rebuttal construction	Can participant construct a coherent rebuttal?
Scientific accuracy	Are the arguments advanced consistent with scientific information?

Content themes of qualitative data, from written and oral responses to questions related to participants' level of informal and environmental moral reasoning, were grouped into categories in order to facilitate analysis. Themes and analysis of the qualitative portion of the research emerged from the data rather than being imposed prior to data collection. According to Patton (2002), the inductive search for patterns can be guided by the research questions. The researcher and other interviewers analyzed the students' comments and organized the responses to find major categories. Final analysis of data incorporated triangulation of the findings from multiple researchers who had reviewed the same datasets for consensus of themes and knowledge content scales. An inter-rater agreement of 80% was sought. Table 12 provides a summary of the data analysis for the present study.

Trustworthiness

The present study used three techniques to address trustworthiness (Lincoln & Guba, 1985) of the results presented. Investigator triangulation was utilized to build credibility and conformability and to guard against the misinterpretation of data. To build consensus about emergent thematic analysis, two raters reviewed 30% of all OSSI written responses. Two raters reviewed 50% of all OSSI interview transcripts. The participants in this research provided member checking to confirm the interviewer's interpretation of their responses and the opportunity to clarify or correct an interpretation. Finally, comprehensive record keeping throughout the course of this study provided an audit trail to further bolster confirmability. The audit trail for this study included detailed notes regarding instrument development, interview questions, modifications, analytical strategies, and development of protocols related to data collection and analysis.

Research Questions 1 and 2:
Survey of Ocean Literacy and Experience (SOLE) & Survey of Ocean Stewardship (SOS)

Survey responses were examined using paired t-tests to determine mean differences between pre and post responses. An overall literacy score was determined to suggest a level conceptual understanding. Significant differences were reported at the alpha level of $p<0.10$. To meet Rasch criteria for a quality instrument SOLE and SOS demonstrated: a) dimensionality or separation reliability (> 0.8, desirable), similar to Cronbach alpha; b) person fit (z-score < 3.0, desirable); and, c) item fit for category ordering and item threshold. Two important statistics provided by Rasch analysis were person performance estimates and item difficulty estimates. The person performance estimates ordered respondents by the likelihood to perform at a given stage. The item difficulty estimates ordered items by their relative difficulty.

Research Question 3:

Scenarios of Ocean Environmental Morality (SOEM)

This study sought to explore the types of environmental moral reasoning (biocentric, anthropocentric, or egocentric) most important to youth in solving specific ocean moral dilemmas. A t-test was performed to determine mean differences between the three types of reasoning (biocentric, anthropocentric, or egocentric). The type of moral reasoning was treated as the nominal level independent variable and the ratings of each type of reasoning treated as the interval level dependent variable. Post hoc testing was used to determine the significance of the relationship. A rubric adapted from the four-component model of Rest and colleagues (1986, 2000), which described moral behavior based on four psychological processes, was used to analyze moral reasoning development about ocean socioscientific issues (Appendix G). To examine if a participant's type of environmental reasoning was predictive of one's likelihood to act in an environmentally-sensitive way, a scenario comparison was conducted. For this analysis, likelihood to act in an environmentally-sensitive way was regressed on each type of environmental moral reasoning. Significant differences were reported at the alpha level of $p<0.05$.

Research Question 4:

Youth's Reasoning about Ocean Socioscientific Issues

For the assessment of reasoning about ocean socioscientific issues, this investigation required a qualitative measure of participants' positions on various issues. Participants challenged with multiple decision making scenarios derived from the three OSSI activities described previously (over fishing, protection of endangered species, ocean pollution). The issues were each based on similar content knowledge (e.g., ocean conservation) and included some level of moral considerations. A series of questions were developed for which participants provided a written response that required a commitment and rationale for the position selected. Following analysis of written responses, post camp interviews were scheduled to clarify themes identified (e.g., member checking). To gain a richer contextual picture of reasoning patterns about OSSI, guided interviews were conducted with a subset of participants. Interviews were recorded and transcripts analyzed for reasoning patterns and quality of reasoning about OSSI. The informal reasoning constructs of Sadler (2003) and Sadler and Zeidler (2005) were utilized for analysis.

Limitations of Study

Important variables potentially affecting a meaningful analysis of ocean literacy include resource limitations to thoroughly exhaust reliability and validity of newly developed instruments. This is due primarily to time constraints in completing this research within the scope of a dissertation. Potential ethical issues that might arise in this research could be participants opting not to participate in the program activities and data collection processes. This was minimized by emphasizing that participation in the Oceanography Camp for Girls was voluntary, students apply and are selected, and data collection was explicitly identified to campers and parents as part of program participation. If any aspect of the program was ethically not agreeable with a student they could opt out of an activity.

The sample population used to represent the data was drawn from an urban, coastal region of central west Florida. The sample was not assumed to be representative of other populations residing in urban or rural, land bound areas. The data were derived from individuals enrolled in a self selected summer experiential, outdoor environmental program and, as such, generalization of results to other populations is not appropriate.

The selection of OCG activities and the four outdoor ocean recreational scenarios likely do not represent universal outdoor activities among all populations. Although selection of these scenarios was based on the national statistics reporting that hiking, picnicking, fishing and swimming are rated consistently high in terms of participation rates (USDA Forest Service, 2001); it was not possible to generalize results from these specific activities and experiences.

The survey method used to collect the data has inherent limitations. Research methods utilizing standardized items with fixed responses compromise depth and specificity of responses for flexibility in design and analysis of these responses, especially those measuring attitudes, beliefs, and behaviors. Survey research occurs outside the realm of real life and thus the context in which much of the phenomena of interest take place is not accounted for. Survey research has been recognized as generally weak on validity and strong on reliability. Therefore, responses to survey items must be understood as only approximations to an individual’s attitudes, beliefs, and behaviors that are compensated for by a standardized format that greatly diminishes the issue of reliability on behalf of the researcher and respondent.

Determining the validity of confidence surveys is critical, because the higher the level of understanding on Bloom's taxonomy, the harder the question is to grade. For large scale educational surveys, the questions must be easy to grade. The challenge for my study, given the limitations, was to find simple proxies for the big questions. Delayed post testing was conducted three and eight months following the summer program, with opportunities to continue post testing multiple years after program participation.

The validity of generalizing the content instruments across populations is a limitation. OCG participants were self selected, therefore preprogram surveys may indicate an upper bound, ceiling effect for ocean literacy in the general population. A control group has not been selected however an appropriate similar cohort group may be available for the purpose of comparison of SOLE, SOS, and SOEM surveys, which would strengthen the research design of this study. A final acknowledgment is that the ocean learning experience targets only females, age 13-14, thus results may not be generalized across populations. Although Batson and others (1999) reported that both male and female college students relied similarly on empathy as a determinant of moral behavior. Similar results have been reported for high school students of both genders regarding empathy, and Sadler (2003) concluded that the ethic of care transcends gender. The moral development literature opinions are still mixed as to whether gender is an important factor. However, research from Zelenzy et al. (2000) clearly demonstrated gender differences in environmentalism. Females of all ages consistently have stronger pro-environmental attitudes and behaviors.

Summary

To implement this study it was necessary to adopt an operational definition of ocean literacy and to develop and multiple instruments to establish a baseline for assessing ocean literacy. These were accomplished by assessing the degree of ocean literacy by developing the Survey of Ocean Literacy and Experience (SOLE) that combined features of ocean and stewardship content, and the Survey of Stewardship (SOS) as an indicator of environmental attitudes influencing ocean literacy. It was anticipated that results from baseline data would identify a suite of factors showing promise towards advancing ocean literacy as defined by the seven essential principles every ocean literate person should understand (COSEE, 2005). Further, evaluation of youth participating in an ocean education program revealed what essential principles of ocean sciences are being addressed through an informal education setting.

Research design proceeded as follows: development and distribution of SOLE, SOS and SOEM, analysis of results from three instruments to identify key factors contributing to ocean literacy; assessment of the relationships among contributing factors and ocean literacy; testing the assumptions of knowledge, attitude, and reasoning based on results from ocean literacy instruments; and finally identifying potential ocean scenarios for socioscientific issues case studies from SOS and SOEM results. This investigation also explored factors contributing to informal reasoning about ocean socioscientific issues (OSSI). Three ocean socioscientific issues scenarios were piloted as part of this study to assess the efficacy of ocean SSI as a component of science literacy.

Table 12. A Summary of Data Analysis

I. Data Processing

a. Coded data and entered into WINSTEP software program for Rasch analysis
b. Knowledge constructs measured used continuous data
c. Moral reasoning constructs measured using Likert-type item and responses coded on a scale of 1-5
d. All categorical data was dummy coded

II. Research question 1a (SOLE) & 2 (SOS)

SOLE and SOS data analyzed using Rasch equivalent of standard descriptive and inferential statistical procedures. Answers related to knowledge and attitude measures analyzed by paired t-tests to determine mean differences between pre and post SOLE and SOS responses. Significant differences reported at the alpha level of p $0<0.05$.

III. Research question 1b

Multiple graders evaluated open-ended responses to the OCG comparative Learning Essay. Responses to open-ended questions were coded and grouped into categories via thematic content analysis and triangulation from multiple researchers to facilitate analysis. Significant differences reported at the alpha level of $p<0.05$.

IV. Research question 3

A qualitative measure of participant's positions on various OSSI utilized thematic content analysis of audio and video recordings during OSSI dialogues. An OSSI questionnaire of individual written responses was examined for patterns of commitment and reasoning level based on rationale for positions selected. Multiple researchers examined data using thematic content analysis towards consensus via triangulation. Post program guided interviews were conducted to assess informal reasoning patterns and quality of reasoning using constructs of Sadler (2003) and Sadler and Zeidler (2005) Table 11 is a summary of constructs used for assessing the quality of informal reasoning about OSSI.

V. Research question 4

a. Results from the SOEM instrument analyzed youth's ocean environmental moral reasoning about four ocean dilemmas. Paired t-tests were conducted to determine mean differences between types of moral reasoning. Significant differences reported at the alpha level of $p<0.05$.

b. Youth's likelihood to act in an environmentally sensitive way was analyzed from SOEM data. To examine this question likelihood to act was compared for differences in each type of reasoning (biocentric, anthrocentric, or egocentric).

CHAPTER FOUR: RESULTS

Introduction

The overarching goal of my study was to test the four constructs of ocean literacy within the context of an ocean education program, the Oceanography Camp for Girls. This chapter presents the results and analysis of ocean literacy in this context and the meaning of these results. The four constructs analyzed in the present study, ocean knowledge, ocean environmental attitudes, environmental moral reasoning, and informal reasoning about ocean issues, were seen as four dimensions on which students could progress towards ocean literacy. The dimensions were positively related because they all related to ocean sciences, but were educationally distinct. Rasch measurement models were employed to explore the four constructs that guided this study (Rasch, 1980; Wright & Mok, 2004).

Data were collected through surveys, extended responses to ocean socioscientific issues, and interviews. Refer to Table 13 for a summary of the number of questions asked from each instrument and alignment with the seven essential principles of ocean sciences literacy. The Rasch model provided a conjoint measurement by analyzing both the items and the respondents, thus maximizing the available information, e.g., variability in the data. The Rasch model calibrated all data types (e.g. ordinal, interval, nominal, etc.) so all were comparable using measured scores in place of raw scores. Measured scores took into account the behavior of the items unlike raw scores. Therefore, constructs could be measured on the same scale for knowledge, affect and morality. The following presentation of data was organized according to the research questions which guided the present study. Each question was restated and relevant findings presented and discussed.

Table 13. Question Groups Asked to Represent Each Construct for SOLE, SOS, SOEM and OSSI as Aligns with the Seven Essential Principles of Ocean Sciences

Seven Essential Principles	**SOLE**	**SOS**	**SOEM**	**OSSI** W=written I=interview
1. Earth has one big ocean with many features	1-11, 13-15, 20	2, 19 35, 40		
2. The ocean and life in the ocean shape the features of Earth	12, 16-18 21-22, 26	11-13, 18, 37		
3. The ocean is a major influence on weather and climate	19, 22, 25 28-33			
4. The ocean makes Earth habitable	39	23, 39	11-66	W 1-23 I 1-20
5. The ocean supports a great diversity of life and ecosystems	35-38 40-48	36, 42	11-66	W 1-23
6. The ocean and humans are inextricably linked	23-24, 27 52, 53-57	4, 7-8, 14-17, 20-22, 25-29, 30-32, 34,39, 41, 44	5-10 11-66	I 1-20
7. The ocean is largely unexplored	49-51, 53			

Interpreting Rasch Model Output Results

The results are presented based on items that were found to fit the Rasch Rating Scale Model. In several instances it was found that 2 and 3-point response scales could be combined to better represent the data than the original 4, 5 and 9-point response scales. The method of assessing change using a dependent t-test often demonstrates statistically significant gains for a group from pretest to posttest. This method however has two limitations. First, changes in the underlying variables are not investigated. For instance, if the variable being measured was not the same from pretest to posttest, evaluation of change was meaningless (refer to Wright, 1996). Second, rather than concentrating on group differences, it was of greater value to see which individuals demonstrated statistically significant gains or losses. The Rasch measurement was used to address both of these limitations of dependent t-tests. Refer to Figure 9 which compares the variable being measured, ocean content knowledge, at pretest and posttest. Several of the items (right-hand side of maps) maintained their location on the variable, which indicated stability (invariance) of the item calibrations. This type of evidence was required to make valid pre-post comparisons. Figure 9 also displays the shift in person measures by observing the shift in the group mean labeled ‘M’ between pre-post responses. Note that results reported for the present study represent calibration of all available data to Rasch measured scores for pre and post responses including partial data, unlike dependent t-tests which are based on complete data only.

Rasch measurement also produced standard errors for each measure. This was a distinct advantage over Classical Test Theory by allowing for the statistical comparisons of pre-post scores at the individual rather than group level (Smith, Lawless, Curda &

Curda, 1999). Using this information, I could identify individuals who displayed statistically significant gains in ocean literacy constructs (e.g., ocean knowledge, attitudes, environmental morality and informal reasoning) and those who demonstrated reductions. Figure 10 demonstrates analysis of change at the individual level. Data points above the identity line indicated statistically significant gains for those individuals from pre to post program responses. This information was of greater value for evaluating the current Oceanography Camp for Girls program and will guide follow-up procedures to investigate how and why the program benefited most individuals while seemingly not affecting a few.

Research Question 1 and Sub-questions

Question 1

How do content and environmental context mediate the development of conceptual understanding about the ocean during an ocean education program, the Oceanography Camp for Girls, an experience for rising 9th graders focused on direct experiences in natural environments?

Sub-Question 1a

To what extent does content knowledge contribute to conceptual understanding about the ocean?

Sub-Question 1b

To what extent do direct environmental experiences (e.g., context) contribute to conceptual understanding about the ocean?

The original intent of research question 1 and its associated sub-questions focused on the influence of content knowledge and context via direct environmental experiences on conceptual understanding about the oceans. Based on dominant research in this area of content knowledge a framework was proposed for analysis of participants. The framework utilized the seven essential content principles of what constitutes ocean literacy as defined by COSEE (2005) to examine the development of conceptual understanding. Ocean literacy was assessed among youth using a multi-item ocean environmental knowledge scale to establish a current baseline of what is presently understood about the ocean. This instrument was called a Survey of Ocean Literacy and Experience (SOLE). A total of 57 items comprised the SOLE instrument and all items were analyzed for this study. Refer to Appendix C for a list of the 57 questions (e.g., items) asked on the SOLE. For content validity, an expert scientist team comprised of four scientists and 2 educators reviewed each item of the instrument and identified which essential principle (EP 1-7) of ocean sciences was addressed by the question item.

My study also examined the extent to which an outdoor ocean education program contributed to ocean literacy through direct experiences with nature. Participants were engaged in ocean learning through physical interactions with multiple natural environments in the Tampa Bay region. Each was asked how the Oceanography Camp for Girls environmental experiences impacted their learning of science. A 500 word learning essay, ‘Compare and contrast learning science during OCG with learning science in school’, was evaluated using thematic content analysis. From a first round of analysis 10 themes emerged as important to youth in comparing science learning via direct experiences with nature and classroom science.

Question 2

How do environmental attitudes (e.g., care, concern and connection) contribute to conceptual understanding about the ocean?

In as much as content knowledge has been shown to contribute significantly to scientific literacy, I sought also to investigate the extent to which it contributes to more favorable ocean environmental attitudes amongst youth. The Survey of Ocean Stewardship (SOS) was used to examine if the OCG experience contributed to more favorable ocean environmental attitudes. SOS was a multi-item scale constructed to assess general environmental attitudes toward science, oceanography, and ocean stewardship. A total of 44 items comprised the SOS instrument and all items were analyzed for this study. Refer to Appendix C for a list of the 44 questions (e.g., items) asked on the SOS.

Question 3

What types of environmental moral reasoning are important to youth in resolving ocean dilemmas and how likely are they to act in an environmentally-sensitive way?

The present study investigated the type of environmental moral reasoning (e.g., biocentric, anthropocentric) important in ocean decision-making and if predictive of one's acting in an environmentally sensitive manner (e.g., ocean stewardship). This was accomplished by developing and piloting four familiar ocean environmental dilemmas adapted from the research of Persing (2006). The Scenarios of Ocean Environmental Morality (SOEM) instrument was used to measure moral motivation and likelihood to act. A total of 81 items comprised the SOEM instrument and 56 items were analyzed for this study. Refer to Appendix C for a list of the 81 questions (e.g., items) asked on the SOEM.

Question 4

How do youth informally reason about ocean socioscientific issues (OSSI) in the context of direct experiences in ocean environments?

The present study examined the influence of learning experiences on informal reasoning about ocean socioscientific issues. This was accomplished by directly engaging participants in ocean socioscientific role-playing and stewardship activities, followed by open dialogue discussions, written responses and interviews. A total of 23 items comprised the OSSI written instrument. Fourteen items were analyzed for this study. Refer to Appendix D for a complete list of OSSI written questions. A total of 20 items comprised the OSSI informal reasoning interviews and seventeen items were analyzed for this study. Refer to Appendix E for a complete list of OSSI interview questions.

Ocean Knowledge Assessment

Research Question 1

How do content and environmental context mediate the development of conceptual understanding about the ocean during an ocean education program, the Oceanography Camp for Girls, an experience for rising 9th graders focused on direct experiences in natural environments?

The Survey of Ocean Literacy and Experience (SOLE) met the Rasch model criteria for the purpose of this research. Participants' responses were analyzed to estimate instrument reliability, e.g., internal consistency. The Rasch model's estimated internal reliability was 0.89, and the equivalent Cronbach's alpha for responses was 0.91. Item analysis of responses revealed that the majority of items, 61.4% were mid-range challenging (difficulty index between 0.41 and 0.60), while 19.3% of items were easy (difficulty index < 0.40) and 19.3% were most challenging (difficulty index > 0.60). Refer to Appendix I for a complete list of items and difficulty indices (e.g., the measurement column of output table).

There was a total of 57 items on the SOLE cognitive instrument. The OCG participant mean scores as a group increased from 54.55 on the pre-test to 60.04 on the post-test. The difference between the mean change scores for the pre and post-test was -5.489 and was statistically significant based on paired t-test. The standard deviation was 5.880 for t= -5.027 (df, 28), p = 0.000. Review of the map of latent distributions and thresholds for SOLE revealed three performance groups. These were participants (18%) that showed highest gains from pre to post (up to 32% gain in SOLE scores), 20% of participants demonstrated moderate gains from pre to post (up to 20% gain in SOLE scores), and 48% of participants showed no significant gain from pre to post (up to 10% gain in SOLE scores). Refer to Figure 9 for construct map of SOLE pre and post person measures and item thresholds. While the majority of participants demonstrated gains in ocean content knowledge, four campers had reduced scores. Qualitative explanations for this trend are addressed below.

In general, results from the analysis of SOLE revealed the majority (25 of 29) of campers had a positive significant gain in ocean content knowledge during OCG. Knowledge gains ranged from 2% to 32% for all but four campers. Three campers had reduced SOLE scores, and one camper completed only 12 of 57 items on the SOLE post-test. Figure 10 demonstrates analysis of change at the individual level. Data points above the identity line indicated statistically significant gains between pre and post camp responses. Most participants demonstrated statistically significant gains, none statistically significant reductions. There are two possible explanations based on a qualitative review of the campers showing no gain in ocean knowledge, 1) the OCG had no effect as measured by SOLE, or 2) these campers did not perform well on the post-test for undocumented reasons (e.g. time limitations, test anxiety, tired, not serious about responses).

The ocean concepts (e.g., essential principles, EP, of ocean sciences literacy) that demonstrated the most significant group gains were items 7, 12, 14, 41 and 48 (Table 14). Four question items performed outside the normal standards for the Rasch analysis. These items were 3, 24, 25 and 32 based on z-scores >3.5. These four questions were likely too difficult as worded. These mis-fitting questions and the ocean literacy essential principle and science disciplines addressed are summarized in Table 15. Two interpretations are possible for why these items performed outside of Rasch standards, 1) items were poorly written or too hard and should be revised or 2) items were within the realm of random expected outliers for a data set with 57 items. It should be noted that items 24 and 25 were identified by the science expert review team as questions of concern, and recommended for revision by two of five experts.

In an effort to improve the precision of the SOLE instrument, following initial analysis of fit statistics, item-to-measure correlations, and redundancy of item difficulty measures additional responses from a group of high school students was added to the

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SOLE Pre-program

SOLE Persons - MAP – Items

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                      <more>|<rare>
75                          +  I0007
74                          +
73                          +  I0025  I0042
72                          +
71                          +T
70                          +
69                     211  +
68                          +  I0009  I0047
67                          +
66                         T+
65                          +
64                          +  I0024
63                          +  I0023  I0031
62                          +
61                     251  +S I0032  I0045
60                161  171 S+  I0012  I0029
59                     091  +  I0030
58           101  131  281  +  I0014  I0053
57           071  191  221  +
56      051  081  121  291  +
55 021  041  151  201  231 M+  I0003
54                          +  I0006  I0008  I0028  I0039
53                          +
52                          +  I0040  I0041
51                     031  +  I0011  I0026  I0056
50                141  181  +M I0005
49                         S+  I0048  I0049  I0054
48                     061  +  I0017
47                     271  +  I0002  I0013  I0033  I0034  I0051
46                241  261  +  I0021  I0027  I0035
45                          +  I0044
44                011  111  +  I0055  I0057
43                         T+
42                          +  I0004  I0038  I0052
41                          +  I0010  I0016  I0018
40                          +  I0019
39                          +S I0015  I0043
38                          +  I0022
37                          +  I0050
36                          +  I0037  I0046
35                          +  I0036
34                          +
33                          +
32                          +
31                          +
30                          +  I0020
29                          +T
28                          +  I0001
                      <less>|<frequ>
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Figure 9a. Construct Map of Person Measures and Item Thresholds for Survey of Ocean Literacy and Experience from Pre-Camp Responses, N=29

SOLE Post-program

Persons - MAP – Items

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            <more>|<rare>
75                +  I0007
74           202 T+
73                +  I0025  I0042
72                +
71                +T
70           232  +
69           042  +
68                +  I0009  I0047
67      212  252 S+
66           172  +
65      192  282  +
64      142  292  +  I0024
63                +  I0023  I0031
62 082  162  242  +
61      072  222  +S I0032  I0045
60           022 M+  I0012  I0029
59 032  122  132  +  I0030
58                +  I0014  I0053
57      052  092  +
56      102  272  +
55      152  182  +  I0003
54                +  I0006  I0008  I0028  I0039
53               S+
52                +  I0040  I0041
51           262  +  I0011  I0026  I0056
50                +M I0005
49      062  112  +  I0048  I0049  I0054
48                +  I0017
47                +  I0002  I0013  I0033  I0034  I0051
46               T+  I0021  I0027  I0035
45                +  I0044
44                +  I0055  I0057
43                +
42                +  I0004  I0038  I0052
41                +  I0010  I0016  I0018
40                +  I0019
39                +S I0015  I0043
38           012  +  I0022
37                +  I0050
36                +  I0037  I0046
35                +  I0036
34                +
33                +
32                +
31                +
30                +  I0020
29                +T
28                +  I0001
            <less>|<frequ>
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Figure 9b. Construct Map of Person Measures and Item Thresholds for Survey of Ocean Literacy and Experience Post-Camp Responses, N=29

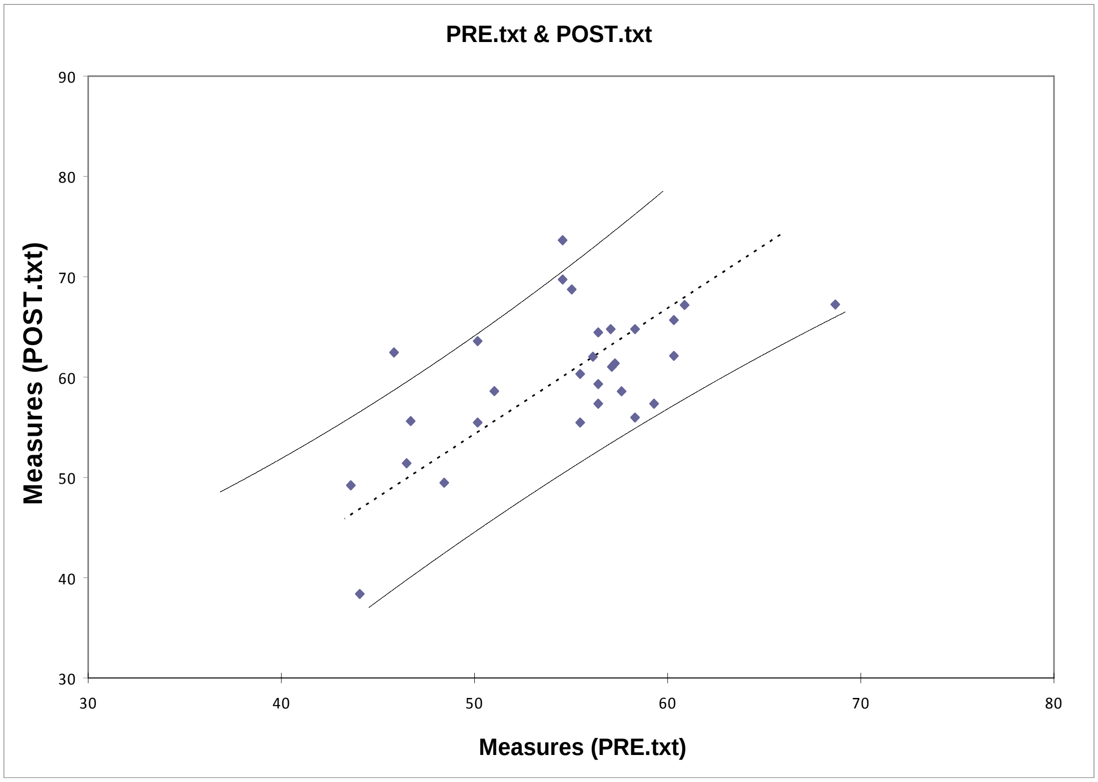

Figure 10. Plot of Pre-Post Measures to Demonstrate Analysis of Change at the Individual Level for the Survey of Ocean Literacy and Experience Responses, N=29

Table 14. SOLE Questions Demonstrating Most Significant Group Gains

SOLE Question	Essential Principle	Science Discipline
7. Approximately how much of the earth's water is fresh and unfrozen (neither ice nor ocean)? (Answer: 1%)	1	physics, chemistry
12. Many earth materials originated in the ocean. Which rock type now exposed on land in the Southwest U.S. formed in the ocean? (Answer: sedimentary)	2	geology, physics
14. Approximately what fraction of the total water on the earth is in the ocean? (Answer: 97%)	1	chemistry
41. Ocean life ranges in size from the smallest virus to the largest animal that has lived on earth, called the (blue whale)	5	biology
48. Which ocean ecosystem provides habitat for one-third of all marine species? (Answer: coral reefs)	5	biology

Table 15. SOLE Misfit Questions Performing Outside Criteria of Rasch Analysis

SOLE Question	Essential Principle	Science Discipline
3. Rivers supply most of the salt to the oceans, which comes from (seafloor reactions, eroding land, volcanic emissions, and the atmosphere)	1	physics, chemistry
24. What is the source of most trash on the beaches in the U.S.? (Answer: people leaving trash)	6	biology, unifying concept
25. The ocean dominates the earth's carbon cycle. Approximately how much of all the carbon dioxide in the atmosphere is absorbed by the ocean? (Answer: 50%)	3	chemistry, physics
32. The ocean dominates the earth's carbon cycle. Approximately how much primary production on earth takes place in the sunlit areas of the ocean? (Answer: 50%)	3	chemistry, biology

SOLE for a second level analysis. The increased sample size (n=105) provided a broader distribution of responses and in turn provided better anchors for calibrating the instrument. The resultant analysis improved the precision of the SOLE instrument as a measurement device of ocean content knowledge aligned with ocean literacy standards. All items that correlated > 0.2 using Rasch point measure analysis (e.g., point bi-serial analysis). Refer to Appendix I for a listing of item measure correlations for the 57 items comprising SOLE. No persons were identified as potential misfit data based on the person fit statistic (all z-scores > 2.0). While the instrument was calibrated with a larger data set (n=105), only results from 29 participants in the 2008 Oceanography Camp for Girls are reported.

Results from the first-round of thematic analysis of 30 Science Learning Essays revealed the following trends from participants written responses. The learning themes that emerged consistently across 30 essays included 1) hands-on learning, 2) caring people to ask and discuss science questions, 3) more than just learning science, 4) all girls-no boys, 5) doing science not talking science, 6) using authentic equipment to do field and lab-based research, 7) having fun learning authentic science and environmental issues, 8) field visits to learn about the jobs oceanographers and other scientists do, 9) career interviews with scientists in their work environment, and 10) scientists as real people and professionals.

Table 16 provides excerpts from participants' learning essays.

Results indicate that the learning context for the Oceanography Camp for Girls had a positive impact on learning about the ocean, science and environmental issues. The importance of context in learning and reasoning has been consistently cited in the literature. This is discussed in more detail in chapter 5.

Ocean Environmental Attitudes Assessment

Research Question 2

How do environmental attitudes (e.g. care, concern and connection) contribute to conceptual understanding about the ocean?

The Survey of Ocean Stewardship (SOS) met the Rasch model criteria for the purpose of this research. Participants' responses were analyzed to estimate instrument reliability, e.g., internal consistency. The Rasch model's estimated internal reliability was 0.89, and the equivalent Cronbach's alpha was 0.90 for the multiple response Likert type items. The SOS instrument had three sub-scales for attitudes about oceanography, attitudes about ocean stewardship, and attitudes about humans and the environment. Refer to Appendix K for a summary map of item and individual (person) indices.

Because there was a total of 44 items on the cognitive instrument, means scores were converted to percent correct for ease of data interpretation. The participants' mean

Table 16. Excerpts from Participants' Science Learning Essays as Revealed from Initial Thematic Content Analysis, N=30

Learning Content Theme	**Excerpts from written learning essays**	**% Occur-rence**
Hands-on science learning	OCG is amazingly fun, hands on science experience. Everything is hands-on.	97%
Caring people to ask & discuss science questions	Also, at OCG you are surrounded by mentors who care about whether or not you understand the things the talk about. I love working with teachers but at OCG we get to work with teachers that are also scientists.	27%
More than just learning science	OCG is a joyous way to learn about marine biology, oceanography, teen issues, and positive energy. I am so glad that I got in because it has changed the way I look at things now. For instance, whenever I see trash on the ground I pick it up and throw it away, cause after the camp showed the other girls and myself the video about what pollution is doing to our marine animals, I just can't let that happen; and another good thing that I learned from camp is, one person can make a big difference.	83%
All girls- no boys	It is a camp for girls and girls only; so we have no one to impress or show off in front of, and try to top any of the girls. I love learning with girls, there are no boys to cause distraction, competition, or annoyance to anyone.	50%
Using authentic science equipment to do field and lab-based research	We also get to experience an equivalent to being "real" oceanographers by working with field equipment, analyzing our data and working in labs.	33%
Field visits to learn the jobs oceanographers and other scientists do	We got to talk to people, well really scientists about the specific field they study. There are a lot of fields in oceanography. For example, one scientist might study sediments, while another will study fish eating habits, or one might study hurricane patterns while another is building the technology to allow these scientists to study the field that they do.	17%
Doing science, not talking about science	When I was on cruise I learned many new things like how to identify plankton, fish and invertebrates, measuring nutrients in the sea, and how to use a Niskin bottle. I really liked learning and observing the life in the sea…	27%
Having fun learning authentic science and environmental issues	The style of learning is awesome! I love it…we always learn new things by voice…We are not locked up in classrooms with books all day. I learn more quickly and I have tons of fun in the process. I'm glad we had the Clam Bayou clean –up. It was self assured to myself that pollution can happen on private property.	Learn-ing = 100% Env. Issues =33%
Scientist as real people and professionals	Teresa and Angie take pleasure in seeing us happy, like when they smile, sing and dance with us… teachers at school don't like seeing us sad but at camp it's a big family and we want everyone to feel great, confident and radiant."	13%
Career interviews of scientist where they work	We got to meet ACTUAL scientists and that was very interesting. These people are THE people to ask if you have a specific question in a particular area.	13%

score as a group was 60.88 (s.d. 5.05). Mean score increased from 59.89 agree to strongly agree positively on the pre-test to 61.87 on the post-test. The difference between the mean change scores for the pre-test and post-test was -1.98 and was not statistically significant using a paired t-test, $p<0.05$. The standard deviation was 1.14 for t= -1.73 (df, 55), p = 0.089. Review of the map of latent distributions and thresholds for SOS revealed two performance groups. These were participants that demonstrated moderate gains from pre to post (14%) and those who showed no significant gain from pre to post (76%). Refer to Figure 11 for map of SOS pre and post person measures and item thresholds.

In general, results from the analysis of SOS revealed positive attitudes of the majority of participants before participation in the Oceanography Camp for Girls. As indicated by this scale the sample population was already positive about the ocean, stewardship and the environment, leaving little opportunity for a gain from pre to post responses. Indeed, it is likely that a ceiling effect was evident and the SOS scale had no sensitivity with this sample population within the range of the instrument. The average person began 1.5 standard deviations above the mean before the OCG experience. Stated another way the average person started at a mean of 62.5 on a mean scale of 50. The result was little room to improve attitudes that were already positive to strongly positive. The SOS met the Rasch model criteria for internal reliability, category order and separation however the SOS scale was not sensitive enough with the 2008 OCG participants. It is possible that the SOS scale was too easy as is and requires a more sensitive and challenging scale.

To test this interpretation, following analysis of fit statistics, item-to-measure correlations, and redundancy of item difficulty measures additional responses from a group of high school students was added to SOS for a second level analysis. The increased sample size (n=119) with a greater range of participants provided a broader distribution of responses to SOS items, and in turn provided better anchors for calibrating the instrument. The instrument was calibrated with a larger data set, but only results from participants in the 2008 Oceanography Camp for Girls are reported. The resultant analysis improved the precision of the SOS instrument as a measurement device of ocean environmental attitudes.

It should be noted that four items (e.g., questions 30, 35 and 41) from SOS were identified as misfit items (z-scores significantly >3.6). Two interpretations are possible, these items are 1) poorly written items or are too easy and should be revised, or 2) these items are within the realm of random expected outliers for a data set with 44 items. Three people were identified as potential misfit data based on the person fit statistic (z-scores > 2). A qualitative examination of these persons revealed that persons completed all survey questions, but had attitudinal changes from pre to post toward a slightly less positive view (e.g., strongly agree to agree; agree to neutral). In general persons did not change (increase or decrease) attitudinally between the pre and post SOS responses. Six persons responded with strongly positive attitudes consistently for pre and post responses, so no significant gain occurred. One person advanced 1.5 standard deviations above the mean between pre and post responses (person 29). Attitudes for some campers were positively impacted by OCG. Refer to Figure 12 which demonstrates analysis of change at the individual level. Darkened symbols above the identity line indicate statistically significant gains for those individuals from pretest to posttest. Some participants demonstrated statistically significant gains, none statistically significant reductions.

The attitude survey was comprised of three subscales, 1) attitudes about oceanography, 2) attitudes about ocean stewardship, and 3) attitudes about humans and the environment. Results for the three subscales were similar. To facilitate ease of interpretation, the following terms were used to refer to specific ranges of mean scores on the attitude assessment: strongly disagree, 1; disagree, 2; neutral, 3; agree, 4; and strongly agree, 5. The SOS instrument sub-scales response frequencies ranged from 7.5% strong agreement, 71% agreement, 14% neutral, and 7.5% disagreement for attitudes about oceanography; response frequencies ranged from 33% strong agreement, 60% agreement, and 7% neutral for attitudes about ocean stewardship; and, response frequencies ranged from 13% strong agreement, 67% agreement, and 20% neutral for attitudes about humans and the environment. Attitudes about stewardship scored positively highest by teens in this sample, followed by attitudes about humans and the environment and no disagreement scores on these two attitude subscales. The majority of items for the attitudes about oceanography subscale were mid-range challenging 93% (difficulty index between 0.41 and 0.60) and 7% of items were most challenging (difficulty index > 0.60). Item analysis of responses about ocean stewardship revealed that all items, 100% were mid-range challenging (difficulty index between 0.41 and 0.60), however not as challenging at items for attitudes about oceanography. Item analysis of responses about humans and the environment revealed that the majority of items, 93% were mid-range challenging (difficulty index between 0.41 and 0.60), and 7% of items were most challenging (difficulty index > 0.60). Refer to Appendix K for a complete list of items and difficulty indices (e.g., measurement column of output table).

SOS Pre-program

Persons - MAP – Items

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                  <more>|<rare>
 80                     +
                        |
                        |
                        |
                        |
                        |
                        |
                        |
                        |
                   281  |
 70                     +
                        |
                       T|
               051 141  |
                        |
                        |  I000
       011 121 171 221 S|
                        |
               101 211  |
               041 161  |  I003
 60        151 241 251 M+T I001
               021 291  |
               061 071  |  I000 I003
   031 081 191 201 231  |
               111 131 S|  I002
           091 181 271  |S I004
                   261  |  I000
                        |  I003 I004
                       T|  I000 I001 I002 I003 I003 I003
                        |  I000 I004
 50                     +M I000 I001 I002 I004
                        |  I000 I001 I001 I001 I001 I002 I002 I003 I004
                        |
                        |  I000 I002 I003
                        |  I000 I001 I003
                        |S I001
                        |  I001 I002
                        |
                        |
                        |  I002 I002 I003
 40                     +T I002
                  <less>|<frequ>
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Figure 11a. Construct Map Person Measures and Item Thresholds for Survey of Ocean Stewardship Pre-Program Responses, N=29

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SOS Post-program

Persons - MAP – Items

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                            <more>|<rare>
  80                              +
                                  |
                                  |
                                  |
                                  |
                                  |
                                  |
                                  |
                             282  |
                             052 T|
  70                              +
                             142  |
                                  |
                     122 172 292  |
                             222 S|
                             152  |  I00
                         162 212  |
                     042 232 252  |
                                 M|
                         022 242  |  I00
  60                         102  +T I00
                     012 062 082  |
     072 092 112 182 192 202 262  |  I00 I00
                         032 132 S|
                             272  |  I00
                                  |S I00
                                  |  I00
                                 T|  I00 I00
                                  |  I00 I00 I00 I00 I00 I00
                                  |  I00 I00
  50                              +M I00 I00 I00 I00
                                  |  I00 I00 I00 I00 I00 I00 I00 I00 I00
                                  |
                                  |  I00 I00 I00
                                  |  I00 I00 I00
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                                  |  I00 I00
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                                  |
                                  |  I00 I00 I00
  40                              +T I00
                            <less>|<frequ>
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Figure 11b. Construct Map of Person Measures and Item Thresholds for Survey of Ocean Stewardship from Post-Program Responses, N=29

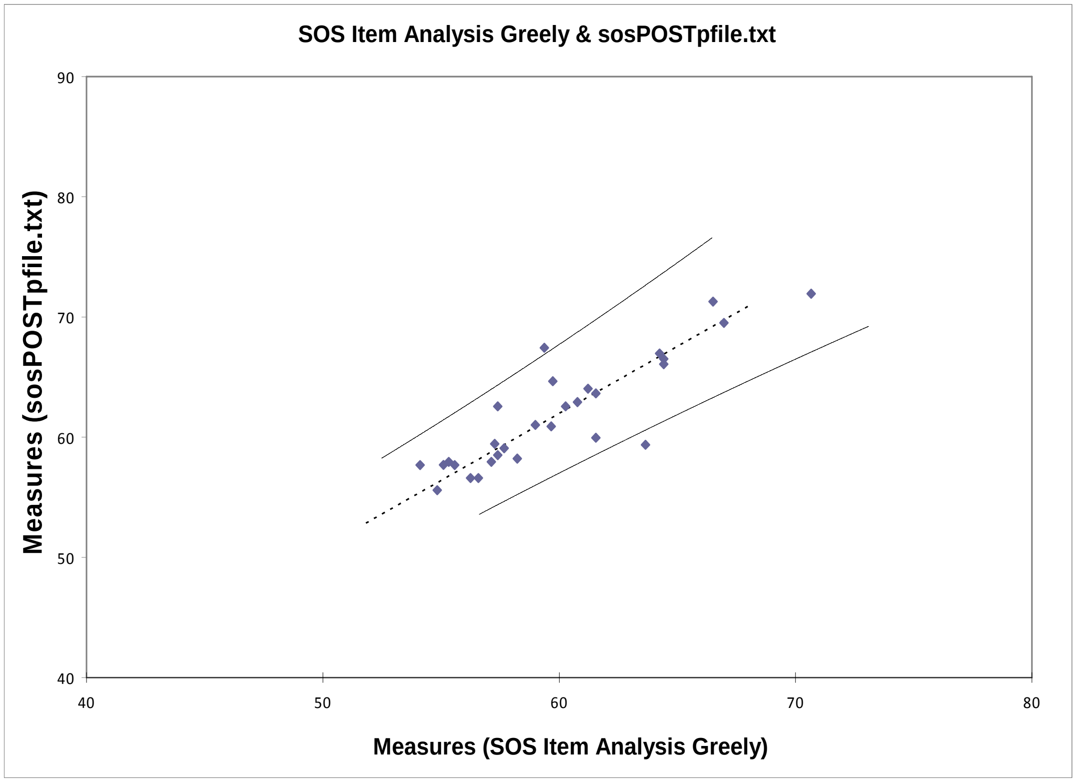

Figure 12. Plot of Pre-Post Measures to Demonstrate Analysis of Change at the Individual Level for the Survey of Ocean Stewardship Responses, N=29

Scenarios of Ocean Environmental Moral Reasoning Assessment

Research Question 3

What types of environmental moral reasoning are important to youth in resolving ocean dilemmas and how likely are youth to act in an environmentally-sensitive way?

The Scenarios of Ocean Environmental Morality (SOEM) met the Rasch model criteria for the purpose of this research. Participants' responses were analyzed to estimate reliability, e.g. internal consistency. The Rasch model's estimated internal reliability was 0.95, and the equivalent Cronbach's alpha for responses was 0.97 for the multiple response Likert type items. The SOEM instrument had four sub-scales for moral sensitivity, moral judgment, moral motivation, and moral character following the Rest model (Rest et al., 1986, 2000). The moral sensitivity scale examined type of environmental moral reasoning (biocentric, anthropocentric, egocentric). Refer to Appendix L for a summary map of item and respondent indices. Because there were a total of 56 items on the Likert-scale instrument, means scores were converted to percent correct for ease of data interpretation. There was no significant difference between the mean change scores between the pre and post responses.

Review of the map of latent distributions and thresholds for SOEM revealed two performance groups. These were participants who demonstrated moderate gains from pre to post, and those who showed no significant gain from pre to post camp responses. Refer to Figure 13 for construct map of pre and post response comparisons for SOEM person measures and item thresholds. The majority of participants was high functioning and stayed functioning at this level for pre and post tests, while the remainder of participants was a super high functioning group that remained at this level for pre and post tests. This sample population demonstrated high levels of moral sensitivity, judgment, motivation and character. Figure 14 illustrates analysis of change between pre and post responses for the four moral development components of the Rest model (1986, 2000). Overall participants demonstrated no significant change in moral sensitivity (Rest, component 1; refer to Appendix H) or moral judgment (Rest, component 2). Moral motivation (Rest, component 3) decreased slightly based on scenario (context-dependent), and moral character (Rest, component 4) which was likelihood to act in an environmentally-sensitive manner, increased slightly between pre and post responses.

SOEM Pre-program

Persons - MAP – Items

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                <more>|<rare>
 71                   151  +
 70                        +T
 69                   121  +  I00
 68               111 251  +
 67                   231  +
 66                   191  +
 65                   271  +
 64                        +
 63                        +
 62                       S+
 61                   241  +
 60                   131  +S
 59                   051  +
 58                        +  I00 I00
 57                        +  I00 I00 I00 I00 I00 I00 I00 I00 I00 I00
 56                        +  I00 I00 I00 I00 I00 I00 I00 I00 I00 I00 I00
 55                        +  I00 I00 I00 I00 I00 I00 I00 I00
 54                        +  I00 I00
 53                        +  I00 I00
 52                        +  I00
 51                       M+
 50                        +M I00 I00 I00
 49                        +  I00
 48                        +
 47               041 181  +
 46                        +  I00 I00
 45 021 141 211 221 291    +
 44                   201  +  I00
 43               101 171  +
 42                   071  +
 41       011 031 061 281  +
 40           081 091 261  +S
 39                   161 S+
 38                        +
 37                        +  I00 I00
 36                        +  I00
 35                        +
 34                        +  I00
 33                        +  I00 I00
 32                        +  I00
 31                        +  I00
 30                        +T I00 I00
 29                        +
 28                       T+  I00
 27                        +  I00

                    <less>|<frequ>
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Figure 13a. Construct Map of Person Measures and Item Thresholds for Scenarios of Ocean Morality from Pre-Program Responses, N=29

SOEM Post-program

Persons - MAP – Items

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          <more>|<rare>
 80             +
                |
                |
                |
                |
            082 |
               T|
            242 |
                |
            152 |
 70            +T
                |  I003
                |
        192 252 |
            122 |
                |
            132 |
            232 |
               S|
                |
 60             +S
                |
                |  I003 I004
                |  I000 I000 I001 I002 I002 I002 I004 I004 I004 I005
                |  I000 I001 I001 I002 I002 I003 I003 I003 I003 I004 I005
                |  I000 I002 I002 I003 I003 I005 I005 I005
                |  I001 I003
            052 |  I000 I001
                |  I000
               M|
 50         012 +M I000 I001 I005
        042 112 |  I004
                |
            292 |
                |  I002 I004
            142 |
202 212 222 262 |  I001
    022 032 182 |
    062 102 172 |
        072 282 |
 40         092 +S
               S|
        162 272 |
                |  I000 I002
                |  I003
                |
                |  I004
                |  I001 I005
                |  I000
                |  I002
 30             +T I001 I004
                |
                |  I004
               T|  I001
          <less>|<frequ>
```

Figure 13b. Construct Map of Person Measures and Item Thresholds for Scenarios of Ocean Morality from Post-Program Responses, N=29

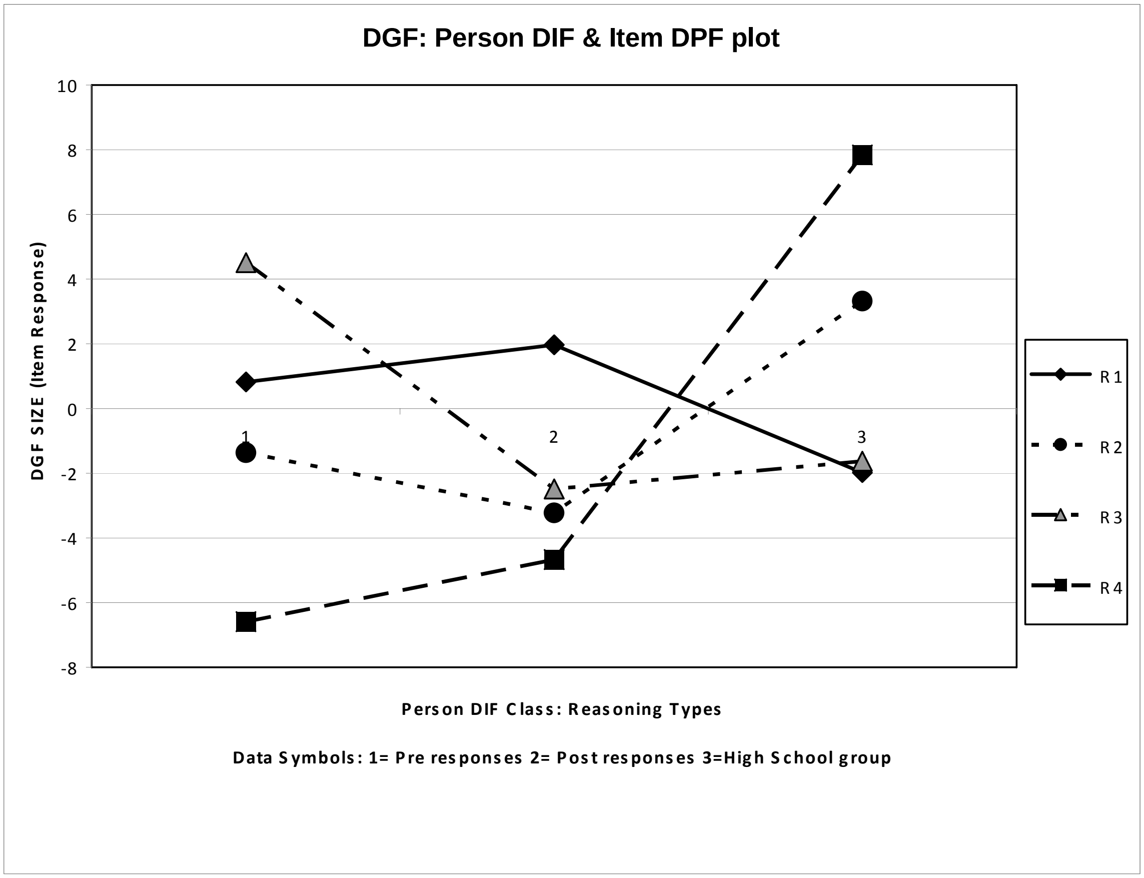

Figure 14. Analysis of Change between Pre and Post Responses for the Four Moral Development Components of the Rest Model (1986, 2000); R_1= Moral Sensitivity, R_2= Moral Judgment, R_3= Moral Motivation, And R_4= Moral Character

Initial analysis of fit statistics, item-to-item measure correlations, and redundancy of item difficulty measures led researchers to add additional responses from a group of high school students for a second level analysis of SOEM. The increased sample size (n=95) with a greater range of participants provided a broader distribution of responses to SOEM items, and in turn provided better anchors for calibrating the instrument. The resultant analysis improved the precision of the SOEM instrument somewhat as a measurement device of ocean environmental morality. However, the second level analysis showed improvement for instrument precision but only minimally. SOEM still had two problems, 1) extreme high group ceiling effect, and 2) item category threshold problems in that there were too many categories for most questions (e.g. 1-5 scale).

This prompted a third level analysis of SOEM that combined ordered categories (Linacre, 1995; McCullagh, 1985) based on categorical output for the majority of items comprising SOEM. Analysis revealed that there were three distinct moral reasoning factors. The moral reasoning questions were collapsed from the original 9-point scale to a 3-point scale to better represent the data while identifying three moral reasoning factors. The remaining original 5-point scale items were each collapsed to 3-point scales, again to better represent the data as revealed by the Rasch Rating Scale Model. The resultant analysis improved the precision of the SOEM instrument and showed distinct categories however, dimensionality was not as distinct. Constructs of moral reasoning could now be compared at the group and individual levels for each scenario. Failure of the SOEM data to conform to the Rasch model implies further work on the substantive problem of scale construction.

Results for the research question, what type of reasoning is most important to young confronted with an environmental moral dilemma was answered by establishing an overall environmental reasoning score that was computed by collapsing a person's type of reasoning across scenarios. Next, a mean score for biocentric, anthropocentric and egocentric reasoning was generated for each of the four scenarios. Finally, scores were compared for biocentric reasoning with anthropocentric and with egocentric reasoning overall, and across each unique context (i.e., walking along beach, picnicking, fishing and swimming). Based on SOEM responses there was a significant difference overall between the reasoning types in that biocentric (71%) reasoning rated significantly more important than anthropocentric (17%) and egocentric (12%) reasoning when making a decision to act in an environmentally-sensitive manner. Post-survey responses revealed biocentric (68%) reasoning remained the most important reasoning type to youth in this study.

Analysis of differences in types of reasoning within each scenario was also evaluated. A Welch t-test revealed no statistical significantly difference between pre-post reasoning type responses. Results indicated higher rating of biocentric reasoning over anthropocentric or egocentric reasoning on the beach walk scenario, picnicking scenario, fishing scenario, and swimming scenario. Post-survey responses indicated the same trends for three scenarios, beach walk, picnicking and fishing. However for the swimming scenario there was a higher rating of the egocentric reasoning over anthropocentric and biocentric reasoning on post responses. A possible reason for this shift in reasoning type is suggested below. The frequency with which different types of environmental reasoning were applied varied across scenarios, indicating that the context of an issue may have influenced how participants responded to that issue. The results of this analysis are presented in Table 17.

To answer the question, if one's type of environmental reasoning is predictive of one's likelihood to act in an environmentally sensitive way, differences in the three types of reasoning for the four scenarios were analyzed. The environmental moral reasoning categories were established based upon the responses to the Items 13, 27, 41, and 65 which asked "which of the reasons do you most agree with?" Those respondents selecting a biocentric response were coded with a one, an anthropocentric response was coded with a two, and an egocentric response was coded with a three. The "likelihood to act" variable was measured on a 5-point Likert-type scale ranging from not at all likely to very likely. Before analysis this scale was collapsed to a 3-point scale to best represent the data.

Table 17. Comparison of Differences within Scenarios between Reasoning Type from Pre and Post-Camp Responses

Reasoning Type	**N=**	**Pre-SOEM**	**N=**	**Post-SOEM**
Biocentric		71%		68%
Anthropocentric		17%		7%
Egocentric		12%		25%
(Overall)	112		103	
Biocentric		72%		73%
Anthropocentric		21%		12%
Egocentric		7%		15%
(Beach Walk)	112		103	
Biocentric		68%		81%
Anthropocentric		18%		15%
Egocentric		14%		4%
(Picnicking)	112		103	
Biocentric		71%		77%
Anthropocentric		11%		0%
Egocentric		18%		23%
(Fishing)	112		103	
Biocentric		75%		40%
Anthropocentric		18%		0%
Egocentric		7%		60%
(Swimming)	112		103	

Findings indicate that in all four of the scenarios, those respondents choosing biocentric, anthropocentric or egocentric reasoning as their most important type of moral reasoning were all likely to act in an environmentally-sensitive manner. There were no significant differences in the biocentric, anthropocentric or egocentric groups for the beach walk, picnicking, fishing or swimming scenarios in likelihood to act in an environmentally-sensitive manner. Data suggested that overall context (type of scenario) for likelihood to act in an environmentally-sensitive way was not significant for this question since 83% participants were likely to act in an environmentally-sensitive way irrespective of scenario. Two participants responded that they would not likely act in an environmentally-sensitive manner to the beach walk scenario (n=1) and picnicking scenario (n=1); meaning they would walk through dunes and sea oats during beach walk or not likely take trash home from picnicking. Three participants (10%) responded neutrally, no commitment one way or another, to beach walk scenario (n=2) and fishing scenario (n=1).

OSSI Informal Reasoning Assessment

Research Question 4

How do youth informally reason about ocean socioscientific issues (OSSI) in the context of direct experiences in ocean environments?

My study investigated the complexity of informal reasoning and positions expressed by youth while discussing issues about the ocean environment. Interviews were recorded on audiotape and transcribed. Data for 12 interviews were collected. Refer to Appendix E for a complete list of 20 interview questions. Interview responses were divided into scorable arguments (Dawson, 1998). A modified clinical interview was employed. Questions and probes were designed to encourage participants to expand upon their conceptions about specific OSSI and elicit their highest level of reasoning. Responses were probed with requests for further elaboration, “What factors influenced your position?’ “Why was that important?’ “Why should the issue include both of those things?” until the interviewer was satisfied that a given participant had presented as full an account as possible of her reasoning on each question. The interviewer did not introduce concepts of her own unless the subject was unable to respond to initial questions. Instead, she noted the elements of the issue that were mentioned by the participant and probed for explanations of why these were important. Interviews varied in length from 20 to 40 minutes.

For the present analysis, 8 of 12 interviews were divided into scorable segments (e.g., statements). Because the interviews were somewhat open-ended, there was no predetermined content-guided basis for segmentation.
Consequently, the following criteria were employed:

1. A scorable segment should, as much as is possible, represent a complete argument for a given proposition or related set of propositions, including all of the “why,” probes and responses associated with that argument.
2. When two or more arguments are intertwined in the same text, the text is left intact and scored only once; and
3. Arguments must include responses to “why” probes or spontaneous justifications, because these, much more than the propositions themselves, reveal the structure of participants’ thinking. When these are not present, the argument is not scorable, and is dropped from the analysis.

Participants' written and oral responses to OSSI were evaluated to demonstrate how a student progressed through an issue and communicated their position on an issue. Analysis of the OSSI responses overall was conducted classifying responses in one of three ways: a) thematic categories that emerged from written responses, b) quality of informal reasoning, or c) one of three informal reasoning patterns. Two raters scored each of the informal reasoning interview and written questions. The first rater assessed the questions, and then compared scoring with the second rater. The first rater was a social scientist and educator skilled in conducting interviews and evaluating qualitative data. The second rater was an ocean scientist and educator skilled in scoring qualitative data and conducting interviews. Overall rates of agreement were high (average, 94.50%), and only agreements >90% were analyzed. The interview questions were chosen on the basis of authentic ocean socioscientific issues (OSSI) of current concern. In all cases, the answers to the written questions were discussed during camp OSSI embedded activities, e.g., Turtle Hurdle and Fish Banks simulations.

Interviews were analyzed using inductive data analysis (Lincoln & Guba, 1985) and the constant comparative method described by Glaser and Strauss (1967). Analysis of written and oral responses was conducted and emergent categories were identified and compared between raters. Upon consensus of >90% on four of five categories, the emergent categories were used to classify arguments offered by each participant in response to one of two scenarios, protection of endangered marine species or regulation of ocean pollution. Analysis relied on the abilities of two raters to recognize emergent categories and relative importance of each by estimating a percent occurrence of each category.

Quality of OSSI Informal Reasoning

Interviews were then subdivided into protocols representing the individual judgments about an ocean issue made by each respondent in response to nonstandard probes. Each protocol included the complete positional statement along with the argument used to support it. The quality of informal reasoning was evaluated using the criteria reported by Sadler (2003). The present study used four of the five criteria from Sadler's work. These were 1) intra-scenario coherence, 2) counter-position construction, 3) rebuttal construction, and 4) scientific accuracy. A summary of this analysis is provided in Table 19, along with sample excerpts representing each criteria of reasoning quality. In general, interviewees provided well structured OSSI interview responses that formulated a position and provided justification, anticipated counter-positions, and constructed rebuttal while incorporating scientific information accurately.

OSSI Informal Reasoning Patterns

Protocols were then examined individually for evidence of the informal reasoning patterns described by Sadler & Zeidler (2005). From the interview data, three informal reasoning patterns, rationalistic, intuitive and emotive were present to varying degrees in the OSSI interview responses. The informal reasoning demonstrated by participants in response to ocean socioscientific issues related to protection of endangered marine species and ocean pollution had both cognitive and affective components. The term, informal reasoning, is characterized by the general processes of negotiating and resolving ocean socioscientific issues that are assumed to be embedded with cognitive and affective processes (Sadler, 2004). Results from the present study revealed that participants relied on a combination of reasoning patterns. Some participants relied on logical arguments to support a position, such as marine animal behaviors and human behaviors and choices, while others displayed no apparent rationalistic informal reasoning. Other participants resolved issues based on an immediate feeling or reaction (positive or negative) to an issue, which is termed intuitive informal reasoning. Many participants were empathetic towards the well being of marine animals and/or their ocean environment. In nearly every case, participants displayed some degree of moral emotions of a sense of care or concern for the animal or environment impacted by the OSSI. This pattern is termed emotive informal reasoning. Sadler & Zeidler (2005) provide a helpful distinction between the three patterns keeping in mind that most often these patterns intersect or overlap during the informal reasoning process.

> Emotive reasoning differed from rationalistic reasoning in that rationalistic reasoning lacked the influence of emotions. Emotive and intuitive informal reasoning are both affective classifications, but remain unique, because, whereas emotive patterns are directed toward real people or fictitious characters, intuitive patterns are personal reactions in response to specific aspects of the scenario. (Sadler and Zeidler, 2005; p. 121)

Examples of excerpts of informal reasoning patterns in response to interview questions about two OSSI (e.g., protection of endangered sea turtles and ocean pollution) are provided in Table 19. Interview excerpts presented do not capture every reason-based consideration but do provide evidence to support the reasoning patterns described. The context of an issue significantly influenced how individuals responded to that issue. The frequencies were variable across scenarios for which mode of reasoning was applied.

Table 18. Examples of Interview Responses by Campers, Organized by Informal Reasoning Constructs Identified by Sadler (2003); Number of Participant (1-29) and Scenario (TH=Turtle Hurdle And OP=Ocean Pollution)

Construct	Example
Intra-scenario coherence (Does the rationale support the stated position?)	8TH: They should not build condos on the land because usually when turtles are born there they usually go back to the same beach that their mother does. 12OP: Uhmm, I would clean it up myself and I would get other people to clean it up. Because you can't just wait around on someone else to do it, especially if you're going to say something about it, like you can't complain about it not being cleaned up because you could clean it up just as easily yourself. 2TH: If they were there for over a hundred years they come back so we shouldn't build there unless we expect the sea turtles to die. Build the homes but as far from the coastline as possible…Sea turtles keep coming back to the same place so if you take away that place it hurts the sea turtles even more and they're already endangered.
Counter-position construction (Can participant construct & explain a counter position?)	8TH: It doesn't really matter to us we are not sea turtles, why should I take my time to write a letter? 12OP: Yeah, this one is really easy because they tell me this a lot. It's just one thing. It's not going to hurt, it's just one thing. 2TH: They could say how the earth is overpopulated and the cost of houses is expensive, because the economy is so horrible right now…
Rebuttal construction (Can participant construct a coherent rebuttal?)	8TH: It doesn't take that long to write a letter. If you like, time manage you can find time. 12OP: If it's just one thing then you can pick that one thing up and throw it in the garbage. Right, it's just one thing and how many people are saying it's just one thing, and how many times do they say that; like a day, a week, a month, a year. It all adds up to so much trash. If everyone that says it's just one thing just picks up their one thing and throws it away we wouldn't have all this litter every where. 2TH: I would argue the point that we don't have to build more houses on the beach…I would say that these animals have been here for so much longer than us and that like in the whole entire ecosystem and food chain and stuff will be hurt severely if sea turtles die. Sea turtles are like one of the only animals that eat jelly fish, right? If sea turtles become extinct there will be more jellyfish which means more people will be stung and that will mean more deaths right?, which means that the entire food chain would be out of whack...
Scientific accuracy (Are the arguments advanced consistent with scientific information?)	8TH: Loosing a species hurts more than just the species. It hurts the environment and that will hurt us. So we should help them to not lose their land and their home. 12OP: …so the area around you or around the ocean isn't all dirty and littered so the habitat and all the animals living in the habitat will have a better life and not die from it 2TH: Sea turtles are like one of the only animals that eat jelly fish 2TH: …these animals have been here for so much longer than us and that like in the whole entire ecosystem and food chain and stuff will be hurt severely if sea turtles die.

Table 19. Examples of Informal Reasoning Patterns (Sadler & Zeidler, 2004) Evident from Written (W) and Oral (O) Responses to Ocean Socioscientific Issues; Specific OSSI; TH = Turtle Hurdle and OP = Ocean Pollution

Pattern	**Example**
Rationalistic (reason-based considerations)	8THO: Losing a species hurts more than just the species. It hurts the environment and that will hurt us. So we should help them to not lose their land and their home. 12OPO: Uhmm, I would clean it up myself and I would get other people to clean it up. Because you can't just wait around on someone else to do it, especially if you're going to say something about it, like you can't complain about it not being cleaned up because you could clean it up just as easily yourself. So I would grab a group of friends and do it because then it's not killing the environment and it just doesn't look good at all. 12OPO: It all adds up to so much trash. If everyone that says it's just one thing just picks up their one thing and throws it away we wouldn't have all this litter every where. 2THO: …I think about that movie we saw when we went to Clam Bayou about the dolphins and stuff, and how bad stuff like was and then I also think about what humans do uhm, for the sea turtles, like when we turn on the lights, like, street lamps, and how some sea turtles like turn around and go to the street lamps thinking it's the moon and how dogs eat them and how people destroy their nests …
Intuitive (immediate reactions to the context of the scenario)	2THW: The world doesn't see how bad the issue is becoming or maybe the world sees but doesn't care 8THO: Yeah, I would say that, I want it to be like stopped if they are endangered. 12OPO: so the habitat and all the animals living in the habitat will have a better life and not die from it , so it's like really easy and it's not hurting anyone (to clean up) 2THO: Well the first thing happens when I hear something about sea turtles all I can think about is the activity we did when we ran around that's just, (slight laughter) the first thing I think of. (*Turtle hurdle activity that simulates turtles life cycle and longevity*).
Emotive (care-based considerations)	2THO: I've always pretty much wanted to become a marine biologist and help these animals. They deserve to live on the planet, too.

Because the frequency counts were not independent measures, inferential statistics, such as Chi-square analysis were not attempted.

OSSI Written Responses

Analysis of OSSI written responses revealed five content themes by consensus of two raters. Initial analysis began with review of five participant responses to three OSSI activities comprised of 23 questions. Refer to Appendix D for descriptions of OSSI activities and written questions. The first analysis of 115 questions resulted in nine themes identified by rater one and six themes by rater two. Following discussions and clarification of themes, raters reached consensus on five categories. Themes that emerged from participants' written responses were content knowledge (e.g. science and environmental issues), affective responses, social aspects, opinions and actions of what should be done, and misconceptions. A summary of analysis of written responses and emerging themes is provided in Table 20.

Participants were also given the option for the OSSI written responses to compose a persuasive letter or law about an issue of concern to a legislature. Letters were scored based on overall persuasiveness, degree of science understanding, and knowledge about the environmental issue. Eighty-three percent of campers completed one, two or three letters each. Of these letters, all were scored based on the three criteria stated above. Letters were scored on a scale of 1-5 (1 lowest score and 5 highest score). Descriptions of aspects of laws, sample excerpts are summarized in Table 21.

Limitations

Measuring Ocean Literacy

There were a number of reasons for choosing to use interviews for qualitative analysis of ocean literacy. Open ended interviews create variability, delaying the operationalization of the variables that the researcher thinks are important. During such interviews the participant may or may not choose to discuss a particular topic which may be important for clarifying the reasoning patterns. While solving specific problems, on the other hand, the participant is more likely to obtain clearer instructions from the researcher regarding which particular topics are important and relevant to address. Of the three quantitative measures of ocean literacy, the SOEM instrument did not perform with the same level of precision as SOLE and SOS. I concluded, as did the measurement professor, that the instrument needed to be redesigned with better quality questions and clearer distinctions between scales.

Scenario Selection for SOEM

The selection of the four outdoor recreation scenarios as somehow representative of universal activities among most populations is a limitation. Although national statistics were used that suggested hiking, picnicking, fishing and swimming rated consistently high in terms of participation rates, it is not possible to generalize results from these specific activities and experiences. The specific activities included were selected as representative of popular outdoor activities that teens likely are familiar with. However this necessary assumption presents an inherent limitation as to how the results can be interpreted.

Sample Population

While access to the OCG population of teen-aged girls was certainly convenient in terms of data collection, it is difficult to make generalizations and assumptions from these results. Because the participants in this study were self-selected to participate in a summer ocean sciences program, there is less likelihood that these rising 9^{th} grade students were representative of the general student body at this age. As a consequence interpretation of the results should be made in light of these acknowledgements. Future studies in this area would benefit from a more diverse sampling pool.

Table 20. Emergent Themes Identified from Written Responses to Ocean Socioscientific Issues (OSSI) Following OSSI Activit; Examples of Written Responses from 29 Participants; Italicized Text Added for Clarification of Statement

Construct	Excerpts from written responses
Conceptual Knowledge (science & environmental issue)	TH: Natural impacts that affect longevity are predators such as other animals like foxes, crabs, birds TH: Human impacts that affect longevity are hunting (food, leather), street/shore lights, pollution, fishing nets (entanglement), and habitat loss OP: Human factors that influence are… trash/litter, boating, building, waste disposal, carelessness, selfishness, noise OP: Types of pollution are…plastic bottles, bags, glass, cigarettes, wood , oil/oil spill, fishing nets/lines, Styrofoam, balloons, chemicals, fertilizer OP: It is important to keep our ocean healthy for the organisms and the resources FB: There is a finite number of fish. If we catch them all, they will be gone. However, they reproduce and if they are managed there will always be fish to catch FB: Sustainable management is taking only a little of a resource and leaving enough for the population
Social Aspects (human impacts related to issue)	TH: Sea turtles are beginning to become endangered because of trash, and plastic and … are winding up dead because of pollution TH: Sea turtles are beginning to become endangered because of trash, and plastic and … are winding up dead because of pollution OP: Yes (*government manage*), they (*citizens*) need people to tell them so they know it is serious. OP: No (*government manage problem*), because it should be on them (citizens) to take care of their own environment FB: Fishes are a very important resource both for the economy and food…salmon fishing in CA was banned because there aren't enough fish FB: People should research where they live and see what they can do to help FB: A little coastal development is alright. But most beaches should be protected FB: We must protect breeding and spawning areas and areas in which the young fish mature
Affective Reaction	TH: They have a hard life since they can be attacked or killed any time TH: If you see a site that has been marked…please do not hurt them OP: The ocean is something precious and it holds more varieties of animals OP: Pick up other people's garbage OP: It is our planet and we have a responsibility to keep it safe and clean FB: It is more important to protect the environment than to live on the beach FB: The fish population need as much protection and monitoring as possible to ensure more fish for consumption and a healthy ecosystem
Recommend-ations & Actions	OP: Yes (*to tax base for issue*), there is lots of money in the world, but only one ocean. If we mess it up we can't go back. OP: Educating industries that they can comply with laws without sacrificing business OP: Recycle a lot more and dispose of things properly TH: Beaches known to have reproducing turtles should be protected from development and disturbances TH: More hatcheries should be established and beaches protected FB: People (*citizens, not government*) should manage the fisheries because if we can all help the environment it will be better for us and the environment FB: Fisheries should be managed by government agencies. Management may mean fewer fish collected now but we will have a steady supply forever FB: People should help to clean up our waters and drive non oil powered water vehicles
Assumptions & Mis-conceptions	TH: It is hard to get most people to listen to teens about the problems now a days TH: The world doesn't see how bad the issue is becoming. Maybe the world sees but doesn't care OP: The more managing (*of ocean pollution by government*) the better things will get and the more people will abide the laws FB: Management may mean fewer fish collected now but we will have a steady supply forever

Table 21. Scores from Ocean Socioscientific Issues (OSSI) Written Response for Persuasiveness of Letters Outlining Proposed Law Related to Issue. Note, Proposed Law was Considered Persuasive if 1) Target Group and Enforcer Identified, 2) Law Clearly Defined, and 3) Penalty Identified; Scores Measured on Scale 0-5; 0= did Not Write A Letter; Higher Number More Persuasive Law; Zero Scores not Included in Average Score Estimates

	Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Average Score by ocean issue**
Turtle Hurdle	3.66 (n=3)	3.75 (n=4)	3.25 (n=4)	3.75 (n=4)	4.25 (n=4)	3.72
Ocean Pollution	3.75 (n=3)	4.00 (n=5)	3.75 (n=4)	4.00 (n=5)	4.50 (n=4)	4.00
Fish Banks	3.66 (n=4)	3.40 (n=5)	3.75 (n=4)	4.00 (n=5)	4.00 (n=3)	3.76
Average Group Score, all Issues	3.69	3.72	3.58	3.92	4.25	Group average 3.83

Nature of Study

Finally, as an exploratory study, my results serve as a good introduction to the discussion of how the constructs ocean knowledge and attitudes, environmental reasoning and informal reasoning about ocean socioscientific issues influence ocean literacy via learning experiences in natural settings. However, this study does not claim to test a complete model of ocean literacy. While it does address some components identified in the literature as essential to ocean literacy and reasoning (e.g., conceptual understanding, moral emotions, stewardship and motivation), there are certainly other factors not accounted for in this study that influence ocean literacy and reasoning within the unique context of the Oceanography Camp for Girls.

Summary

Results from analysis of the four research questions that guided this study reveal that youth participating in this study, teen-aged girls participating in the Oceanography Camp for Girls, had a baseline of ocean literacy and improved their literacy over the course of the program. The constructs showing the most significant gains were the content knowledge assessed using the Survey of Ocean Literacy and Experience (SOLE); attitudes about ocean stewardship assessed using the Survey of Ocean Stewardship (SOS); and, environmental reasoning towards biocentric values assessed using Scenarios of Ocean Environmental Morality. The introduction of ocean socioscientific issues as part of the program revealed that youth informally reasoning about challenging ocean environmental dilemmas are capable of forming a position, counter-argument, rebuttal and incorporating scientific concepts in support of their positions. Most encouraging was that youth are willing to be a part of the solution to ocean environmental challenges and are motivated to advance from interest to commitment to action.

CHAPTER FIVE: DISCUSSION

Introduction

The goal of the present study was to examine the validity of the construct ocean literacy as defined by COSEE (2005), within the context of an ocean education program. The purpose was to provide a baseline of data to describe what youth currently understand about the ocean and how they reason about ocean environmental dilemmas and issues. Because the ocean is inextricably interconnected to students' lives, it provides a significant context for socioscientific issues that foster decision-making, classroom discussions, human interactions and environmental stewardship. The present study sought to support the science education community's understanding of reasoning and resolution of socioscientific issues by expanding the research to include the influence of ocean conceptual understanding (e.g., content), environmental experiences (e.g., context) and environmental morality on reasoning about the ocean. The present investigation adopted a definition of ocean literacy and reasoning that closely aligned with the international definition of scientific literacy (OECD/PISA, 2001, p. 76), such that an ocean literate person is an individual equipped to use ocean knowledge to engage in oral or written discussion about the oceans (e.g., support a position), to understand the changes made to the ocean through human activity, and to apply ocean knowledge through actions as citizen, steward or consumer. The present study examined the role of four constructs to assess their contribution in advancing ocean literacy. These were ocean content knowledge, environmental attitudes and reasoning about the ocean and informal reasoning about ocean socioscientific issues.

The remainder of this chapter will discuss the results as they align to each research question, draw conclusions from the results of this study and conclude with the study's significance for science education practitioners and researchers. A framework for investigating ocean literacy and reasoning was developed and evaluated (refer to Appendix F) in the context of the Oceanography Camp for Girls, summer 2008. The present research focused on teen's ocean-content knowledge, environmental attitudes and morality, and informal reasoning about ocean socioscientific issues.

Content and Environmental Context

Content

Content knowledge and environmental context both mediated the development of conceptual understanding about the ocean during the ocean education program, the Oceanography Camp for Girls. Findings revealed that conceptual understanding significantly contributed to ocean literacy as evidenced in pre-post camp responses for SOLE. The difference between the mean change scores for the pre and post responses was -5.489 and was statistically significant based on a paired t-test, $t = -5.027$ (s.d. 5.880), $p = 0.000$. In addition, 100% of participants cited the authentic ocean learning settings as significant to their understanding of ocean concepts as evidence in OCG Learning Essays. Results from the present study are consistent with findings that the degree of scientific content knowledge significantly contributes to scientific literacy (AAAS, 1993; NRC, 1996, 2000) and reasoning about OSSI (Sadler & Zeidler, 2004; Zeidler & Shafer, 1984; Zeidler et al., 2005).

The present study examined the impact of building ocean content knowledge from the point of personal relevance towards scientific understanding by engaging youth in direct sustained experiences with nature (e.g. local ocean environments). Baseline data about ocean literacy was gathered 20 years ago (Brody, 1996; Brody & Koch, 1990; Fortner & Mayer, 1983, 1991). My study contributes more current findings from youth participating in an informal learning setting. This was accomplished by assessing the degree of ocean literacy among youth using a multi-item ocean environmental knowledge scale (SOLE) to establish a current baseline of what is presently understood about the ocean. Further, the need to develop an epistemology of ocean literacy to effectively engage ocean socioscientific issues (OSSI) was addressed in the present research. The Oceanography Camp for Girls provides a series of integrated ocean learning activities that successfully built content knowledge via direct experiences with the ocean and ocean research settings.

Studies that have examined levels of ocean cognitive literacy revealed a general lack of even a baseline of ocean content knowledge among youth (Brody, 1996; Fortner & Mayer, 1983, 1991), high school students (Lambert, 2005), college students (Cudaback, 2006), and adults (Belden et al., 1999; Steel et al., 2005) who participated in these studies. General trends suggested content gains in early grades (5^{th} grade) with no significant gains in later grades (8^{th}-11^{th}). High school and undergraduate students who participated in a marine science course demonstrated significant content gains in some areas of oceanography (Cudaback, 2006; Lambert, 2005). The findings from those studies support the critical need to establish a validated, reliable scale to measure conceptual understanding about the ocean across grade levels. The present study has initiated development of an instrument, SOLE to address this critical need.

Results from the present study also demonstrated that participants had obtained a level of conceptual understanding about the oceans required to *reason* about ocean issues. Studies related to the influence of content on reasoning about socioscientific issues provided evidence that increased content knowledge influences the quality of informal reasoning (Sadler & Zeidler, 2004; Zeidler & Sadler, 2005; Zeidler & Shafer, 1984). Sadler & Zeidler (2004) specifically focused on the role of content knowledge and informal reasoning. Results support a link between level of content knowledge and quality of informal reasoning; however, additional work is needed to examine the nature of the relationship in various contexts or settings. My study provided more evidence to show that in the context of the Oceanography Camp for Girls, environmental conceptual understanding about the oceans was increased and participants were able to reasonably engage in reasoned argumentation about socioscientific dilemmas related to the ocean environment.

Context

I examined the extent to which an outdoor ocean education program contributes to improved ocean literacy amongst youth. Participants were engaged in ocean learning through physical interactions with multiple natural environments in the Tampa Bay region. My results corroborate the significance of context on multiple constructs of ocean literacy, namely cognitive gains to expand conceptual understanding and when reasoning about environmental dilemmas or socioscientific issues. Many researchers have identified context as a significant factor contributing to learning content, moral development and reasoning about socioscientific issues. The evidence for a relationship between nature-rich experiences and cognitive functioning are only just emerging. Kellert (1996, 2002) suggests that within contemporary society, children experience nature in one of three ways: direct, indirect, and symbolic. Direct experiences examined in the present study required the individual to be physically involved and interacting with the natural world in a marine environment.

My results are consistent with findings that direct experiences have great potential for positive youth development (Kals et al., 1999; Taylor et al., 2001; Wells, 2000). Findings via thematic content analysis from Learning Essays revealed that direct experiences with the ocean environment and ocean research settings significantly impacted learning of ocean sciences. The Learning Essays were 500 words written response to the question, 'Compare and contrast learning science during OCG with learning science in school'. This finding was further supported by positive significant gains in ocean conceptual knowledge from SOLE pre-post responses. Results from the OCG Learning Essays were an initial analysis only and should be considered in this light. Raters analyzed 30 essays independently and identified 10 common themes without further analysis for this study. More in-depth analysis is necessary. The next steps would be to evaluate the data to see if categories could be collapsed. In addition, essays would be scored using the Hierarchical Complexity Scoring System (HCSS). Then, reliability of the scale could be assessed through statistical modeling using Rasch analysis and by examining inter-rater agreement rates. In this way scores from SOLE, SOS and Learning Essays could be cross-walked to identify relationships and weighted effect factors.

My results are, therefore, consistent with findings that context is a significant and meaningful factor influencing informal reasoning about socioscientific issues. Context was reported by Sadler and Zeidler (2005) and Zeidler and Schafer (1984) as a factor consistently influencing the informal reasoning patterns invoked while negotiating socioscientific decision making. Sadler and Zeidler (2005) demonstrated how reasoning patterns varied significantly based on individual's immediate response to the context of six different scenarios within the context of genetic engineering dilemmas. Sadler suggested a greater context-dependence for emotive and intuitive informal reasoning patterns, as compared with rationalistic reasoning patterns. This pattern is not as evident in the present study; however, additional informal reasoning interviews may provide more evidence of underlying trends.

Environmental Attitudes

In as much as content knowledge has been shown to contribute significantly to scientific literacy, my study investigated the extent to which knowledge contributed to ocean environmental attitudes amongst youth. It was reasonable to expect experiences in nature to carry an emotional component. Studies suggest that the affective domain is believed to precede cognition in the production of knowledge (Iozzi, 1989). The natural world provides opportunities for youth to experience such emotions as curiosity and indifference, attraction and repulsion, courage and fear, like and dislike. It has been suggested that the intensity of these emotions significantly affects how strongly one interprets, perceives, and remembers the experience (Milton, 2002).

Environmental attitudes (e.g., care, concern and connection) contributed to conceptual understanding about the ocean. Findings from the present study revealed that teens participating in the Oceanography Camp for Girls began the program with strong positive attitudes about oceanography, stewardship, and the environment. Girls retained these positive attitudes after the camp experience. Most encouraging were findings that youth were willing to *act* on their feelings to actively engage in ocean stewardship activities beyond the camp experience. For example, 63% of 2008 campers participated in a marine debris clean-up activity and/or a habitat restoration project during an OCG Fall Reunion, three months after the summer program. Other campers participated in the International Coastal Clean-up in September 2008, which was two months after the summer program. My results are consistent with findings of others. Studies in environmental morality consistently reported the significant influence of direct personal experiences with nature in developing positive attitudes, values, and behaviors towards the environment (Caduto, 1998; Palmberg & Kuru, 2000; Zelenzy, 1999).

Mittelstaedt et al. (1999) provided a comprehensive study of the impacts of week-long, outdoor, science summer camps on youths' attitudes and behaviors toward the environment. Results clearly demonstrated significant improvements on all levels measured, positive environmental attitudes and intentions. Most striking were the delayed post test results 12 months after the summer program that revealed 69 originally reported intentions resulted in 60 actual behaviors toward the environment. These findings are particularly relevant to my study which will access ocean stewardship behavior as a post impact of the three-week, summer science program, 6, 9, and 12-months after the Oceanography Camp for Girls.

Environmental Moral Reasoning

The main purpose of this portion of the investigation was to determine what types of environmental moral reasoning (i.e., egocentric, biocentric, anthropocentric) were demonstrated by teens when making a decision about ocean environmental dilemmas. The moral orientations toward nature examined were: 1) egocentric is viewing everything in relation to oneself, self has value, nature has value only relative to self; 2) anthropocentric is viewing nature as having value and deserves to be protected as it affects human well-being; and, 3) biocentric is when nature is perceived as worthy of rights and protection because of its intrinsic value. This research also sought to determine whether the type of environmental reasoning used in decision-making was predictive of one's likelihood to act in an environmentally-sensitive manner. The current investigation examined reasoning within the context of various popular ocean-related outdoor recreational activities (SOEM). This study conceptualized environmental moral reasoning based upon these three constructs as a means of measuring the relative importance of these pathways to environmental moral thinking and action.

Studies related to environmental morality and its facilitation via outdoor, environmental programs show promise as a new line of research in moral development. The majority of research related to environmental and outdoor education programs demonstrate a significant change in students' pro-environmental attitudes; however correlations with corresponding behaviors that align with attitudes are only recently emerging (Mittelstaedt et al., 1999). Moral environmental research has examined the influence of outdoor programs on moral orientations (Kortnerkamp & Moore, 2001; Persing, 2006), attitudes (Palmberg & Kuru, 2000; Zelezny et al., 2000), behaviors

(Mittelstaedt et al., 1999), and direct experiences with nature (Caduto, 1998; Zelezny, 1999).

My study identified biocentric environmental reasoning as most important to youth in resolving ocean dilemmas. The results indicated that all moral dilemmas encountered during outdoor learning experiences significantly elicited biocentric reasoning. Egocentric and anthropocentric reasoning were expressed for each environmental dilemma, however not significantly. Patterns between various dilemmas and associated reasoning are discussed below. Biocentric orientations engender concern and interest for the ocean environment, and even result in positive actions toward the ocean. The significance in understanding these orientations has potential implications for decisions about natural resource management and in designing more effective ocean education programs. From a broad perspective, these results are consistent with previous findings by Beringer (1992) and Kahn (2002, 2004), that individuals think in moral terms about how their actions affect the well-being and interests of nature from biocentric and anthropocentric perspectives.

The difference in reasoning was further analyzed by looking at differences across the four scenarios. Results revealed a significantly higher demonstration of biocentric reasoning for all four scenarios, beach walk scenario, picnicking scenario, fishing scenario and swimming scenario. My findings differ from Persing's (2006) findings based on similar scenarios in forest settings. Biocentric reasoning was rated higher for hiking (equivalent to beach walk for present study), anthropocentric for picnicking, and no significant differences between fishing and swimming.

My findings about behavioral intentions revealed strong intentions for all scenarios (beach walk, picnicking, fishing or swimming). Participants were likely to follow through with their actions regardless of reasoning type. Participants of all reasoning types (egocentric, biocentric, anthropocentric) were likely to act in an environmentally-sensitive manner for each scenario. The beach walk scenario revealed one example when an overall anthropocentric reasoning orientation responded with a counter moral course of action of not likely to stay on the beach, and walk in the dunes. The picnicking scenario revealed one example when an overall biocentric reasoning orientation responded with a counter moral course of action of not likely to take trash home. In general the present study has demonstrated that participants elicited moral responses that were strongly care-oriented and suggest that youth conceive of environmental dilemmas from a care perspective (empathy; Rest, 1999, moral sensitivity) and are able to judge which action is most justifiable from a moral perspective (Rest, 1999, moral judgment).

Youth in this study demonstrated high levels of commitment to a moral action and equally high behavioral intentions. In the future, it would be interesting to survey participants who have a high level of involvement and commitment to their chosen outdoor activity as a means of determining how these factors influenced their decision-making process when confronted with environmental moral dilemmas. My results are similar with previous findings that examined youths' responses to environmental dilemmas (Persing, 2006). Persing's findings supported that youth choosing biocentric reasoning as their most important type of moral reasoning were more likely to act in an environmentally-sensitive manner than those choosing anthropocentric or egocentric reasoning for fishing ($t(223) = -2.243$, $p<.026$) and for swimming ($t(226) = -2.528$,

$p<.012$). Persings's hiking (equivalent to beach walk for present study) and picnicking did not produce significant differences between reasoning types in likelihood to act in an environmentally sensitive way. Persing (2006) provides to possible explanations.

Participants may not have perceived the consequences of not acting as acceptable in terms of harm to others, self or the environment. For example, scenarios about trampling on wild flowers (sea oats in the present study) during a hike or leaving other's garbage at a picnic site may have been perceived to have little effect on their experience, others, or the well-being of the environment. Alternatively, some participants simply may not be aware of the consequences of not acting in an environmentally sensitive way towards sea oats or leaving other's garbage. Kortenkamp and Moore (2001) state that, "it is more difficult to take the interests of the environment into consideration if those interests and the effects on them are either not known or not salient" (p. 268).

Informal Reasoning about Ocean Issues

My study examined the influence of informal learning experiences on reasoning about ocean socioscientific issues. This was accomplished by directly engaging participants in ocean socioscientific role-playing and stewardship activities, followed by open dialogue discussions, written responses and interviews. Building on the work of Sadler & Zeidler (2004, 2005), I identified the informal reasoning patterns youth demonstrated while resolving ocean environmental socioscientific issues.

Characteristics of Informal Reasoning

Reasoning about and discussing socioscientific issues provides opportunities to practice and experience connections between what science students are learning and the issues they are likely to confront in their daily lives. The goal of OSSI case studies was to develop the competency of the learner via authentic, direct experiences with the ocean in order to integrate what was being learned with actions required to contribute to everyday socioscientific issues in one's community. The participants demonstrated multiple patterns of informal reasoning when resolving ocean socioscientific issues in the context of direct experiences with ocean environments.

My findings are consistent with previous findings (Kahn, 1995, 1997, 1999) that youth are capable of identifying a position and supporting that position with scientific knowledge and moral considerations. During social interaction and discourse (e.g., written or oral) students were engaged in informal reasoning as they negotiated and resolved complex problems that lacked clear solutions. Zeidler and Keefer (2003) identified eight characteristics apparent when learners are reasoning about socioscientific issues: 1) process of inquiry, 2) negotiation, 3) discourse, 4) argumentation, 5) compromise, 6) conflict, 7) decision-making, and 8) commitment.

OCG participants' informal reasoning interviews manifested the following characteristics 1) negotiation, 2) argumentation, 3) conflict, 4) decision making, and 5) commitment when reasoning about OSSI. Thus, five of the eight characteristics were evident in the present study.

Patterns of Informal Reasoning

My study explored if the three informal reasoning patterns evidenced in adult college students (Sadler & Zeidler, 2005) were manifested in teen-aged girls when negotiating ocean related socioscientific issues. My results are consistent with findings that college students' informal reasoning patterns while resolving socioscientific issues may be (a) rationalistic, which encompasses reason based considerations; (b) emotive, which encompass care based considerations; and/or (c) intuitive which encompasses considerations based on immediate reactions to the context of the scenario or dilemma presented. Results from this study are consistent with previous findings that the degree of personal relevance of an issue is associated with increased validation of knowledge claims (Sadler & Zeidler, 2004; Zeidler et al., 2005).

For my study ocean socioscientific issues were introduced after students engaged in a content-embedded role playing (e.g. Fish Banks, Turtle Hurdle) or stewardship activities (e.g., Coastal Clean-up). OSSI were selected based on relevancy and accessibility to youth by including issues impacting where they live and play daily. Results support previous findings to provide developmentally appropriate OSSI (Bingle & Gaskell, 1994; Kellert, 2002; Kolsto, 2001), and pedagogical strategies (Pedretti, 2003; Keefer, 2003) that advance ocean literacy through social action and local relevance.

The present study examined the assumptions of the Zeidler et al. (2005) framework by piloting three OSSI case studies. The approach used to present the OSSI was a new strategy for SSI implementation, not the traditional classroom-based role playing or discussion or debate. OCG participants were confronted with OSSI dilemmas while engaged in interactive learning activities taking place indoors as well as outdoors in a natural setting. Participants were learning relevant content about an OSSI as they were doing an activity. The OSSI was embedded within the activities (Turtle Hurdle, Fish Banks, or Ocean Pollution; refer to Appendix E). Following engagement, participants were asked explicit questions about the OSSI via written responses and interviews. Descriptions of the OSSI learning activities used in this study are available in Appendix E. I also added new ocean-based OSSI to the family of SSI topics. The present study provided an example of how to integrate content with flexibility and with relevancy to the students. Results support that the order of SSI presentation can be concurrent with relevant science content as evidenced by campers' ability to effectively support a position on an OSSI, utilize scientific information accurately, and identify specific ways to take action to support that position (stewardship). In contrast, some researchers have argued that learning the science content needs to precede socioscientific reasoning events (Kolsto, 2001; Sadler, 2004).

Recommendations and Future Research Needs

The following is a summary of research or theoretical work that is needed to address and increase our understanding of the issue—ocean literacy to promote scientific literacy and socioscientific issues. Lines of needed research include: a) opportunities to build a knowledge base for ocean literacy and have ocean learning experiences; b) professional development and access to ocean teaching resources; and c) practice and experience reasoning about ocean socioscientific issues.

Opportunities to Build an Ocean-Knowledge Base

As demonstrated in the current study, providing authentic ocean learning experiences in natural settings, research facilities, and career interviews with scientists can make a positive difference. There is a need for individuals to have opportunities to practice and to assess the integration of ocean content and ocean-related SSI as part of curriculum to initiate more relevant and meaningful learning experiences. One scenario for explicit connections to practice may be to integrate ocean-related SSI as part of marine science 1 and 2 courses at the high school level. Alternatively, infusing ocean science concepts and ocean socioscientific issues as part of traditional science courses may offer a new context to apply fundamental (e.g., standards based; Schroedinger, Cava & Jewell, 2006) science concepts. Another scenario may be to present explicit SSI as part of experiential education programs (e.g., summer camps, field trips to natural marine settings) to engage students in the social relevancy of science learning in a place-based context.

A final strategy is to provide place-based learning experiences to build ocean content knowledge and develop reasoning skills and informed ocean decision making. Based on the current study such experiences provided relevant connections for campers to not only learn ocean knowledge but to also apply that knowledge to the place they live. Even in land-locked locations without an ocean, science concepts can be applied to parallel environments that characterize where students live. Concurrently, students are building their science knowledge via their curiosity about the ocean and applying that curiosity and science principles in their local environment. Providing teachers and students with opportunities to participate in environmental field trips, student designed research projects, and current issues of concern to scientists in students' place has global implications for indirectly connecting ocean concepts. Other opportunities for students to build ocean knowledge are provided by Ocean Camps, Project Oceanography, and the National Ocean Sciences Bowl.

Ocean science literacy may contribute to teaching and learning through free-choice education programs that promote scientific and social engagement. For example, guided visits to Aquariums, Science Museums, and Exploratoriums could include relevant ocean socioscientific issues (OSSI). Interactive exhibits and simulation scenarios can provide ocean content that requires evaluation and a choice based on the content-rich experiences gained from the exhibits. The primary consumers at free-choice, public exhibits are school children, thus the implications are significant in advancing ocean literacy through informal learning environments.

Professional Development and Teaching Resources for Ocean Literacy

There is a critical need to provide teachers with professional opportunities to develop or extend an ocean knowledge base, experience using integrated content and teaching strategies, and increased exposure to textbook alternatives to teach and learn about the ocean. Next, there is a need to develop or identify existing pedagogy to effectively engage ocean socioscientific issues. There is a need to assess the effectiveness of current ocean education programs (e.g., experiential education, summer camps, high school marine science I&II courses, teacher professional development) to increase ocean literacy and the audiences targeted. My study has provided initial constructs to consider in this process.

Practice and Experience Reasoning about Ocean Socioscientific Issues

There is a need to develop additional ocean socioscientific case studies and to provide opportunities for practice and experience to develop the attitudes and skills to reason about ocean socioscientific issues (OSSI). I utilized a socioscientific issues framework to provide scientific ocean-based issues that were personally and socially relevant to students. While the ocean sciences may be credible as a rich source for socioscientific issues and discourse, I am realistic in acknowledging the potential challenges for teaching and learning about the ocean.

Some examples from my teaching experiences include a) students' initial perception that the ocean is too far away in distance to be of value in their daily lives, and

b) a common belief amongst middle grade students that their opinion does not matter and will not change anything. However, with explicit attention to how the ocean connects to something within a student's daily realm these perceptions can be countered. Place-based learning is a strategy that promotes meaning in science and self identity within a science context. In most locations (places) starting with an area's watershed may lead to personal relevance that ultimately connects to the oceans. Another connection may be to address ocean issues from the perspective of products and consumption of products transported by ship as imported products or products produced by the ocean and used in daily life.

Contribution to Science Education

The areas of science education that ocean science literacy can contribute to include 1) coupled nature of science and real world topics, 2) ocean socioscientific case-based issues, 3) an integrated ocean pedagogy, 4) relevancy and connections of science learning to everyday life decisions through ocean socioscientific issues, and 5) contributions to the paucity of ocean science education research (e.g. Day, 1999; Kelly & Takao, 2002; Lambert, 2005). On a broader scale ocean literacy contributes a) content knowledge about the planet's largest ecosystem—the ocean, b) an integrated curriculum, and c) personal, cultural, and social relevance of ocean sciences to our everyday lives. As a discipline oceanography has rarely been examined by social scientists (Goodin, 1995; Mukerji, 1998). Geosciences education research includes many examples and applications of teaching strategies such as place-based courses (Kean, Posnanski, Wisniewski, & Lundberg, 2004; Semken, 2005), role playing via regional planning group activities (Abolins, 2004), and global warming debates via role playing (Rebich &

Gautier; Schweizer & Kelly, 2005). However, this research has not been equivalent in rigor and meaning to educational research.

The present study contributes to science literacy in general and specifically to ocean literacy, including an action component called ocean stewardship. Science education research will benefit from this newly emerging field of ocean literacy research as an inherent model for integrating science content and SSI. Components of this research that contribute to the socioscientific arena are the addition of ocean environmental issues to SSI topics, and an implementation strategy to introduce embedded OSSI through direct experiences with the ocean environment and experiential learning activities. Given our growing dependency on the ocean as a society, the relevance and critical need for research in this area will likely grow as an integral part of international SSI research.

Summary

Although the oceans contribute significantly to our everyday lives, there exists a critical disconnect between what research scientists know about the oceans (e.g., ocean content knowledge, conservation) and what the public understands about the oceans (e.g. ocean literacy, personal relevancy, moral decision making). Given the oceans' critical and direct role in regulating many of the physical comforts of human society, international economies, personal and environmental health, the paucity of ocean literacy is a clear and present concern. Ocean education and literacy that goes beyond emotive factors (e.g., care, concern and connection with the ocean) is critical and relevant towards preparing our students, teachers, and citizens to regularly contribute to ocean decisions and socioscientific issues that impact their health and well being on Earth.

For the present study the role of content knowledge, environmental attitudes and reasoning about the ocean, and informal reasoning about OSSI were analyzed as mediating factors contributing to ocean literacy. The significance of content (Lambert, 2005; Sadler, 2004; Sadler & Zeidler, 2004), context, (e.g. culture, individual beliefs, experience, place/time in life; McGinnis, 2003; Persing, 2006; Sadler, 2004; Semken, 2005), morality (Abd-El-Khalick, 2003; Persing, 2006; Sadler & Zeidler, 2004; Zeidler & Keefer, 2003), critical thinking skills (Ault, 1998; Keefer, 2003; Zeidler, Lederman & Taylor, 1992), and the nature of science (Sadler, 2004; Zeidler & Keefer, 2003) are often cited as components to attend to when engaged in knowledge-building and socioscientific issues. Decision making is further influenced by personal experiences, emotive factors, and social considerations. Many of these same processes contributed significantly to the acquisition of ocean knowledge and resolution of ocean socioscientific issues in my study. In particular, content knowledge, context as direct experiences in nature, and environmental morality each contributed to ocean literacy as defined in this study.

Because the ocean is inextricably interconnected to students' lives, it provided a significant context for socioscientific issues that fostered decision making, social discussions, human interactions, and environmental stewardship. This study supports the science education community's understanding of reasoning and resolution of socioscientific issues by expanding the research to include the influence of conceptual understanding of the ocean (e.g., content and attitudes), direct environmental experiences (e.g., context) and environmental and informal reasoning about ocean dilemmas and issues.

Science literacy research studies have primarily focused on three main areas as factors contributing to literacy (e.g., content, process skills and attitudes). The present study examined content knowledge and attitudes about science and towards science. More recently socioscientific decision-making has emerged as a research area of scientific literacy and has advanced a functional aspect to literacy. Elements of socioscientific decision making that guided this study included informal reasoning, understanding of embedded content, and emotive factors. Although current methodologies precluded direct empirical access to an individual's ocean literacy and informal reasoning about ocean issues, the analysis of ocean learning experiences revealed underlying factors contributing to ocean literacy and decision-making. Findings from the present study revealed that both science content and social components contributed to ocean literacy in the context of an ocean education program.

A trend that emerged across all research areas was the pervasive influence of direct, personal experiences with nature (ocean environments) on knowledge construction, reasoning about socioscientific issues, and environmental morality. These findings were evidenced in pre-post camp responses for SOLE, SOS, and OCG Learning Essays. The present study supported findings of others that personal experience mediated scientific knowledge without exclusion. Personal experiences emerged consistently in ocean literacy surveys as one of the most influential factors reported by adults and undergraduate students when asked about their interest in the ocean and source of prior knowledge (Belden et al, 1999; Cudaback, 2006; Steel et al., 2005). Studies in environmental morality consistently reported the significant influence of direct personal experiences with nature in developing positive attitudes, values, and behaviors towards the environment (Caduto, 1998; Palmberg & Kuru, 2000; Zelenzy, 1999). Specific to reasoning about socioscientific issues a trend is less clear, personal experience in some studies appeared to mediate scientific knowledge (Tytler, 2001; Zeidler & Shafer, 1984), while in other studies personal experience was used to the exclusion of scientific knowledge (Sadler & Zeidler, 2005; Zeidler et al., 2002).

Recognizing and addressing how personal experiences affect development of ocean literacy, reasoning, and decision making was an explicit focus of the present study. The future of ocean health relates directly to personal, individual decisions about its management and exploitation. The role of prior knowledge and personal experiences in developing conceptual understanding has been well-established (Berk, 2000; Bransford et al., 1999; Flavell et al., 2002). The present study advanced ocean knowledge from the point of personal relevance towards scientific understanding. As evidenced from OSSI written and oral responses, rising 9th graders participating in OCG were capable of quality decision-making about ocean socioscientific issues.

In summary, ocean content, context, and reasoning all contribute to ocean literacy as defined by my study. My findings contribute a new line of research for scientific literacy by including ocean sciences content and concepts. My study further contributes to socioscientific issues research by presenting an alternative approach for implementing SSI via interactive content-rich activities that are embedded with SSI provided via direct experiences in nature. Finally, my research provides a series of three ocean-based socioscientific issues to present in both formal classrooms and informal learning environments (e.g., free-choice learning).

Two major education needs are at the heart of ocean science literacy. These are the need to provide (a) ocean science content and experiences as part of a 21st century integrated science curriculum, and (b) opportunities to engage in ocean-related socioscientific issues (OSSI) meaningful to the life experiences of most citizens. The present research contributes to each of these needs. OCG participants as citizens can contribute to the social, economic, and cultural development of an ocean literate society permeated with individual, regional, and global implications. An overarching outcome of the present study was to establish that the OCG program is multimodal and goes beyond cognitive understanding to include social and emotive aspects of learning. Findings from this study clearly support that OCG successfully integrates cognitive, affective, and social aspects of learning to advance ocean literacy.

Supported by the findings of SOLE, the current ocean sciences standards provide a framework for building cognitive understanding about the oceans. However, current ocean literacy standards using the seven essential principles of ocean sciences may not be multimodal. The relevancy of social and affective aspects also critical to an ocean literate citizenry, are lacking. This study proposes that ocean literacy include engagement in OSSI and stewardship. Current ocean literacy standards inform about the ocean but do not engage people to apply what they know. I therefore reiterate the definition of ocean literacy adopted for this research. *An ocean literate person is an individual equipped to use ocean knowledge, to engage in oral or written discussion about the oceans (e.g., support a position), to understand the changes made to the ocean through human activity, and to apply ocean knowledge through actions as citizen, steward or consumer*.

Further research is needed to more completely assess the breadth and relevancy of an ocean literate person and society.

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Appendices

Appendix A: Description of the Centers of Ocean Sciences Education Excellence (COSEE)

The ten Centers for Ocean Sciences Education Excellence (COSEE):

- promote partnerships between research scientists and educators,
- disseminate best practices in ocean sciences education, and
- promote ocean education as a charismatic, interdisciplinary vehicle for creating a more scientifically literate workforce and citizenry.

ocean literacy
COSEE's work on ocean literacy is already guiding many local, state and national efforts to develop science standards, instructional materials, assessments, teacher professional development programs, museum and aquarium exhibits, free choice learning opportunities, and state and federal ocean policy.

ocean careers
What are your interests? Visit OceanCareers.com for an overview of dozens of careers, learn about how to prepare for these careers, locate career guidance, and much, much more.

scientist partners
COSEE has ideas, inspiration, and tools to assist scientists in becomming effectively involved in education and outreach. Visit these COSEE websites for more information: COSEE New England and COSEE California.

"***The COSEE network promotes a better understanding*** *of the key role* the ocean plays in global environmental cycles and processes. COSEE activities highlight the contributions ocean science researchers make to scientific knowledge in these important areas. NSF is encouraging the ocean-science research community to become more involved in education at all levels." (Larry Clark, acting director of NSF's Division of Ocean Sciences, NSF press release January 3, 2006)

Each COSEE represents one or more ocean science research institutions, an informal science education organization, and at least one affiliate organization representing the formal education community.

Center activities include:

- establishing links between people and organizations conducting ocean science research and those providing educational leadership or outreach among diverse communities
- providing expertise and guidance for research scientists involved in education, such as conducting workshops to encourage scientists to develop collaborative grant proposals with educators or to experiment with various education and teaching strategies
- providing incentives and assistance for school districts and teachers to integrate ocean sciences into their curricula
- facilitating the integration of research results into high-quality educational materials, as well as fostering the development and dissemination of those materials both regionally and nationally

View summary information about NSF's COSEE awards here.

The Consortium for Oceanographic Research and Education (CORE) in Washington D.C. coordinates the network and promotes the program, including outreach to professional societies and organizations.

Other partners at the national level include the Bridge project at the Virginia Institute of Marine Science, the National Sea Grant College Program, and the Office of Program Evaluation at the University of South Carolina.

Appendix B: A Description of the Oceanography Camp for Girls Education Program

Oceanography Camp especially for Girls
http://www.marine.usf.edu/girlscamp

The Oceanography Camp is a three-week summer educational program for teenaged girls who are poised to enter high school. The primary goals are to retain young women's interests in science and to encourage their pursuit of science careers by sparking their curiosity about the natural world around them. The program provides a multidisciplinary, hands-on, inquiry learning experience in both laboratory and field environments. The camp takes place in an ocean setting at USF's marine science laboratories where students actively use the knowledge they acquire to understand local and global environments. Bridging the gap between the real world and the classroom is accomplished by taking students on cruises aboard a research vessel to collect real-time data, taking them on field trips to provide outdoor ecology classrooms, and engaging them in practical laboratory research.

The Oceanography Camp seeks to actively recruit, educate and inspire *all* students. Under the intrinsically interdisciplinary umbrella of oceanography, participants are directly involved in those disciplines in which women and minorities are most often underrepresented: chemistry, geology, and physics. To date, over 800 young women have participated and include minority and non-minority girls inclusive of all learning abilities (e.g. high achieving, average, and high potential).

Short-term evaluation of this program indicates that intervention has made a difference. Alumni have: 1) taken more math and science courses in high school; 2) gained a realistic and positive image of science and scientists; 3) improved their understanding of the research process; and, 4) strengthened their commitment to pursue careers in math, science or engineering. Nearly 20% of alumni in college are pursuing science-related degrees. Other results

- 93% increased interest in doing science
- 93% increased confidence in ability to excel in science
- 93% more science courses
- 97% understanding of research process
- 83% > 50% chance will become a scientist
- 96% participate in a similar project

The uniqueness of this educational outreach lies not only in its "real world" environmental studies but also in its ability to provide one-to-one mentoring between teenaged girls and scientifically accomplished women. Participants work directly with female professors and graduate students from USF's College of Marine Science, as well as professionals from industry and governmental agencies. Community partners include the United States Geological Survey, Florida Wildlife Research Institute, Center for Ocean Technology, and Pinellas County Schools.

The OCG presents an outstanding opportunity to educate young women about the ocean environment and inspire them to assume leadership roles in the scientific fields that will alleviate some of the Earth's environmental stresses. The enthusiasm expressed by new and alumni campers each year is a testament to their willingness to be involved in the ongoing process of environmental problem solving; campers provide the energy and the camp provides direction. It is our hope that the OCG will continue to inspire young women to continually learn so they are well prepared to make informed, societally relevant decisions.

We are grateful for support from the United States Geological Survey Center for Coastal and Watershed Studies, Progress Energy Foundation, and contributors to Camp Endowments.

Appendix C: Three Quantitative Instruments Developed to Measure Ocean Literacy

Survey of Ocean Literacy and Experience (SOLE) Instrument

Question	Answer	Answer	Answer	Answer	Answer	Answer
1. Approximately how much of the earth is covered by ocean?	a. 30%	b. 50%	c. 60%	d. 70%	e. 90%	f. 97%
2. There is one big ocean. The continents divide the ocean into basins. Which of the following are major ocean basins?	a. Arctic, Red Sea, Atlantic, Pacific	b. Pacific, Gulf of Mexico, Atlantic, Mediterranean Sea	c. Pacific, Atlantic, Indian, Bering Sea	d. Arctic, Pacific, Atlantic, Indian	e. Pacific, Caribbea n Sea, Atlantic	
3. Rivers supply most of the salt to the oceans, which comes from	a. seafloor reactions	b. eroding land	c. volcanic emissions	d. atmosphere	e. all of these	f. none of these
4. The movement of the earth's lithospheric plates influences an ocean basin's	a. shape	b. features (islands, trenches)	c. color	d. size	e. answer a, b & d	
5. The ocean's circulation (currents) is powered by	a. tides	b. winds	c. earth's rotation	d. both a and b	e. answer a, b & c	
6. What processes cause sea level changes?	a. plate tectonics	b. ice caps melt & grow	c. seawater expands & contracts	d. sea level does not change	e. answer a, b & c	
7. Approximately how much of the earth's water is fresh and unfrozen (neither ice nor ocean)?	a. >50%	b. 40-50%	c. 20-30%	d. 10-20%	e. 3%	f. 1%
8. The ocean is connected to all the earth's water reserves (supplies) via	a. con-densation	b. precipitation	c. evaporation	d. both b and c	e. none of these	f. all of these

9. Which of these statements best describes the depth of the ocean?	a. less than 1/100th the diameter of the earth	b. about 1/100th of the diameter of the earth	c. about 1/10th the diameter of the earth	d. about 1/2 the diameter of the earth	e. none of these describe the depth of the ocean	
10. The ocean contains the earth's	a. flattest plains	b. highest mountains	c. deepest valleys	d. all are in the ocean	e. none are in the ocean	
11. The path of ocean circulation is influenced by	a. satellites	b. shape of ocean basins	c. adjacent land masses	d. both b and c	e. none of these	
12. Many earth materials originated in the ocean. Which rock type now exposed on land in the Southwest U.S. formed in the ocean?	a. igneous	b. metamorphic	c. sedimentary	d. all of these	e. none of these	
13. The ocean is large and finite. It's resources are	a. unlimited	b. all renewable	c. all non-renewable	d. limited	e. answer a and b	
14. Approximately what fraction of the total water on earth is in the ocean?	a. 42%	b. 34%	c. 52%	d. 72%	e. 97%	f. 99%
15. Which of the following are transported by rivers from watersheds to estuaries and to the ocean?	a. nutrients	b. salts	c. sediments	d. pollutants	e. all of these	f. answer b and d
16. In nature, which factors redistribute sand along a beach?	a. wave motion	b. coastal currents	c. tectonics	d. birds	e. plants	f. answer a and b
17. Sea level changes over time have	a. increased and decreased continenta l shelves	b. created and destroyed inland seas	c. shaped the surface of land	d. all of these	e. none of these	
18. Sediments are formed from erosion of land based earth materials. These include	a. rocks	b. minerals	c. soils	d. plants and animals	e. all of these	f. none of these

19. Climatic conditions constantly change and erode the landscape of barrier islands (beaches). Climatic changes occur in the form of	a. heavy winds	b. wave action	c. tidal surges	d. coastal storms	e. all of these	f. none of these
20. Water moves from the ocean to the atmosphere to the land and back again to the ocean by a process called	a. water shed	b. hurricane	c. water cycle	d. tsunami	e. cyclone	f. perfect storm
21. The physical structure and landforms of the coast are naturally influenced by	a. sea level changes	b. force of waves	c. gopher tortoises	d. tectonic activity	e. answer a, b and d	f. none of these
22. If our planet were without its ocean but otherwise the same as it is today, would surface temperatures be more extreme than they are now (warmer summers and colder winters) or less extreme, or what?	a. more extreme	b. less extreme	c. no change in temperatures			
23. Which sources put the most oil in the ocean?	a. oil spills from ships	b. leaks from refineries and pipelines	c. used motor oils washed into storm drains	d. leaks from offshore oil rigs	e. none of these sources put oil in the ocean	
24. What is the source of most trash on the beaches in the U.S.?	a. municipal garbage dumped at sea	b. people playing on the beach and leaving trash	c. people smoking on the beach	d. cruise ships dumping trash at sea	d. none of these are sources put trash on beach	
25. The ocean dominates the earth's carbon cycle. Approximately how much of all the carbon dioxide in the atmosphere is absorbed by the ocean?	a. 30%	b. 50%	c. 60%	d. 70%	e. 90%	f. 97%

26. What is the essential nature of barrier islands?	a. static and stability	b. motion and change	c. none of these			
27. All but one of the following decompose in ocean water	a. sewage	b. tin cans	c. plastic bags	d. chemical fertilizers		
28. The ocean controls weather and climate by dominating which of the earth's systems?	a. energy	b. plants	c. water	d. carbon	e. answer a, c, & d	f. none of these system s
29. By which process does the ocean lose heat that it absorbs from solar radiation?	a. precipitati on	b. condensation	c. evaporation	d. both a and c	e. both a and b	f. all of these
30. Most rain that falls on land originally evaporated from the	a. tropical ocean	b. polar ocean	c. temperate ocean	d. rain does not begin in ocean	e. none of these	
31. Global weather is changed by the El Nino Southern oscillation by changing the way heat is released in the atmosphere over which ocean basin?	a. Atlantic	b. Pacific	c. Gulf of Mexico	d. Indian	e. Arctic	f. Red Sea
32. The ocean dominates the earth's carbon cycle. Approximately how much primary production on earth takes place in the sunlit areas of the ocean?	a. 30%	b. 50%	c. 60%	d. 70%	e. 90%	f. 97%
33. The ocean has and will continue to have a significant influence on climate change by storing, absorbing, and moving	a. salts	b. carbon	c. heat	d. water	e. plants	f. answer b, c & d

34. The uneven heating of the earth's surface causes the ocean's temperature to vary with latitude. Which of the following is ordered from warmest ocean water to coldest ocean water?	a. temperate to equator to poles	b. equator to poles to temperate	c. poles to temperate to equator	d. temperate to poles to equator	e. equator to temperate to poles
35. Most of the living space on earth is found	a. on the land	b. in the ocean	c. in the atmosphere	d. equally in all areas	
36. Pressure in the ocean increases with depth. What happens to temperature?	a. increases with depth	b. decreases with depth	c. stays the same	d. increase & decrease	e. none of these
37. What happens to sunlight in the ocean as depth increases?	a. increases with depth	b. decreases with depth	c. stays the same	d. increase & decrease	e. none of these
38. Where is a greater diversity of living organisms found?	a. on the land	b. in the ocean	c. both equally		
39. What produces most of the earth's oxygen?	a. forests	b. plants (algae) in the ocean	c. both equally	d. none of these	
40. Which of the following groups of organisms would be more closely related?	a. bony fish, jelly, seastar, crayfish	b. spider, crab, insect, mouse	c. human, cat, dog, manatee	d. alligator, shark, bony fish, pelican	
41. Ocean life ranges in size from the smallest virus to the largest animal that has lived on earth, called the	a. giant squid	b. basking shark	c. blue whale	d. sperm whale	e. Locness monster
42. The most abundant life form in the ocean is	a. phyto-plankton	b. fishes	c. shrimp	d. microbes	e. zoo-plankton
43. In the ocean living spaces and habitats are found	a. at the surface	b. in the water column	c. on the seafloor	d. all of these	e. none of these

44. Ocean habitats are defined by environmental factors. Life is not evenly distributed due to interactions of abiotic factors such as	a. nutrients	b. sunlight	c. pH	d. oxygen	e. substrate	f. all of these
45. Which of the following causes vertical zonation patterns along the shore that influence the distribution and diversity of organisms?	a. predation	b. waves	c. tides	d. both a and c	e. all of these	f. none of these
46. Marine habitats that have brackish water and provide productive nursery areas for many marine species are	a. seas	b. estuaries	c. rivers	d. open ocean	e. lagoons	
47. Deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms are	a. hydro-thermal vents	b. submarine hot springs	c. methane cold seeps	d. both b and c	e. all of these	
48. Which ocean ecosystem provides habitat for one-third of all marine species?	a. coral reef	b. seagrass meadow	c. mangrove forest	d. open ocean	e. estuary	
49. The ocean is the last and largest unexplored place on earth. How much of the ocean remains unexplored?	a. 30%	b. 50%	c. greater than 90%	d. less than 5%	e. 65%	
50. Why is it important to study the ocean?	a. better understand ocean systems	b. satisfy our curiosity	c. understand ocean processes	d. not important to study the ocean	e. answer a, b & c	
51. Over the last 40 years, use of ocean resources has significantly increased. Why is it important to know this? So that we	a. can do our part to sustain the resources	b. will discontinue ocean recreational activities	c. will better understand ocean resources and limitations	d. answer a, b & c	e. both a and c	

52. Which of the following statements are true about the ocean?	a. It provides food and medicine	b. It provides mineral and energy resources	c. It provides transportatio n and jobs	d. It benefits our economy and national security	e. All of these	f. both c and d
53. Ocean scientists are relying more and more on which of the following technology tools to explore the ocean?	a. buoys	b. satellites	c. subsea observa-tories	d. unmanned sub-mersibles	e. all of these	f. both c and d
54. What does the statement, the ocean and humans are inextricably connected mean? Humans need the ocean	a. for freshwater	b. for oxygen	c. to regulate the temperature	d. for new health cures	e. all of these	
55. Humans affect the ocean in a variety of ways. Human development and activity often leads to	a. pollution (point, non-point, noise)	b. physical changes to beaches	c. removal of most large vertebrates	d. answer a, b & c	e. humans do not affect the ocean	
56. Which natural hazards can impact coastal regions?	a. bird migrations	b. hurricanes	c. storm surges	d. both b and c	e. none of these	
57. Which of the following statements is most relevant to ocean literacy? Much of the world's population lives	a. near rivers	b. in rural areas	c. in coastal areas	d. in mountain areas	e. in wooded areas	

Appendix C (Continued)

Survey of Ocean Stewardship (SOS) Instrument

Here are a number of statements that may or may not describe your beliefs about learning oceanography (Cudaback, 2006). You are asked to rate each statement by selecting a number between 1 and 5 where the numbers mean the following:

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly agree

Choose one of the above five choices that best expresses your feelings about the statement. If you don't understand a statement, leave it blank. If you have no strong opinion, choose 3.

1._____ Thinking like a scientist helps me understand the ocean.[3]

2._____ The topics I study in oceanography are not related to each other. [3]

3._____ I cannot learn oceanography if the teacher does not explain things well in class.[1]

4._____ I study oceanography to learn knowledge that will be useful in my life outside of school.[1]

5._____ Nearly everyone is capable of understanding oceanography if they work at it.[1]

6._____ To understand oceanography I discuss it with friends and other students.[1]

7._____ The subject of oceanography has little relation to what I experience in the real world. [3]

8._____ To understand oceanography, I sometimes think about my personal experiences and relate to the topic being analyzed. [1]

9._____ When studying oceanography, I relate the important information to what I already know rather than just memorizing it the way it is presented. [1]

10._____ A significant problem in learning oceanography is being able to memorize all the information I need to know. [2]

11._____ I can usually make sense of how the ocean works. [2]

12._____ Spending a lot of time understanding why the ocean behaves and reacts the way it does is a waste of time. [2]

13._____ Learning oceanography changes my ideas about how the world works. [2]

14._____ Reasoning skills used to understand oceanography can be helpful to me in my everyday life. [2]

[1]CLASS
[2]CLASS-Geosciences
[3] Cudaback, C. (2006). What do college students know about the ocean? *Eos, 87*, 418-421.

Here are a number of statements that may or may not describe your beliefs about protecting the ocean (Cudaback, 2006). You are asked to rate each statement by selecting a number between 1 and 5 where the numbers mean the following:

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly agree

Choose one of the above five choices that best expresses your feelings about the statement. If you don't understand a statement, leave it blank. If you have no strong opinion, choose 3.

15._____ My actions can have a significant effect on the health of oceans and coastal areas. [3]

16._____ I have a personal responsibility to work for the health of oceans and coastal areas. [3]

17._____ I know some specific things I could do to help the ocean. [3]

18._____ I am familiar with the environmental issues facing the coastal areas in my home state. [3]

19._____ I am familiar with the issues facing the global ocean. [3]

20._____ I have enough background knowledge to write a substantive letter to my congressional representative about an issue affecting the ocean. [3]

21._____ The ocean and coastal regions overall are so vast and healthy that they can continue to absorb pollution and other kinds of man-made stresses for the foreseeable future.[4]

22._____ Human-made stresses are endangering coastal regions and the ocean's ability to sustain itself and may well be leading to long-term damage and serious problems. [4]

23._____ The health of the ocean is important to human survival. [5]

24._____ We do not need to worry about the health of the oceans, because we will develop new technologies to keep them clean. [5]

25._____ What I do in my life doesn't impact the ocean at all? [3]

26._____ Business and industry should be responsible for protecting marine environments.[6]

27._____ Government should be responsible for protecting marine environments.[6]

28._____ Individual citizens should be responsible for protecting marine environments. [6]

29._____ Agriculture and forestry should be responsible for protecting marine environments.[6]

[4]AAAS Public Opinion Survey
[5]Ocean Project Public Opinion Survey
[6]Based on questions used for Minnesota Environmental Literacy Report Card

Appendix C (Continued)

Here are a number of statements that may or may not describe your beliefs about the relationship between humans and the environment (Cudaback, 2006). For each one, please indicate your agreement by selecting a number between 1 and 5 where the numbers mean the following:

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly agree

30._____ We are approaching the limit of the number of people the earth can support.[7]

31._____ Humans have the right to modify the natural environment to suit their needs.[7]

32._____ When humans interfere with nature, it often produces disastrous consequences.[7]

33._____ Human ingenuity will ensure that we do NOT make the earth unlivable.[7]

34._____ Humans are severely abusing the environment.[7]

35._____ The earth has plenty of natural resources if we just learn how to develop them.[7]

36._____ Plants and animals have as much right as humans to exist.[7]

37._____ The balance of nature is strong enough to cope with the impact of modern industrial nations.[7]

38._____ Despite our special abilities humans are still subject to the laws of nature.[7]

39._____ The so-called “ecological crisis” facing humankind has been greatly exaggerated.[7]

40._____ The earth is like a spaceship with very limited room and resources.[7]

41._____ Humans were meant to rule over the rest of nature.[7]

42._____ The balance of nature is very delicate and easily upset.[7]

43._____ Humans will eventually learn enough about how nature works to be able to control it.[7]

44._____ If things continue on their present course, we will soon experience a major ecological catastrophe.[7]

[7]New Ecological Paradigm: Dunlap & Van Liere (2000). *Journal of Social Issues* 56 (3), 448-442.

Scenarios of Ocean Environmental Morality (SOEM) Instrument

Section A: This section asks a few questions about yourself, your family &your friends.

1. What is your age? _____

2. What is your gender? ____ Female _____Male

3. Which of the following categories best describes the area where you currently live? *(Circle one).*
- o Farm or rural area
- o Small town (fewer than 10,000 people)
- o Large town or small city (at least 10,000 people but less than 50,000)
- o Medium-sized city, including suburbs (at least 50,000 people but less than 250,000)
- o Large city, including suburbs (250,000 people or more)

4. Which category best describes the area where you grew up?
- o Farm or rural area
- o Small town (fewer than 10,000 people)
- o Large town or small city (at least 10,000 people but less than 50,000)
- o Medium-sized city, including suburbs (at least 50,000 people but less than 250,000)
- o Large city, including suburbs (250,000 people or more)

5. Over the past year, how often have you talked with your *family* about environmental issues like air and water pollution, recycling, buying environmentally-friendly products, and carpooling? (circle one)

never   only a few times   a few times a month   a few times a week   once or twice a year

6. Over the past year, how often have you talked with your *friends* about environmental issues like air and water pollution, recycling, buying environmentally-friendly products, and carpooling? (circle one)

never   only a few times   a few times a month   a few times a week   once or twice a year

7. Over the past year, how often have your *family* recycled things like cans, bottles, plastics and newspapers?
(circle one)

never   only a few times   a few times a month   a few times a week   once or twice a year

8. Over the past year, how many of your friends do you think have recycled things like cans, bottles, plastics and newspapers? (circle one)

none   one or two   some   most   all

9. Over the past year, how often has your family bought environmentally-friendly products like organic foods, dolphin-safe tuna, or all-natural cleaning products? (circle one)

never   only a few times   a few times a month   a few times a week   once or twice a year

10. Over the past year, how many of your friends do you think have bought environmentally-friendly products like organic foods, dolphin-safe tuna, or all-natural cleaning products? (circle one)

none   one or two   some   most   all

Section B - SCENARIO 1: BEACH WALK

Imagine that you are **WALKING** along an undeveloped beach. The beach is in a state park public land, meaning that it is owned by the state of Florida for everyone to use. You come to a sand dune covered with sea oats (tall grasses that are protected in Florida). You notice that some people have walked through the dune. Some of the sea oats have been trampled and crushed where they walked. The beach has signs along the way saying "stay off the sand dunes and no picking sea oats."

It looks like it might be fun to walk through the dunes and sea oats.

11. How much do you agree that it O.K. for a person to walk through the sand dunes? (circle one)

Strongly agree　　Slightly agree　　Slightly disagree　　Strongly disagree

12. Some people say it is all right because the sea oats will grow back. How much do you agree with these people? (circle one)

Strongly agree　　Slightly agree　　Slightly disagree　　Strongly disagree

13. Imagine that you really are in this situation. What *would* you do? (circle one)

____ I *would* walk through the sand dune.
____ I *would not* walk through the sand dune.

Suppose you are thinking about *not walking* through the sand dune. Read the following statements and then circle the statement that indicates **how important** each reason would be in making a decision to not walk through the dune. I would not walk through the sand dune because:

1) Extremely important to me
2) Somewhat important to me
3) Neither Important nor Unimportant
4) Somewhat not important to me
5) Not at all important to me

14) It could destroy the dunes and then the park officials might close the beach to beach combers.

1　2　3　4　5

15) There are some parts of nature that should remain as they are and not be disturbed.

1　2　3　4　5

16) The sand dunes don't have a trail through it and if people started walking through the dunes they could fall and get hurt.

1　2　3　4　5

17) All plants and animals in the dunes are living beings just like us and walking through the dunes may hurt them.

1　2　3　4　5

18) There wouldn't be as many sea oats for me to enjoy viewing.

1　2　3　4　5

19) It is important to live in balance with nature and not harm more than we need to.

1　2　3　4　5

20) I want to leave the dunes pretty and attractive for others to enjoy viewing.

1　2　3　4　5

21) The beach belongs to everyone and nobody has the right to ruin it for others.

1　2　3　4　5

22) I should be responsible to the places I enjoy so I can continue to enjoy them.

1　2　3　4　5

23. With which one of the above reasons do you most agree with? (a, b, c, d, e, f ,g, h, or i) ______

24. Based on the reason you most agree with, how likely are you to stay on the beach. (circle one)

not at all likely　　not very likely　　a little bit likely　　somewhat likely　　very likely

Section B - SCENARIO 2: PICNICKING SCENARIO

Imagine that you are having a **PICNIC** in a state park located along the bay or ocean with your family . After finishing your picnic, you notice that all of the trash cans are full and there is no room in them for your garbage. You did not bring any garbage bags of your own and it would be easy to just leave garbage there for someone else to clean up.
There is no one else at the picnic area to see what you do.

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25. How much do you agree that it is O.K. for a person to leave their garbage? (circle one)
Strongly agree Slightly agree Slightly disagree Strongly disagree

26. Some people say it is all right because someone will clean it up. (circle one)
Strongly agree Slightly agree Slightly disagree Strongly disagree

27. Imagine that you really are in this situation. What *would* you do? (circle one)
____ I *would* leave the garbage.
____ I *would not* leave the garbage.

Suppose you are thinking about *not leaving your garbage*. Read the following statements and then circle the statement that indicates **how important** each reason would be in making a decision <u>not to</u> leave your garbage at the picnic site.

1) Extremely important to me
2) Somewhat important to me
3) Neither Important nor Unimportant
4) Somewhat not important to me
5) Not at all important to me

28) If the picnic area is left dirty, people like myself will not want to visit again.
1 2 3 4 5

29) The plants and animals in the area are living creatures just like us and they have a right to live in a clean area just like we do.
1 2 3 4 5

30) Nobody has the right to litter the picnic area, it is there for everyone to enjoy.
1 2 3 4 5

31) The picnic area is a part of nature and should be preserved for its own sake.
1 2 3 4 5

32) I want it to be kept clean for the next time I visit.
1 2 3 4 5

33) No one wants to see litter and garbage when are out on a picnic.
1 2 3 4 5

34) It is important for people to live in balance with nature.
1 2 3 4 5

35) If people litter, it costs money to clean it up and the people who use the picnic area are the ones who will end up paying for it.
1 2 3 4 5

36) I should be responsible to the places I enjoy so that I can continue to enjoy them.
1 2 3 4 5

37. With which one of the above reasons do you most agree with? (a, b, c, d, e, f ,g, h, or i) ______

38. Based on the reason you most agree with, how likely are you to take your garbage home. (circle one)
not at all likely not very likely a little bit likely somewhat likely very likely

Section B - SCENARIO 3: BAY FISHING

Imagine that you are **FISHING** at a bay. The bay is on public land, meaning that it is owned by the state of Florida for everyone to use. The bay is "catch and release" only, meaning that you cannot keep any of the fish that you catch.
You have just caught the biggest fish of your life and would really like to take it home to show all of your friends.

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39. How much do you agree that it O.K. for a person to keep the fish?

Strongly agree   Slightly agree   Slightly disagree   Strongly disagree

40. Some people say it is all right because it's only one fish and there are many others in the bay.

Strongly agree   Slightly agree   Slightly disagree   Strongly disagree

41. Imagine that you really are in this situation. What *would* you do? (circle one)

____ I *would* leave the fish.

____ I *would not* leave the fish.

Suppose you are thinking about *leaving the fish*. Read the following statements and then circle the statement that indicates **how important** each reason would be in making a decision to leave the fish in the bay?

1) Extremely important to me
2) Somewhat important to me
3) Neither Important nor Unimportant
4) Somewhat not important to me
5) Not at all important to me

42) We can live in harmony with nature without taking fish we don't need.
1 2 3 4 5

43) Nobody has the right to break the rule because the bay is there for everyone.
1 2 3 4 5

44) I like to see a lot of big fish in the bay.
1 2 3 4 5

45) Fish belong in the bay, it is their home
1 2 3 4 5

46) People want to see a bay full of fish.
1 2 3 4 5

47) Fish are living creatures just like us and have a right to live.
1 2 3 4 5

48) Other people come to the bay to fish and would like the opportunity to catch big fish.
1 2 3 4 5

49) If it is over fished (too many fish taken) I cannot fish there anymore.
1 2 3 4 5

50) I should be responsible to the places I enjoy so that I can continue to enjoy them.
1 2 3 4 5

51. With which one of the above reasons do you most agree with? (a, b, c, d, e, f ,g, h, or i) ______

52. Based on the reason you most agree with, how likely are you to put the fish back in the ocean. (circle one)

not at all likely	not very likely	a little bit likely	somewhat likely	very likely

Section B – SCENARIO 4: OCEAN SWIMMING SCENARIO

Imagine that you are **SWIMMING** at this ocean in a state park with some of your friends. It is a hot day and you are sitting on the beach eating lunch. As you get your sandwich out of the cooler, you notice the freezer pack keeping your sandwich cold has leaked all over the bottom of the cooler. You want to wash out the cooler and the ocean is a closer source of water to you than the showering area.
You remember that the freezer pack contains chemicals that may or may not be harmful to the ocean and all the things that live and swim in the ocean

---

53. How much do you agree that it O.K. for a person to wash the cooler in the ocean?

Strongly agree   Slightly agree   Slightly disagree   Strongly disagree

54. Some people say it is all right because it is only one small amount of pollution and it's no big deal.

Strongly agree   Slightly agree   Slightly disagree   Strongly disagree

55. Imagine that you really are in this situation. What *would* you do? (circle one)

____ I *would* wash the cooler in the ocean.

____ I *would not* wash the cooler in the ocean.

Suppose you are thinking about *not washing* the cooler in the ocean. Read the following statements and then circle the statement that indicates how important each reason would be in making a decision <u>not to</u> wash the cooler in the ocean?

1) Extremely important to me
2) Somewhat important to me
3) Neither Important nor Unimportant
4) Somewhat not important to me
5) Not at all important to me

56) The ocean and the fish have value for their own sake and deserve respect.

1 2 3 4 5

57) If we pollute the water it could cause people to get sick if they swim in it.

1 2 3 4 5

58) The ocean is a living thing with fish and plants that have the right to live and be healthy just like us

1 2 3 4 5

59) People want to see clean water when they go swimming, not dirty, gray water.

1 2 3 4 5

60) I want it to be kept clean for the next time I visit.

1 2 3 4 5

61) We are part of nature and so we must learn to live in balance with it.

1 2 3 4 5

62) If the ocean got polluted I wouldn't swim in it anymore.

1 2 3 4 5

63) The ocean is for everyone to enjoy and we should keep it clean for everyone.

1 2 3 4 5

64) I should be responsible to the places I enjoy so that I can continue to enjoy them.

1 2 3 4 5

65. With which one of the above reasons do you most agree with? (a, b, c, d, e, f ,g, h, or i) ______

66. Based on the reason you most agree with, how likely are you to wash the cooler somewhere else. (circle one)

not at all likely	not very likely	a little bit likely	somewhat likely	very likely

Section C: This section asks about your favorite outdoor activities.

Over the past year, about how often have you participated in these activities when in season? (Place an X in the answer of your choice)

	Never	Once or twice	Few times Year	Few times a month	Few times a week
Fishing					
Hiking					
Ocean Swimming					
Jet-Skiing					
Picnicking					
Canoeing/Kayaking					
Bird Watching					
Bicycling					
Boating on the bay or ocean					
Surfing/boogey boarding					
Snorkeling/scuba diving					
Walking along the beach					
Sunbathing on the beach					
Sail boating					
Water Skiing					
Others (list)					
Others (list)					
Others (list)					

Appendix D: Description of Ocean Socioscientific Issue Case Studies and Questions for Written Responses

Description of Turtle Hurdle (Case Study I), a marine species and habitat protection role playing activity (Turtle Hurdle © 1987 Western Regional Environmental Education Council)

The objectives of Turtle Hurdle are that students will be able to: 1) describe the life cycle of sea turtles; 2) identify specific mortality factors related to sea turtles; 3) make inferences about the effects of limiting factors on sea turtle populations; and 4) make recommendations for ways to minimize the factors which contribute to the possible extinction of sea turtles. The methods are that students become sea turtles and limiting factors in a highly active simulation game.

After completing the activity, encourage the students to discuss the results. It is likely that some students will be disturbed by the high mortality of the turtles and will benefit from the realization that there are groups actively trying to diminish human contributions to such high mortality. However, it is also important to emphasize that natural limiting factors are built into the scheme of things. If all sea turtle eggs survived, there might well be an overabundance of these creatures. Many animals produce more young than will survive, serving as food for other species as a part of nature's dynamic balance.

Following the activity, participants provided written responses to the following six questions.

1. Describe and illustrate the major stages of sea turtles' life cycle, beginning with the egg.

2. Summarize the importance of the high numbers of turtles that result from one reproduction cycle. Identify and discuss the factors that limit the turtles' survival.

3. Since sea turtles are threatened with extinction, the limiting factors affecting their survival seem to be out of balance. What specific recommendations would you suggest to increase the successful reproduction and survival of sea turtles?

4. Name at least four limiting factors that prevent sea turtles from reaching the adult breeding stage.

5. Write a law that would help to protect sea turtles. What would the law include? Who would enforce it?

6. Write a persuasive letter to your state legislature describing an ocean socioscientific issue of importance to you and why and what legislation should be put in place to address the issue.

Appendix D (Continued)

Description of Fish Banks (Case Study II),
a natural marine resource decision making role-playing activity

(Fish Banks © 1992 University Massachusetts)

How to introduce the game:

We are going to play a game with several teams. It will take several hours to play this game. To play this game successfully, each team will need to

1. work well together as a team
2. formulate and stick to a long-term strategy.

If a team accomplishes both 1 and 2, they will prosper. If they fail in either criterion, they will go broke (bankrupt).

Congratulations! You and the other teams have just bought fishing companies. You and the other teams will be in competition to maximize assets by buying and selling fishing boats and by deciding where to send them fishing. You have bought into an extremely successful industry. As you can see, the catch has been going up with time and so has the number of fishing boats. The "wiggles" in the catch through time are due to the weather (overhead B13). Some years have good weather and bigger catches; some have bad weather and smaller catches. But overall the catch has been increasing through time.

This game has several parts (overhead B14). The ocean is divided into three areas: the deep sea, the coastal area, and the harbor. There is also a bank and a shipyard where new fishing boats are constructed.

During this game, each team will need to make team decisions about

- Whether to or not to expand your fishing boat fleet and
- Where to send the boats fishing.

To help structure decision making by each team we have given you a decision sheet. It has three areas:

- Annual Report: It has 7 lines. Each team will get a computer printout for each fishing year that will help you fill this out.
- Auctions, trades and orders: This lets each team keep track of how many boats they have. Remember, building new boats takes a year!
- Where you send your boats to fish each year.

Play game for 10 years. Keep a running tally of each year's results including catch/unit effort, total fish caught/area, total profits and expenses.

Appendix D (Continued)

Following the activity, participants provided written responses to the following nine questions.

1. What natural factors influence the number of fish in the sea?

2. What human factors influence the number of fish in the sea?

3. Fish catch is the principal determinant of success in the game. What 3 factors influenced the number of fish that are caught each year?

4. What is sustainable management of a natural resource, like fishes? On the back of this page, write a law that would help to protect fisheries stocks. What would the law include? Who would enforce it?

5. Should fisheries be managed by government agencies like NOAA National Marine Fisheries and state agencies like the Florida Fish and Wildlife Conservation Commission? Why or why not (support your position)?

6. Are fish populations a limited or non-limited resource in the ocean?

7. How do you suggest humans decide between coastal development for places to live and protecting coastal marine habitats (sea grass meadows, mangrove forests, and open beaches) for fishes to grow and develop?

8. List up to five questions that you would like to consider before making decisions about managing a natural ocean resource (living or non-living)?

9. On the back of this page, write a persuasive letter to your state legislature describing an ocean socioscientific issue of importance to you and why and what legislation should be put in place to address the issue.

Appendix D (Continued)

Description of Marine Pollution and Coastal Clean-up Activity (Case Study III), a participatory ocean stewardship activity (Oceanography Camp for Girls © 1992 University of South Florida)

The objectives of Coastal Clean-up Activity are that students will be able to: 1) identify the sources of marine pollution and debris; 2) identify specific types of marine pollution and debris; 3) make inferences about the effects of marine pollution and debris; on the ocean environment; and 4) make recommendations for ways to minimize the factors which contribute to marine pollution and debris.

The methods are for students to first view two videos related to marine pollution. The first video titled, Saving Inky, demonstrates the effects of marine debris (plastic bags) on a pygmy sperm whale rescued and rehabilitated by NOAA and the Baltimore Aquarium. The second video titled, Marine Debris, is a visual overview of the sources, types, and impacts of marine debris on the ocean and coastal environments. The impacts on the living and non-living resources in the ocean are emphasized.

After viewing the videos, students are encouraged to openly dialogue about what they heard and saw, how they felt, and to put forth recommendations to diminish human contributions to marine debris. All marine debris is from human origins. The number one source of marine debris is from recreational activities.

Following the dialogue session, students are invited to participate in a Coastal Clean-up and divided into teams. Data sheets, safety gear (gloves, trash pickers), collection receptacles, and pencils are distributed. Data sheets are provided by the Ocean Conservancy. All data collected by participants is then given to the Ocean Conservancy and is incorporated into an international data set on marine debris. Statistics are published from this data set annually from coastal clean-up events that take place throughout the year nationally and internationally. Participants record the debris items collected and count the number of each item collected.

After completing the activity, participants are encouraged to discuss the results. It is likely that some students will be disturbed by the amount of marine debris readily collected within the 30-minutes of the clean-up. However, most benefit from the realization that there are groups actively trying to diminish human contributions to marine pollution and that they can volunteer for these activities after the camp. The activity is closed by emphasizing that marine pollution is an issue that we can all contribute to bettering by actively acting and helping others to act in environmentally sensitive ways with our individual debris. The impact of marine debris on nature’s dynamic balance is also highlighted.

Participants complete Ocean Conservancy data sheets and compare data with other teams for the most abundant debris item, most unusual, and most overall debris collected by weight by a team.

Following the activity, participants provided written responses to the following eight questions.

1. List ten types of ocean pollution.

2. What human factors influence the pollution in the ocean?

3. Should ocean pollution be managed by federal and state government agencies? Why or why not?

4. Would you be willing to vote for tax dollars to be used to enforce and clean-up ocean pollution? Why or why not?

5. How do you suggest humans manage pollution and keep it from entering the ocean?

6. List up to five questions that you would like to consider before making decisions about managing ocean pollution.

7. Write a law that would help to protect fisheries stocks. What would the law include? Who would enforce it? Use the back of this page as needed.

8. On the back of this page, write a persuasive letter to your state legislature describing an ocean natural resource of importance to you. Why and what legislation should be put in place to address the issue?

Appendix E: Informal Reasoning Ocean Socioscientific Issues Reading and Interview Questions

(Participants read these prior to answering any questions)

Ocean as Context for OSSI

The ocean shapes our weather, links us to other nations, and is crucial to our national security. From the life-giving rain that nourishes crops and our bodies, to life-saving medicines; from the fish that come from the ocean floor, to the goods that are transported on the sea's surface--- the ocean plays a role in our life in some way everyday (NOAA, 1998). The ocean more than any other single ecosystem, has social and personal relevance to all persons. In the 21^{st} century we will look increasingly to the ocean to meet our everyday needs and future sustainability.

Appendix E (Continued)

Sea Turtle Reading (Case Study I)

(Participants read this prior to answering any questions)

Scenario: Protection of Endangered Marine Animals and Their Habitat

Sea turtles are survivors of the great age of dinosaurs and yet at this time are threatened with extinction. They live in nearly all the oceans of the world and leave the water only during nesting periods. It is during these nesting periods that turtles and their offspring are the most vulnerable.

As with most reptiles, turtles lay eggs. The eggs look somewhat like wet, pliable, table tennis balls. Female sea turtles dig deep holes on beaches with their rear flippers. They lay and bury their eggs in these holes. Sometimes the females make repeated nesting visits in one season. Mature female sea turtles may deposit several hundred eggs in one season. Once the eggs are buried, the female returns to the sea or seeks new nest sites. The eggs are left alone for nearly two months. If the eggs survive predation by raccoons, ghost crabs, foxes, dogs, and humans—the sea turtles hatch, dig their way upward through the sand, and promptly head toward the sea.

The hatchlings' journey across the beach is typically accompanied by predatory crabs, raccoons, and dogs, with gulls and frigate birds joining in. Once hatched, only about one to five percent of the turtles survive the first year. In the sea the turtles must mature for nearly a decade before returning to nesting sites as a natural part of their life cycle. Biologists are uncertain how long sea turtles reproduce and live. They are preyed upon by fish, sharks, killer whales, and humans.

The motives for human predation are based predominantly on products that are outlawed in many countries. Jewelry, leather, oil, and food are the primary uses. Turtle eggs are seen by some as a boost to longevity and vigor; tens of thousands of eggs are illegally harvested for vanity sales, Evidence suggests that a serious human threat to the turtles is the poaching of their eggs in their nesting sites.

There are other, human-caused factors. Dune buggies may break the eggs buried in the sand. More damaging, given the scope of the impact, is commercial and private construction (condominiums, private homes, hotels, etc.) on coastal sites. This may create a barricade that prevents the turtles from reaching their traditional nesting sites and eliminate many nest sites. Entanglement in discarded fishing gear and plastic waste cast into the oceans is a serious hazard, killing many sea turtles each year. Many turtles fall accidental victims to the nets of large fishing trawlers. Once caught in the nets, they drown. Efforts are being made to popularize special trawling devices that will prevent turtles form getting into the nets. Tone of the turtles' favorite foods is jellyfish. Many turtles mistake the human-produced litter of floating plastic bags for this food. The result is that their digestive tracts become blocked with the discarded plastic and they perish.

Six of the seven known sea turtle species are officially designated either endangered or threatened. The leathery of Leatherback, Olive Ridley, Kemp's Ridley, Hawksbill, Green, and Loggerhead are all either officially endangered or threatened. Only the Australian Flatback is not so designated. If laws are obeyed protecting the turtles from use for commercial and personal products, they are more likely to survive.

Appendix E (Continued)

Interview Questions for the Turtle Hurdle Activity

1. When you hear something about sea turtles or other marine animals threatened with extinction, do you have an immediate reaction or initial feelings regarding this issue?

2. Should society attempt to protect marine animals threatened with extinction such as sea turtles and the West Indian Manatee over the needs of people? Please explain your response and provide justification for your answer.

3. Do you think that decisions regarding protection of marine animals and their habitat (beaches, sea grasses, or mangroves) should involve moral principles (religious or others), ethical guidelines or values? If so, please describe those guidelines or values and how they influence the issue.

4. Imagine a situation in which a species of sea turtle (Kemp Ridley) only nests on three beaches in Florida. Two of the beach locations are protected by the state of Florida as State Parks. The third beach is in a county that is growing in human population and thus, demand for more homes has increased. Economically the county really needs the growth of new people and businesses. The beach area where Kemp Ridley sea turtles have nested for over 100 years is now being considered for development by building 500 new condos on the turtle nesting beach. Should sea turtle protection be used to stop humans from development (building homes or businesses) on beach front property? Please explain your response and provide justification for your answer.

5. How would you convince a friend or acquaintance of your position on this issue?

6. (*If necessary*) Is there anything else you might say to prove your point?

7. Can you think of an argument that could be made against the position that you have just described? How could someone support that argument?

8. If someone confronted you with that argument, what could you say in response? How would you defend your position against that argument?

9. (*If no counter-position is articulated*) If someone said __________, how would you respond? How would you defend your position against his/her argument?

10. (*If necessary*) Is there anything else you might say to prove that you are right?

Appendix E (Continued)

Fish Banks Reading (Case Study II)

(Participants read this prior to answering any questions)

Scenario: Marine Fisheries Management for Sustainability (Living Natural Resource)

Marine resources such as finned fishes (grouper, tuna, redfish, flounder, shrimp), shell fish (oyster, clams), natural gas, crude oil, sand, live rock and corals, algae, dolphins for captivity, sharks for biomedical/cancer research, horseshoe crabs for biomedical research, and rare minerals are just a few of the natural marine resources fished, harvested or mined by humans all around the world. In some countries like the United States fishing, harvesting and mining of ocean resources are managed and regulated by laws to control how much of a natural resource can be taken from the ocean. In many other countries laws or enforcements are in place to regulate the amounts of natural resources taken from the ocean. Many natural resources harvested from the ocean are used in your everyday activities, such as cosmetics (make-up), toothpaste, medicines (prescription drugs), supplements (fish oil capsules, shark cartilage, calcium from sea shells, kelp), and pet food (fish by products).

You played a decision making role-playing activity called Fish Banks during the Oceanography Camp for Girls. This activity simulated the management of a natural resource harvested from the ocean, fishes. Try to think about the Fish Banks activity and the decisions you made as a team to manage your fishing company.

Interview Questions for Fish Banks Activity

1. Should society attempt to manage natural resources such as fisheries for sustainability over needs/demands of people? Please explain your response and provide justification for your answer.

2. Do you think that decisions regarding protection and management of marine animals and their habitat (beaches, sea grasses, or mangroves) should involve moral principles (religious or others), ethical guidelines or values? If so, please describe those guidelines or values and how they influence the issue.

3. Should fish (for food) and other natural resources (crude oil for energy) in the ocean be harvested or drilled as much as needed to support the needs of humans? Why or why not? (Support your position)

4. How would you convince a friend or acquaintance of your position on this issue?

5. (*If necessary*) Is there anything else you might say to prove your point?

6. Can you think of an argument that could be made against the position that you have just described? How could someone support that argument?

7. If someone confronted you with that argument, what could you say in response? How would you defend your position against that argument?

8. (*If no counter-position is articulated*) If someone said __________, how would you respond? How would you defend your position against his/her argument?

9. (*If necessary*) Is there anything else you might say to prove that you are right?

Appendix E (Continued)

Ocean Pollution Reading (Case Study III)

(Participants read this prior to answering any questions)

Scenario: Marine Pollution and Human Impacts on the Ocean

Imagine a situation in which the canal near your home is covered with floating marine debris (plastic bottles, clear food storage bags, balloons, cigarette butts, and Styrofoam coolers). The number one source of marine debris is from human recreational activities. You notice an oil slick in the area where the marine debris has accumulated in the canal. Several days later you see many dead fish floating in the debris. Economically, cleaning marine debris from coastal and oceanic waters is expensive. Given the large number of waterways within the area, the local government can only clean canals on average of once every few years. You can choose to act by cleaning up the marine debris yourself or wait for the local officials to do so. How will you likely respond to the marine pollution in your neighborhood?

Should ocean protection policies include imposing littering fines on humans for disposing of trash in or near the ocean during recreational activities? Washing used oil down the storm drain? Please explain your response and provide justification for your answer.

Interview Questions for Ocean Pollution

1. What factors were influential in determining your position regarding protection of the ocean against human imposed marine pollution?

2. How would you convince a friend or acquaintance of your position on this issue?

3. (*If necessary*) Is there anything else you might say to prove your point?

4. Can you think of an argument that could be made against the position that you have just described? How could someone support that argument?

5. If someone confronted you with that argument, what could you say in response? How would you defend your position against that argument?

6. (*If no counter-position is articulated*) If someone said _________, how would you respond? How would you defend your position against his/her argument?

7. (*If necessary*) Is there anything else you might say to prove that you are right?

Appendix F: Matrix 1, Construct Map of Ocean Literacy

(Using Essential Principles of Ocean Sciences and KIDS Organizational Framework to Examine Conceptual Understanding, Attitudes, and Reasoning)

ESSENTIAL PRINCIPLES OF OCEAN SCIENCES (OCEAN LITERACY, OL 1-7)	**OL 1. there is one big ocean**	**OL 2. ocean & it's life shape Earth features**	**OL 3. ocean major influence weather & climate**	**OL 4. ocean makes Earth habit-able**	**OL 5. ocean support diversity of life & eco-systems**	**OL 6. ocean & humans in-extric-ably linked**	**OL 7. ocean is largely un-explored**
KNOWLEDGE (science content standards & literacy)							
1. <u>NSES Content Standards</u>							
a. physical science & chemistry	X	X	X	X	X	X	X
b. life science	X	X		X	X	X	X
c. earth & space science	X	X	X			X	X
d. science & technology			X			X	X
e. personal & social			X	X		X	X
f. history & NOS	X	X	X			X	X
g. science as inquiry							X
h. unifying concept & processes	X		X		X	X	
2. <u>Environmental Education (EE) Knowledge</u>							
a. basic understanding of environment	X	X	X	X	X	X	X
b. associated problems			X		X	X	

Appendix F (Continued)

ESSENTIAL PRINCIPLES OF OCEAN SCIENCES (OCEAN LITERACY, OL 1-7)	**OL 1. there is one big ocean**	**OL 2. ocean & it's life shape Earth features**	**OL 3. ocean major influence weather & climate**	**OL 4. ocean makes Earth habit-able**	**OL 5. ocean support diversity of life & eco-systems**	**OL 6. ocean & humans in-extric-ably linked**	**OL 7. ocean largely un-explored**
IMPACT (expected change in behaviors)							
1. Environmental Education (EE) Participation							
a. opportunity to be actively involved toward environmental problems			X		X	X	
b. opportunity to be actively involved ocean stewardship					X	X	
2. Environmental Education (EE) Awareness							
a. awareness and sensitivity to environment	X	X	X	X	X	X	X
b. awareness and sensitivity to environment's allied problems			X		X	X	
3. Likelihood to Act						X	

Appendix F (Continued)

ESSENTIAL PRINCIPLES OF OCEAN SCIENCES (OCEAN LITERACY, OL 1-7)	OL 1. there is one big ocean	OL 2. ocean & it's life shape Earth fea-tures	OL 3. ocean major influence weather & climate	OL 4. ocean makes Earth habit-able	OL 5. ocean support diversit y life & ecosyste ms	OL 6. ocean & human s in-extric-ably linked	OL 7. ocean largely un-explore d
DISPOSITIONS (moral development; environmental attitudes and environmental morality)							
1. <u>Moral development (Rest)</u>							
a. Sensitivity (caring)	X	X	X	X	X	X	X
b. Reason (judgment)				X	X	X	
c. Commitment (motivation)				X	X	X	
d. Courage (character)				X	X	X	
2. <u>Environmental Education (EE) Attitudes</u>							
a. set of values and feelings of environmental concern	X		X	X	X	X	
b. motivation for actively participating in improvement and protection	X		X	X	X	X	
3. <u>Environmental Morality</u>							
a. biocentric	X	X	X	X	X	X	X
b. anthropocentric						X	
c. egocentric						X	

Appendix F (Continued)

ESSENTIAL PRINCIPLES OF OCEAN SCIENCES (OCEAN LITERACY, OL 1-7)	**OL 1. there is one big ocean**	**OL 2. ocean & it's life shape Earth features**	**OL 3. ocean major influence weather & climate**	**OL 4. ocean makes Earth habit-able**	**OL 5. ocean support diversity life & eco-systems**	**OL 6. ocean & humans in-extric-ably linked**	**OL 7. ocean largely un-explored**
SKILLS (process, reason, affect)							
1. EE Skills							
a. identify envir. problems	X	X	X	X	X	X	X
b. solving envir. problems	X	X	X	X	X	X	
2. Reasoning Patterns							
a. rationalistic	X	X	X	X	X	X	X
b. emotive	X	X	X	X	X	X	X
c. intuitive	X	X	X	X	X	X	X
3. Stewardship Actions							
a. coastal cleanup	X		X			X	
b. habitat restoration	X	X		X	X	X	
c. catch and release fishing	X	X		X	X	X	
d. seabird counts	X	X		X	X	X	
e. contains used oil	X		X			X	
f. purchased only sustainable seafood on watch list	X	X			X	X	X
g. bagged trash recreation	X					X	
h. bagged lawn clippings	X					X	
i. sea turtle monitoring	X			X		X	
j. served on environmental group, team, council, club	X			X		X	X
k. told friend/family how to help the ocean	X					X	X

Appendix G: Matrix 2, Items Matrix for Ocean Literacy Using

Essential Principles of Ocean Sciences

ESSENTIAL PRINCIPLES OF OCEAN SCIENCES (OCEAN LITERACY, OL 1-7)	**OL 1. there is one big ocean**	**OL 2. ocean & it's life shape Earth features**	**OL 3. ocean major influence weather & climate**	**OL 4. ocean makes Earth habit-able**	**OL 5. ocean support diversit y of life & eco-systems**	**OL 6. ocean & humans inextric ably linked**	**OL 7. ocean is largely un-explored**
KNOWLEDGE (science content & literacy)							
1. Survey of Ocean Literacy and Engagement							
2. Survey of Ocean Stewardship							
IMPACT (expected change in behaviors)							
1. Turtle Hurdle, Fish Banks, Coastal Clean-up (participation) 2. OSSI Written & Verbal Responses (awareness) 3. SOEM Items (likelihood to act)							
DISPOSITIONS							
1. SOEM Items Responses (moral development) 2. SOS Items (environmental attitudes) 3. SOEM Responses (environmental morality)							
SKILLS (process, reason, affect)							
1. OSSI Responses (position about enviro issue) 2. OSSI Responses (reasoning patterns) 3. SOEM items (stewardship actions)							

Appendix H: A Rubric to Analyze Types of Moral Development

and Environmental Reasoning

Component	**Definition**	**Cognitive & Affective Processes**	**SOEM Metric for present study**
moral sensitivity	Requires the individual to be able to interpret the situation by role taking how various actions may affect the parties involved and thinking in terms of cause and effect	Grounded in the research on empathy in which an individual, even at a very early age is able to recognize distress in others as a primary affective response (Hoffman, 1981)	*Moral environmental reasoning:* 9-items/scenario; 3 anthropocentric items (welfare, aesthetic, justice); 3 biocentric items (intrinsic, justice, harmony); 3 egocentric items (aesthetic, justice, personal); each item measured on a 5-point Likert scale
moral judgment	Involves the individual's ability to judge which action is most justifiable from a moral perspective	Concepts of justice, fairness, and care	*Deontological judgment*: 1-item/scenario; yes or no response to commit a specific act that has a potentially negative environmental consequence. *Responsibility judgment*; 1-item/scenario; asked if they would or would not engage in above behavior.
moral motivation	The degree of commitment an individual has in taking the moral course of action; competing non-moral values may play a role in whether the individual is able to redirect these alternatives and persist in the moral course	Entails the imagining of a desired goal and implies both cognition (the imagining) and affect (the desiring)	*Moral motivation:* 1-item/scenario; asked to select the moral reason they most agree with in guiding their decision to not act in an environmentally harmful way.
moral character	Involves the execution of a particular action; requires an individual to persevere and overcome the temptation of competing values and goals to achieve the moral task	Manipulation of self-regulatory processes has suggested that how an individual feels while in the course of helping someone else may influence the level of persistence and effort in that action (Rest, 1986)	*Moral justification:* 1-item/scenario; contingent upon specified societal rules or conventions *Likelihood to act:* 1-item/scenario; asked how likely they are to act in a morally sensitive way towards the environment based upon the moral motivation reasoning type selected.

(Adapted from the four-component model of Rest and colleagues (1986, 2000), which describes moral behavior based on four psychological processes)

Appendix I: Output Data for SOLE Item Analysis

(column labeled measure provides difficulty indices)

INPUT: 105 Persons 57 Items MEASURED: 105 Persons 57 Items 2 CATS 3.66.0

Person: REAL SEP.: 2.82 REL.: .89 ... Item: REAL SEP.: 4.15 REL.: .95

Item STATISTICS: ENTRY ORDER

ENTRY NUMBER	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PT-MEASURE CORR.	PT-MEASURE EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
1	93	104	27.78	3.39	1.25	1.1	1.71	1.6	.06	.32	88.5	89.4	I0001
2	66	105	46.68	2.24	.92	-.8	.86	-1.1	.51	.43	70.5	71.7	I0002
3	46	102	55.35	2.18	1.32	3.9	1.51	3.7	.08	.40	51.0	66.5	I0003
4	75	104	41.54	2.42	.91	-.7	.79	-1.2	.52	.42	75.0	77.1	I0004
5	59	103	49.66	2.20	1.16	1.8	1.18	1.6	.27	.42	63.1	69.5	I0005
6	51	104	53.63	2.16	1.01	.1	1.08	.7	.39	.41	67.3	67.2	I0006
7	14	105	74.52	2.98	1.01	.1	.99	.1	.24	.25	86.7	86.6	I0007
8	46	97	54.17	2.23	1.10	1.3	1.09	.8	.32	.41	60.8	66.9	I0008
9	22	103	68.20	2.55	1.06	.5	1.95	3.0	.16	.31	78.6	79.0	I0009
10	76	105	41.32	2.41	.98	-.1	.92	-.4	.44	.42	77.1	77.2	I0010
11	57	104	50.72	2.18	1.07	.8	1.08	.8	.36	.42	65.4	69.0	I0011
12	37	104	60.24	2.22	1.29	3.3	1.23	1.5	.13	.37	55.8	68.8	I0012
13	62	100	47.31	2.28	1.05	.5	1.11	.9	.38	.43	69.0	71.5	I0013
14	41	105	58.41	2.17	1.13	1.7	1.29	2.0	.25	.39	58.1	67.5	I0014
15	80	105	38.89	2.53	.78	-1.7	.77	-1.1	.59	.41	85.7	79.5	I0015
16	76	104	40.89	2.45	.97	-.2	.91	-.4	.45	.42	79.8	77.7	I0016
17	63	105	48.16	2.21	.90	-1.1	.84	-1.3	.53	.43	73.3	70.7	I0017
18	76	105	41.32	2.41	.84	-1.4	.83	-.9	.55	.42	84.8	77.2	I0018
19	79	105	39.51	2.50	.70	-2.5	.62	-2.2	.67	.41	89.5	78.9	I0019
20	90	104	30.49	3.10	.91	-.4	.61	-1.2	.47	.35	86.5	86.7	I0020
21	65	102	45.93	2.28	.75	-2.7	.69	-2.6	.66	.43	84.3	72.1	I0021
22	80	104	38.40	2.57	.81	-1.4	.64	-1.8	.60	.41	82.7	79.9	I0022
23	32	103	62.53	2.29	1.07	.8	1.25	1.4	.27	.36	71.8	71.6	I0023
24	30	102	63.65	2.33	1.22	2.2	2.09	4.5	.03	.35	68.6	72.6	I0024
25	15	103	73.44	2.91	1.13	.7	2.88	3.8	-.01	.26	84.5	85.4	I0025
26	56	104	51.26	2.17	1.18	2.1	1.17	1.5	.27	.42	57.7	68.7	I0026
27	67	104	45.88	2.27	1.08	.8	1.06	.5	.37	.43	67.3	72.6	I0027
28	49	103	54.29	2.17	1.08	1.1	1.05	.5	.34	.41	62.1	67.1	I0028
29	37	102	59.63	2.23	1.14	1.6	1.32	2.0	.22	.38	68.6	68.4	I0029
30	39	104	59.23	2.20	1.03	.4	1.03	.2	.35	.38	67.3	68.0	I0030
31	31	102	62.74	2.31	1.20	2.0	1.50	2.4	.13	.36	69.6	72.1	I0031
32	35	103	60.99	2.25	1.33	3.5	1.75	3.8	.02	.37	59.2	69.8	I0032
33	63	102	47.45	2.25	.74	-2.9	.68	-2.9	.66	.42	82.4	71.1	I0033
34	63	101	47.05	2.28	.71	-3.1	.64	-3.1	.69	.43	82.2	71.9	I0034
35	66	103	46.26	2.27	1.00	.0	.97	-.2	.44	.43	68.0	72.2	I0035
36	84	103	34.88	2.78	.84	-1.0	.64	-1.5	.55	.39	84.5	82.8	I0036
37	84	104	35.61	2.73	.63	-2.6	.42	-2.9	.73	.40	88.5	82.3	I0037
38	72	101	41.65	2.43	1.02	.2	.95	-.2	.41	.42	72.3	76.5	I0038
39	51	104	53.60	2.16	1.17	2.1	1.35	2.8	.24	.41	55.8	67.3	I0039
40	54	104	52.20	2.16	1.01	.2	.98	-.1	.42	.42	66.3	68.1	I0040
41	54	104	52.20	2.16	1.08	1.1	1.13	1.2	.34	.42	66.3	68.1	I0041
42	15	101	73.16	2.92	.97	-.1	1.34	1.0	.26	.27	86.1	85.1	I0042
43	79	104	39.05	2.53	.82	-1.4	.68	-1.7	.59	.41	83.7	79.4	I0043
44	68	102	44.58	2.33	.67	-3.4	.59	-3.3	.73	.43	86.3	73.8	I0044
45	35	101	60.61	2.26	.94	-.6	.86	-.8	.44	.38	67.3	69.5	I0045
46	82	102	36.02	2.73	.81	-1.2	.63	-1.6	.58	.40	85.3	82.1	I0046
47	22	100	67.91	2.56	1.02	.2	1.50	1.8	.24	.31	78.0	78.4	I0047
48	59	101	49.38	2.23	1.25	2.6	1.33	2.6	.19	.42	59.4	70.0	I0048
49	61	103	48.83	2.21	1.29	3.0	1.37	2.9	.14	.42	61.2	70.2	I0049
50	82	104	37.05	2.64	.75	-1.8	.52	-2.4	.65	.40	85.6	81.1	I0050
51	65	104	46.90	2.25	.85	-1.5	.83	-1.4	.56	.43	78.8	71.7	I0051
52	73	103	42.31	2.41	.71	-2.6	.60	-2.7	.69	.43	84.5	76.4	I0052
53	42	104	57.80	2.18	.99	-.2	.94	-.4	.41	.39	66.3	67.1	I0053
54	59	102	49.38	2.22	.88	-1.3	.82	-1.6	.55	.43	73.5	70.3	I0054
55	70	103	44.04	2.34	.95	-.4	.89	-.7	.48	.43	74.8	74.6	I0055
56	56	103	50.93	2.19	.93	-.8	.90	-.9	.49	.42	72.8	68.9	I0056
57	69	103	44.39	2.33	.79	-2.0	.74	-1.9	.62	.43	82.5	73.9	I0057
MEAN	57.4	103.1	50.00	2.39	.99	.0	1.06	.1			73.7	74.0	
S.D.	20.0	1.5	10.58	.26	.18	1.7	.43	2.0			10.3	6.0	

Appendix J: Output Data for SOS Item Analysis

(column labeled measure provides difficulty indices)

INPUT: 119 Persons 44 Items MEASURED: 119 Persons 44 Items 5 CATS 3.66.0

Person: REAL SEP.: 2.68 REL.: .88 ... Item: REAL SEP.: 4.69 REL.: .96

Item STATISTICS: ENTRY ORDER

ENTRY	TOTAL			MODEL	INFIT		OUTFIT		PT-MEASURE		EXACT MATCH		
NUMBER	SCORE	COUNT	MEASURE	S.E.	MNSQ	ZSTD	MNSQ	ZSTD	CORR.	EXP.	OBS%	EXP%	Item
1	427	119	51.75	.95	1.04	.4	1.03	.3	.50	.45	41.2	38.1	I0001
2	479	118	45.98	1.09	1.05	.4	1.08	.6	.23	.39	49.2	42.9	I0002
3	271	119	64.78	.94	1.27	2.2	1.27	2.1	.33	.48	31.9	33.9	I0003
4	456	119	48.97	1.01	1.03	.3	.98	-.1	.54	.42	47.1	40.4	I0004
5	473	119	47.16	1.05	1.05	.4	1.09	.7	.39	.41	42.0	41.5	I0005
6	353	119	57.98	.90	.80	-1.9	.79	-1.9	.53	.49	36.1	35.2	I0006
7	441	119	50.45	.98	1.14	1.2	1.15	1.2	.48	.44	40.3	39.2	I0007
8	402	119	53.95	.92	.84	-1.4	.84	-1.4	.41	.47	44.5	36.5	I0008
9	434	119	51.11	.96	.73	-2.3	.76	-2.1	.46	.44	55.5	39.0	I0009
10	327	118	59.78	.90	1.03	.3	1.07	.7	.25	.49	29.7	34.6	I0010
11	454	119	49.17	1.00	.80	-1.7	.77	-1.9	.42	.43	47.9	39.8	I0011
12	490	119	45.17	1.11	1.24	1.6	1.16	1.1	.52	.39	39.5	43.9	I0012
13	428	119	51.66	.95	.79	-1.9	.79	-1.8	.53	.45	47.1	38.4	I0013
14	455	119	49.07	1.01	.62	-3.4	.61	-3.4	.65	.43	53.8	40.2	I0014
15	500	119	43.89	1.16	1.09	.7	1.08	.6	.56	.37	46.2	45.1	I0015
16	458	119	48.76	1.01	.74	-2.2	.75	-2.0	.61	.42	52.1	40.4	I0016
17	479	119	46.48	1.07	.56	-3.9	.56	-3.8	.64	.40	52.9	42.4	I0017
18	446	119	49.96	.99	.79	-1.8	.77	-1.9	.53	.43	44.5	39.3	I0018
19	460	119	48.56	1.02	.73	-2.2	.74	-2.2	.47	.42	52.9	40.8	I0019
20	372	119	56.44	.90	.97	-.3	.99	-.1	.51	.48	35.3	35.5	I0020
21	460	119	48.56	1.02	1.47	3.3	1.54	3.6	.41	.42	30.3	40.8	I0021
22	500	119	43.89	1.16	.94	-.4	.89	-.8	.58	.37	52.1	45.1	I0022
23	524	119	40.30	1.30	1.23	1.4	1.37	2.2	.41	.33	56.3	50.2	I0023
24	522	119	40.63	1.28	1.31	1.9	1.08	.6	.54	.34	47.1	49.7	I0024
25	517	118	40.70	1.29	1.19	1.2	.97	-.1	.53	.34	52.5	49.1	

													I0025
26	427	119	51.75	.95	1.14	1.2	1.20	1.5	.43	.45	35.3	38.1	I0026
27	459	119	48.66	1.02	.92	-.6	.88	-.9	.59	.42	45.4	40.8	I0027
28	478	119	46.60	1.07	.82	-1.3	.78	-1.7	.61	.40	46.2	41.9	I0028
29	443	118	49.97	.99	.57	-4.0	.62	-3.4	.54	.43	51.7	39.4	I0029
30	313	119	61.21	.90	1.73	5.4	1.87	6.2	-.25	.49	25.2	34.0	I0030
31	427	119	51.75	.95	.71	-2.6	.70	-2.6	.69	.45	47.1	38.1	I0031
32	458	119	48.76	1.01	.88	-.9	.92	-.6	.33	.42	45.4	40.4	I0032
33	339	114	57.87	.92	1.22	1.8	1.43	3.3	-.15	.49	36.0	35.2	I0033
34	485	119	45.78	1.09	1.04	.3	.96	-.3	.48	.39	44.5	43.5	I0034
35	409	118	53.04	.94	1.54	3.9	1.85	5.6	.08	.46	30.5	37.3	I0035
36	517	119	41.44	1.25	1.49	2.9	1.24	1.5	.53	.34	50.4	48.5	I0036
37	428	119	51.66	.95	1.32	2.4	1.39	2.8	.29	.45	37.0	38.4	I0037
38	465	117	47.17	1.06	.63	-3.1	.66	-2.8	.51	.41	51.3	41.5	I0038
39	415	116	51.79	.96	1.14	1.1	1.12	1.0	.49	.45	37.9	38.1	I0039
40	394	119	54.62	.91	1.22	1.8	1.22	1.8	.29	.47	27.7	35.9	I0040
41	431	118	51.05	.97	1.69	4.7	1.86	5.5	.36	.44	22.9	39.1	I0041
42	449	119	49.67	.99	.99	.0	1.04	.3	.45	.43	42.9	39.5	I0042
43	410	118	52.94	.94	1.12	1.0	1.19	1.5	.27	.46	41.5	37.3	I0043
44	446	117	49.12	1.01	1.08	.7	1.02	.2	.48	.42	43.6	40.2	I0044
MEAN	439.1	118.6	50.00	1.02	1.04	.1	1.05	.2			43.0	40.2	
S.D.	55.0	1.0	5.24	.10	.28	2.2	.32	2.3			8.5	4.0	

Appendix K: Output Data for SOEM Item Analysis

(column labeled measure provides difficulty indices)

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TABLE 10.1 SOME Greely                           ZOU154WS.TXT Oct 26 1:15 2008
INPUT: 95 Persons 56 Items MEASURED: 95 Persons 56 Items 5 CATS       3.66.0
--------------------------------------------------------------------------------
Person: REAL SEP.: 3.94 REL.: .94 ... Item: REAL SEP.: 3.34 REL.: .92
         Item STATISTICS:  MISFIT ORDER
--------------------------------------------------------------------------------
|ENTRY   TOTAL                   MODEL|   INFIT  |  OUTFIT  |PT-MEASURE |EXACT MATCH|
|NUMBER  SCORE  COUNT  MEASURE  S.E. |MNSQ  ZSTD|MNSQ  ZSTD|CORR.  EXP.| OBS%  EXP%| Item

|    39    242     93   45.79     .98|1.06    .5|1.25   1.3|T .65   .68| 31.2  34.9| 3AR1Canthro3
|    18    240     92   45.70     .99| .79  -1.4| .98    .0|V .66   .69| 41.3  35.0| 2BR1Abio2
|     6    257     94   44.52     .97| .88   -.8| .97   -.1|W .65   .70| 35.1  33.7| 1BR1Bbio1
|    52    216     91   47.68    1.01| .72  -2.0| .88   -.6|X .74   .66| 39.6  37.3| 4ER1Bego4
|    32    219     92   47.76    1.00| .84  -1.1| .71  -1.6|Y .76   .66| 33.7  37.1| 3BR1Abio3
|    36    233     93   46.65     .98| .77  -1.6| .68  -1.8|Z .71   .67| 41.9  36.1| 3BR1Cbio3
|        BETTER FITTING OMITTED      +----------+----------+           |           |
|    38    239     93   46.07     .98| .68  -2.4| .74  -1.5|  .74   .68| 40.9  35.7| 3ER1Bego3
|     4    230     95   47.27     .98| .68  -2.4| .72  -1.6|  .73   .66| 45.3  36.5| 1BR1Abio1
|     8    261     94   44.15     .97| .64  -2.7| .71  -1.7|  .71   .70| 45.7  32.5| 1BR1Cbio1
|    25    239     92   45.80     .99| .71  -2.0| .66  -2.0|z .75   .69| 37.0  35.0| 2AR1Canthro2
|    48    211     91   48.19    1.01| .64  -2.6| .55  -2.7|y .84   .65| 40.7  37.7| 4BR1Bbio4
|    35    211     92   48.67    1.01| .63  -2.9| .54  -2.8|x .80   .64| 45.7  38.7| 3AR1Banthro3
|    22    233     92   46.38     .99| .61  -2.9| .58  -2.6|w .78   .68| 45.7  36.2| 2BR1Cbio2
|    37    226     93   47.34     .99| .60  -3.0| .54  -2.8|v .83   .66| 36.6  36.6| 3ER1Aego3
|    19    208     92   48.89    1.01| .60  -3.1| .53  -2.8|u .82   .64| 46.7  39.9| 2AR1Aanthro2
|     7    227     93   47.26     .99| .60  -3.1| .54  -2.9|t .83   .66| 34.4  36.2| 1AR1Banthro1
|     9    229     92   46.88     .99| .60  -3.1| .53  -3.0|s .83   .67| 38.0  36.6| 1ER1Aego1
|    10    253     93   44.74     .97| .60  -3.1| .58  -2.7|r .79   .70| 39.8  33.9| 1ER1Bego1
|    50    214     91   47.88    1.01| .60  -3.1| .53  -2.9|q .81   .65| 40.7  37.3| 4BR1Cbio4
|    40    226     93   47.34     .99| .59  -3.2| .51  -3.1|p .83   .66| 47.3  36.6| 3ER1Cego3
|     5    218     94   48.28    1.00| .58  -3.3| .53  -2.9|o .81   .65| 44.7  37.7| 1AR1Aanthro1
|    53    214     91   47.88    1.01| .58  -3.2| .51  -3.0|n .83   .65| 41.8  37.3| 4AR1Canthro4
|    51    218     91   47.48    1.01| .58  -3.2| .51  -3.1|m .84   .66| 39.6  37.0| 4ER1Aego4
|    47    215     91   47.78    1.01| .58  -3.3| .53  -2.9|l .80   .66| 46.2  37.3| 4AR1Aanthro4
|    24    215     92   48.18    1.01| .56  -3.4| .52  -2.9|k .83   .65| 41.3  37.5| 2ER1Bego2
|    33    227     93   47.24     .99| .56  -3.4| .49  -3.2|j .83   .66| 47.3  36.6| 3AR1Aanthro3
|    12    229     93   47.04     .99| .56  -3.4| .49  -3.3|i .83   .67| 46.2  36.6| 1ER1Cego1
|    49    210     90   48.16    1.01| .56  -3.4| .55  -2.7|h .77   .65| 44.4  37.3| 4AR1Banthro4
|    26    222     91   47.25    1.00| .55  -3.5| .49  -3.2|g .83   .67| 40.7  36.8| 2ER1Cego2
|    54    224     91   46.87    1.00| .54  -3.5| .55  -2.8|f .83   .67| 49.5  36.9| 4ER1Cego4
|    11    231     93   46.85     .98| .54  -3.6| .50  -3.2|e .84   .67| 37.6  36.5| 1AR1Canthro1
|    23    224     92   47.27    1.00| .53  -3.7| .54  -2.9|d .79   .67| 45.7  36.8| 2ER1Aego2
|    21    218     91   47.72    1.00| .51  -3.9| .46  -3.4|c .84   .66| 47.3  37.2| 2AR1Banthro2
|    20    219     91   47.50    1.01| .51  -3.9| .48  -3.3|b .83   .67| 45.1  37.0| 2BR1Bbio2
|    46    211     91   48.19    1.01| .51  -3.9| .46  -3.3|a .85   .65| 40.7  37.7| 4BR1Abio4
|------------------------------------+----------+----------+-----------+-----------+------------
| MEAN   201.3   92.0   50.00    1.09| .99   -.9|1.19   -.2|           | 42.8  43.6|
| S.D.    36.8    1.4    4.44     .19| .61   3.2| .92   3.2|           |  7.6  10.4|
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About The Author

Teresa M. Greely received a Bachelor's in Natural Sciences from New College in Sarasota, FL in 1985, and a Master's in Marine Science from USF in St. Petersburg, FL in 1994. Her Master's research addressed the age and growth of lantern fish in the Southern Ocean. As a science mentor for the Oceanography Camp for Girls she discovered her passion for teaching science. In 1995 Dr. Greely joined USF's College of Marine Science as the Coordinator of Education and Outreach. With a desire to make ocean sciences more accessible and engaging for science teachers, and to promote a more ocean literate citizenry, Dr. Greely entered the Ph.D. program. Dr. Greely has taught numerous science and education courses, authored over twenty publications, written two book chapters, and made over one hundred presentations at national and international meetings. Dr. Greely will continue in her faculty position with USF's College of Marine Science.