

## RESEARCH REPORT

# High School Marine Science and Scientific Literacy: The promise of an integrated science course

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This descriptive study provides a comparison of existing high school marine science curricula and instructional practices used by nine teachers across seven schools districts in Florida and their students' level of scientific literacy, as defined by the national science standards and benchmarks. To measure understandings of science concepts and Science–Technology–Society-related issues, students were assessed at the beginning and end of their course using three instruments developed by the researcher. Paired-sample *t* tests revealed a significant improvement ( $p < .001$ ,  $t = 4.42$ ,  $n = 399$ , Cohen's  $d = 0.22$ ) from 39.5% on the pre science assessment to 42.9% on the post science assessment. Students of teachers who integrated biological, chemical, geological, and physical characteristics of the oceans performed higher on the content assessment than other students. Based on a Likert scale survey, students' understandings of Science–Technology–Society-related issues did not significantly change, although post-instruction qualitative responses were reflective of the national science standards and benchmarks. Results indicate that marine science can be used as a model for teaching integrated science if curricula and instructional practices are aligned to national standards.

## Introduction

As we begin the twenty-first century, many efforts are underway to change and reform science education and to improve scientific literacy for all Americans. Scientific literacy has become the term expressing the multiple purposes of science education and is most thoroughly defined by the *National Science Education Standards (NSES)* (National Research Council [NRC], 1996) and the *Benchmarks for Science Literacy (Benchmarks)* (American Association for the Advancement of Science, 1993). Scientific literacy is defined as the knowledge and understanding of scientific concepts and processes required for personal decision-making, participation in civic

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and cultural affairs, and economic productivity. Being scientifically literate implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed (NRC, 1996). Based on this definition, high school students who complete earth and space science, biology, chemistry, and physics courses are most likely to become scientifically literate adults by learning the content and processes outlined in the *NSES* and *Benchmarks*. However, the majority of U.S. students do not complete this sequence, and 12th-grade students are performing worse in science relative to eighth-grade students on the most significant national and international assessments, the National Assessment of Educational Progress and Third International Mathematics and Science Studies.

Integrated science courses—in which earth and space science, biology, chemistry, and physics concepts are taught within a common context—have been proposed as one possible solution. Many science educators propose that integrating the science curriculum will help students learn most of the standards and benchmarks, and reach higher levels of scientific literacy, while also enabling them to have a more meaningful learning experience (Horton, 1981; Hurd, 1997; McComas & Wang, 1998). For the past three decades, another integrated instructional approach, known as Science–Technology–Society (STS), has been proposed as a way of improving science education and providing direction for achieving scientific and technological literacy through the investigation of real-world issues. Many problems facing society involve human values, social organization, environmental concerns, economic resources, political decisions, and several other factors. These problems can only be solved by the application of scientific knowledge, technical expertise, social understanding, and human compassion (Kranzberg, 1991). STS-related themes are also incorporated into the *NSES* and *Benchmarks*, and provide a framework for inventing new school science curricula relevant to the life of every student (Hurd, 1998).

Marine science is one course of study that can address all of the NRC science standards: Unifying Concepts and Processes in Science, Science as Inquiry, Physical Science, Life Science, Earth and Space Science, Science and Technology, Science in Personal and Social Perspectives, and History and Nature of Science (Watkins, 1997). Even though marine science courses have been in existence for decades and are models of integrated science courses that interest many students, they have not received national recognition for the role they could play in reforming science education. Nor has significant educational research been conducted on marine science teaching and learning. Hundreds of articles can be found on curriculum materials, programs, government reports, or career guides. A few articles provide an analysis of the status of marine science education; that is, the recent review of the state of marine education, published by the National Oceanic and Atmospheric Administration (1998). Four studies were identified that address students' marine science knowledge and attitudes toward the ocean at various grade levels (Brody & Koch, 1990; Fortner & Mayer, 1983, 1991; Fortner & Teates, 1980). While no educational research was found on the relationship between taking of a marine science course and high school students' understanding of general science concepts or STS-related issues, a

preliminary report to President George W. Bush recommends the development of a framework for evaluating and assessing the effectiveness of ocean-related education programs, K-12 professional development programs, and best practices for incorporating ocean-based examples into K-12 education and public education programs (U.S. Commission on Ocean Policy, 2004).

This study begins to address the recommendation called for by the U.S. Commission on Ocean Policy, and, unlike prior studies, was guided by the *NSES* and *Benchmarks*, which define science concepts and understandings of STS-related issues that students should master by the end of specific grade levels. These standards and benchmarks were used as a framework for defining scientific literacy. Through quantitative and qualitative data collection and analyses, this study provides a baseline description of existing curricula and instructional practices used by a sample of high school teachers in marine science courses and their students' pre and post understandings of general science concepts and STS-related issues.

### **Conceptual Framework for High School Marine Education**

Marine science is one area of study that meets the requirements for a broadly inclusive integrated science course that can offer a common theme or context for an entire academic year. The rationale is based on two interacting conceptual frameworks—the integrated nature of marine science promoted through an STS approach and constructivist approaches to teaching and learning—that can enhance student outcomes.

The study of marine science phenomena often involves researchers from different fields who work together to solve systemic problems. For example, the oceans and atmosphere are interdependent and act together as a complex system that regulates the global climate of Earth while nutrients and materials are constantly being recycled throughout the oceans and crust. Capra (1982) describes systems as dynamic, integrated wholes whose properties cannot be reduced to those of smaller units. Instead of concentrating on basic building blocks, the systems approach emphasizes basic principles of organization and views the world in terms of relationships and integration.

A marine science context also provides coherence, which is a property necessary for a good integrated high school science course. According to Rutherford (2000, p. 25), "A coherent course tells a story—or, more likely, many interconnected stories within a grand story—about some important aspects of the natural world and science." Themes run through the entire course, illustrating what is common among what otherwise may appear to be separate units. Integrated science courses need coherence to help students reach higher levels of scientific literacy, and the context of the oceans can naturally provide coherence.

The STS approach to teaching and learning begins with real-world problems that incorporate science and technology components from students' perspectives. (See Pedretti, 1999, for a review of empirical studies on STS implementation.) The National Science Teachers Association (1993) characterizes good programs as

ones that are learner-centered and that have built-in opportunities for students to extend their knowledge beyond the classroom to their local environments. While actively investigating, analyzing, and applying concepts and processes to real situations, students are encouraged to enjoy science and to become aware of possible careers in science and technology (Yager & Roy, 1993). STS courses should also help empower students so that, as future citizens, they realize they have the power to make changes and the responsibility to do so. The oceans provide one context for incorporating STS curriculum and instruction—our oceans affect almost every aspect of life on Earth. The National Oceanic and Atmospheric Administration (1998) estimates that one out of six jobs in the United States is marine related and that 75% of Americans will live in coastal areas by 2025. Ocean's living resources also provide food, recreational experiences, and new medicines to improve health and cure diseases, as well as oil and natural gas obtained from the continental shelf.

The second conceptual framework that supports a rationale for offering high school marine science courses is related to cognitive development theories. The integrated nature of marine science as a discipline makes this course appropriate for implementing science education reform through constructivist approaches to teaching and learning as called for in the *NSES*. Educational theories, based on the writings of Dewey (1938), the empirical work of Piaget (1975) and his followers, and the socially situated theories of learning of Vygotsky (1962, 1978) and others, emphasize the active participation of the student in learning. This core axiom of the constructivist position—that knowledge is not transmitted directly from one knower to another, but is actively built up by the learner—is shared by a wide range of research traditions relating to science education (Driver, Asoko, Leach, Mortimer, & Scott, 1994). Another common agreement among the constructivists is the importance of prior knowledge. Bruner (1960, 1966) described the role of prior experience in learning and proposed that curricula be organized in a spiral manner so that students continually build upon what they already have learned. Marine science offers a curriculum that is built on prior scientific knowledge. Furthermore, Vygotsky (1962, 1978) describes the “zone of proximal development,” which can be used to explain how marine science provides a means for students to construct new knowledge based on their previous science background.

## **Methods**

### *Research Context and Participants*

Nine secondary level teachers located in seven different counties throughout Florida participated in the study. Purposeful sampling was used in selecting the teachers and schools to represent a diverse range of teacher backgrounds and student populations and to increase generalizability of the findings. Teachers' experience varied, with 15 years as the average length of teaching experience. All

of the teachers had an undergraduate education in a biology-related field. Two of the nine teachers had a bachelor's degree in marine biology and two had a master's degree in science education. One of the teachers, who had both an undergraduate degree in marine biology and a master's degree in science education, was also pursuing a doctorate in science education. Of 399 students, approximately 75% were in the 11th or 12th grade and 37% were minorities. All of the schools counted marine science as a science credit for graduation; however, students' prior background in science varied, with 75% having a biology course, 51% earth science, 43% physical science, 31% chemistry, 22% Integrated Science I, 19% Integrated Science II, and 8% physics.

### *Instruments*

Three instruments were developed to measure students' knowledge of general science concepts, self-perceptions of their understandings of STS-related issues, and self-perceptions on marine STS-related issues and the teaching and learning in their marine science class. All of the instruments were constructed by the researcher for this study. (See Lambert, 2001, for complete instruments and a detailed description of their development.)

*Science Assessment in Literacy (SAIL)*. This instrument was developed to assess students' knowledge of physical science, life science, earth and space science, science as inquiry, science in personal and social perspectives, the history and nature of science, and unifying concepts and processes (see Appendix for sample items). Over 90% of the 80 questions were directly related to specific national science standards and/or benchmarks as they were constructed. Most items were constructed to assess students' understanding at the comprehension, application, or analysis level, according to Bloom's Taxonomy (Bloom, 1956). While this was a multiple-choice test, careful consideration was given to the construction of four item responses for each question. Effective distractor responses were included as common student ideas or misconceptions (Sadler, 1998).

*My Attitudes toward Science, Technology, and Society (MASTS)*. This instrument is a Likert-scale survey developed to assess students' self-perceptions of their understandings of STS-related issues at the beginning and end of their participation in a marine science course. MASTS items were constructed to address the STS literature and the STS-related standards and benchmarks. Items are grouped into sections to assess students' beliefs about science and technology, the relevance of science, the difficulty of science, and understandings of scientific worldviews and science as an enterprise (see Appendix for a list of sample items). MASTS provides a standards-based assessment of the degree to which an integrated subject such as marine science enables students to internalize the values and understandings of the role of science and technology in society.

*Students' Worldviews and Interest in Marine Science (SWIMS)*. Student responses to this instrument provided the majority of qualitative data for addressing all three research questions (see Appendix for a list of sample items). Students were asked to describe the teaching and learning environment in their marine science class based on course curricula and instructional practices. They were asked how they thought the curricula and instructional practices affected their knowledge of science and understandings of marine STS-related issues.

*Reliability and validity of instruments.* Validity was built into SAIL, MASTS, and SWIMS from the outset of the instrument development. The items on SAIL were correlated with the American Association for the Advancement of Science benchmarks and NRC standards. A high school teacher, outside the sample in the study with over 20 years of experience teaching all of the traditional sciences, then reviewed the SAIL items to confirm that they reflected content taught in typical general physical science, life science, and earth science courses. MASTS and SWIMS items were developed based on STS issues and the national standards and benchmarks to ensure that the students' attitudes about STS issues were actually being measured. A few of the SWIMS items were specifically related to students' experience in marine science. A group composed of marine scientists and science educators reviewed the three instruments to establish content validity. Both the post-SAIL assessment and post-MASTS survey were found to be reliable; Cronbach coefficient alphas were .94 and .86, respectively.

#### *Data Collection and Analysis*

Several data sources were used to describe the curricula and instructional practices that were characteristic of the high school marine science classes. First, classroom instruction and/or field trips were observed approximately four times with each teacher during the year. Field notes were recorded to document the content and types of curricula and instructional practices. Second, course syllabi were collected to describe curricula and instructional practices. Third, students' written responses to post-SWIMS questions also provided descriptions of the curricula and instructional practices in their marine science classes. Finally, both teachers and students were interviewed about course content, curriculum resources, integration of multiple sciences and STS-related issues, and instructional practices. The teacher interview was based on a questionnaire developed by the author (see Lambert, 2001). High school students' interviews were based the post-SWIMS questionnaire. Data from these multiple sources were triangulated and used to develop case profiles for each teacher.

To examine the outcomes of the science curricula and instructional practices with students, SAIL, MASTS, and SWIMS were administered to the students of all nine teachers at the beginning and end of their marine science course. Teachers administered the instruments according to instructions provided by the researcher. Each

student was issued a number, which was recorded on the three instruments, to track individual students throughout the year and to match pre and post surveys.

Data to assess students' change in knowledge of science were based on their quantitative pre-SAIL and post-SAIL scores and qualitative responses to post-SWIMS questions. Quantitative data were analyzed using pre and post paired-sample *t* tests to compare the mean for the percentage of questions that students answered correctly on the pre-SAIL and post-SAIL assessments for high school and university students. Students were asked to write about their perceived changes in confidence in science and knowledge of science as a result of taking a marine science course. These responses were used to help explain the results of the quantitative data and were analyzed according to themes relating to students' confidence in science and perceived knowledge of science, and awareness of the integrated nature of marine science.

Data to assess students' understandings of STS-related issues were based on their quantitative MASTS scores and qualitative responses to several SWIMS questions. Quantitative data were analyzed using pre and post paired-sample *t* tests to compare the mean scores on the pre-MASTS and post-MASTS surveys. Students were asked to write about how their participation in marine science class had affected their awareness of STS-issues and careers in science, interest in a career in science and life-long learning of science, enjoyment of science, and view of the relevancy of science. Qualitative data analyses of these written responses were guided by the research questions and themes incorporated into the development of the SWIMS questionnaire.

## **Results**

Marine science curricula and instructional practices are described first to provide an overview of similarities and differences among the teachers' courses. Changes in students' understanding of science content and STS-related issues are explained next. Finally, relationships between curricula and/or instructional practices and students' self-perceptions of their understanding of science content and STS-related issues are discussed.

### *Curriculum and Instruction*

*Curriculum.* Beginning in 1999, Florida combined existing marine science and marine biology semester courses to form a 1-year marine science course. The Florida Department of Education course descriptions for Marine Science I and II describe the 2-year course sequence as "an ongoing integrated study of all aspects of the marine environment." Marine Biology was replaced with Marine Science I, a course that addresses more of the national science standards and benchmarks, as well as the state's standards. The course requirements for Marine Science I (Florida Department of Education, 1999) guided the teachers in selecting the content for their syllabi.

Despite this positive state-wide change in the content requirements of marine science courses, textbook companies for formal K-12 education still do not publish appropriate oceanography, marine science, or marine biology textbooks. Most of the marine science textbooks commercially available are at a university reading level and do not include inquiry-based activities. Marine science textbooks were being formally considered for state adoption in Florida high schools during the 1999–2000 academic year, but no company submitted a textbook.

Accordingly, the teachers did not have a secondary level textbook to use. Six of the nine teachers used university-level marine biology textbooks. Three teachers also used an oceanography textbook. Six teachers used textbooks more than 7 years old. Two did not issue textbooks and had students take notes based on their lectures. One teacher used a number of specific activities from the University of Hawaii's Hawaii Marine Science Studies curriculum.

The content of the curricula varied, with a few of the teachers spending over 50% of the time on the biology of marine flora and fauna. Most of the teachers taught the disciplines of biology, chemistry, physics, and geology separately, but in the context of the oceans. Two teachers consistently taught in an integrated manner, emphasizing synthesis of multiple disciplines of science, while focusing on real-world issues in local settings. One of these teachers taught at a school where marine science was used as a theme for teaching Integrated Science III, the third 1-year course in a sequence of three integrated science courses. For example, this teacher taught biology, chemistry, and geology through the topic of coral reefs.

*Instructional practices.* Descriptions of instructional practices are based on observations, teachers' reports, and students' responses on the SWIMS questionnaire. Instructional practices used by the teachers in the study consisted of mostly teacher-developed lectures, laboratory activities, and video presentations. All nine teachers said they used these approaches to teaching. One difference in lecture approaches was observed. This teacher described his lectures as interactive and participatory.

Laboratory activities varied among the teachers, with approximately one-half focusing on observation or dissection of marine organisms. Other instructional practices included speakers from the local community, field trips (six teachers' classes), and projects. One teacher's students had the opportunity to attend scientists' lectures and participate in laboratories and field-based experiences at a local oceanographic research institution approximately three times per week. Student projects varied greatly among the groups (e.g., summaries of current events, research on marine science-related careers and oceanographic institution, class debates on local issues, seafood festivals, interdisciplinary projects, writing and illustrating marine-related children's books, and volunteer community projects). Students from the majority of groups were able to participate in volunteer projects in their local area, such as removing invasive species of plants, planting mangroves, building artificial reefs, or participating in beach clean-ups. Three of the teachers and their team(s) of students participated in the regional ocean science bowl.

To obtain students’ perspectives on instructional practices, they were asked whether they had to actively seek out information or whether information was provided mostly by the teacher and which way they learned best (SWIMS Question 12). Of 362 respondents, 73% said the teacher provided the information. The majority of students said they wanted the teacher to provide the information, but also wanted to do quality “hands-on” activities, including field trips. Students said they enjoyed a balance of meaningful lectures, laboratories and other hands-on activities, videos, and field trips in their marine science class. Several students expressed that they did not want to color and label organisms from books or do too many dissections, as they had done previously in their biology classes.

*Understanding of Science Content Standards and Benchmarks*

Results on the SAIL assessment were analyzed by comparing pre and post means for the percentage of the 80 questions that students answered correctly. A paired-sample *t* test showed a significant mean score improvement from 39.5% correct (*SD* = 16.8) on the pre-SAIL to 42.9% correct (*SD* = 19.7) on the post-SAIL ( $p < .001$ ,  $n = 399$ ) (Table 1). Cohen’s *d* was 0.22, indicating a small effect size. A significant improvement in SAIL scores indicates that overall students’ knowledge of general science increased during their marine science course. While the improvement was

Table 1. SAIL scores for high school groups of students

Group <sup>a</sup>	<i>n</i>	Pre-SAIL		Post-SAIL		Gain	Correlation	<i>t</i> value	Cohen’s <i>d</i> (effect size)
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>				
1	36	25.8	8.6	24.1	13.0	-1.8	.55	-0.97	0.16
2	12	26.4	6.5	26.8	4.1	0.4	.38	0.22	0.06
3a	53	38.8	15.6	55.7	16.1	16.9***	.65	9.22	1.27
3b	20	54.9	18.3	61.6	18.5	6.7	.65	1.93	0.43
4	62	40.6	15.6	37.8	16.7	-2.8	.66	-1.62	0.21
5a	60	49.4	15.8	52.9	20.5	3.4	.70	1.80	0.23
5b	37	48.7	13.5	42.9	19.3	-5.8*	.70	-2.53	0.42
6	49	33.4	11.8	42.3	17.0	9.0***	.45	3.99	0.57
7	15	56.8	14.6	58.3	16.2	1.6	.74	0.55	0.14
8	38	30.2	13.8	31.9	8.9	1.7	.44	0.83	0.13
9	17	26.9	11.6	27.4	9.0	0.4	.11	0.13	0.03

Notes. <sup>a</sup>Group numbers indicate each of the nine teacher’s students. Group 3a includes Integrated Science III (marine science) students, and Group 3b includes dual enrollment oceanography students. Teacher 5 taught 1-year marine science courses during the fall (5a) and the spring (5b). Statistically significant at: \*\*\* $p < .001$ ; \*\* $p < .01$ ; and \* $p < .05$ .  $d > 0.20$  is “small” effect size;  $d > 0.50$ , “medium”; and  $d > 0.80$ , “large.” Pearson product moment correlation between pre-SAIL and post-SAIL assessments = .671 ( $n = 399$ ).

statistically significant, the average improvement was small with students answering an average of three to four more questions correctly on the post-SAIL.

Significance varied across the high school teachers' classes. Seven of the nine teachers' classes of students improved, but only two of these teachers' classes improved significantly by answering an additional 17% and 9% of the 80 questions correctly on the post-SAIL. The result is consistent with classroom observations, in which these two teachers taught marine science using an integrated approach with approximately equal time devoted to geological, chemical, physical, and biological topics.

Students' written responses to items on the SWIMS questionnaire provide qualitative data that indicate their knowledge of science increased after participation in a marine science course. Table 2 presents the SWIMS questions that related to knowledge of science and representative responses of high school students. Of 366 student respondents, 65% said they were more confident in the field of science as a result of taking marine science. Of 369 respondents, 49% chose marine science as the science class in which they had actually learned the most science during high school. When students were asked what science concepts they had learned about

Table 2. Students' perceptions of their knowledge of science

Theme	SWIMS question	Examples of representative students' quotes
Confidence in the field of science	As a result of your marine science class, do you feel more confident in the field of science? ____ Yes ____ No Explain	All the stuff I didn't even know I was learning has become evident. I feel like it was taught to me by my teacher so well that I could even go for a career in marine science if I wanted to. This confidence even got me into a statewide competition (NOSB) when I never thought I liked science  At first I thought physics and biology would be hard, but marine science has shown me how interesting and fun it could actually be. In reality, its very simple and I no longer fear physics. I actually am very eager to take a class specifically on it
Knowledge of science	During which science class throughout high school did you actually learn the most science? Explain	Out of my whole high school career, I have had more fun and learned more in my oceanography class than in any other science class I have taken. Because of this class, I understand hard topics much easier by applying them to the ocean
Recognition of the integrated nature of maine science	What other fields of science have you learned about during your marine science course? Give a few examples	The information in this class was very useful, and after the year, it all seemed to fit together, like a huge puzzle that I never had the odd pieces to. A beautiful way to learn science—truly integrated, but not choppy like the other classes which had no common foundation. This marine science course was integrated, but had water and oceans as common foundation. That is what made it all join together instead of all the pieces spread our all over the table, unconnected and alone

during their marine science course, respondents ( $n = 500$ ) listed an average of 37 different topics from the fields of meteorology, earth science/geology, biology, chemistry, physics, astronomy, and environmental science.

### *Understanding of STS-related Issues*

A paired-sample  $t$  test revealed no significant difference between the pre-test and post-test MASTS scores for the high school students (4.4 versus 4.4,  $t = 1.63$ ,  $n = 421$ , Cohen's  $d = 0.08$ ). A score of 4.0 meant that on a Likert Scale of 1 (*strongly disagree*) to 6 (*strongly agree*), students partly agreed with the statement indicating the goal of the *Benchmarks*. The mean scores of all the items were over 4.0. The results indicated that students partly agreed with the *Benchmarks* at both the beginning and end of marine science courses and that their perceptions of their understanding of STS-related issues did not significantly change.

The qualitative data analysis of students' responses on SWIMS indicates that many students had developed attitudes reflective of a successful STS curriculum. Table 3 presents the STS themes used to develop the SWIMS items, percentages of students who wrote a positive response, and examples of representative quotes from these students. Students' written explanations on SWIMS indicate that their experiences in marine science classes helped them become more aware of STS-related issues. The students were able to identify several ways in which marine science is related to economical, technological, and environmental issues. Students listed approximately 39 different examples of how they thought marine science affects the economy (e.g., ocean resources, education and research, careers, transportation, recreation, natural phenomena, and coastal development). Students listed 37 different ways marine technology is beneficial to humans with the majority of responses relating to ocean exploration and fishing industries. Over 10% of the responses were about benefits related to medical technology to cure diseases or satellites for weather prediction or navigation. Students were able to identify 62 global or local environmental problems related to marine science (e.g., habitat destruction, pollution, climate issues, lack of conservation or knowledge of environmental problems, impact on species, coastal development, human use, and others). While the majority of students identified problems related to pollution, over 10% of the students identified issues relating to climate (e.g., global warming, melting of ice caps, and excessive use of fossil fuels).

While 84% of 384 respondents said they had become more aware of careers in the field of marine science or science, 31% said that marine science had affected their career choices in a positive way. Approximately two-thirds of the students wanted to learn more science as a result of taking a marine science course whether they were influenced to pursue a science career or not. Over one-half of the students chose marine science as the science class they had enjoyed the most in high school for reasons such as being interested in the oceans, doing hands-on activities, or learning so much science content. Ninety percent of the students thought the oceans affected humans living anywhere on Earth, listing 40 examples (categorized as resources, jobs/careers, transportation, ocean-atmosphere interactions, pollution, and natural

Table 3. Students' perceptions of marine science and STS-related issues

Issue	Student response
<b>Identification of STS issues</b>	
How do you think marine science affects the economy of the United States?	Marine science greatly affects our economy. Fernandina Beach has thrived from the shipping industry. Our population has grown due to this and it has caused more jobs to be created in our area
What examples of marine technology can you think of that are most beneficial to humans?	Marine technology enables meteorologists to provide humans knowledge about storms, weather, hurricanes, and drought. This knowledge enables protection and preparation for the weather that is coming. Marine technology also allows for offshore, self-sufficient oil structures
What do you think are important environmental problems related to marine science on a global scale? On a local scale (in your local area)?	Some third-world fishing companies choose harmful methods to fish that diminishes the entire population at the same time. Dynamite fishing is harmful to all species on the reefs. People use cyanide to capture the reef tropicals and kill the coral. The Japanese shark-fin fishing boats cut off only the fins of the shark and then throw it back  The dumping of water into the Indian River Lagoon from Lake Okeechobee damages the local ecosystem. Fertilizers from Okeechobee farms flow into the lake from rain, and then they want to rid excess water by dumping it into the Indian River Lagoon, causing huge algal blooms, killing fish populations, and hurting the local environment
<b>Career awareness/goals</b>	
Has this class helped you become more aware of careers in marine science or science in general? [84% answered yes. $n = 384$ ]	Before this class I never really knew what people even could research in our oceans, and now I understand that there are so many different jobs and opportunities dealing with marine science
Has your marine science class affected your career plans? [31% answered yes. $n = 454$ ]	Before taking this class, I felt that I may want to make a career in marine science. After 3 years, I know I do. I have been accepted to Florida Tech on a full scholarship for a physical oceanography major
<b>Interest in life-long learning in science</b>	
Has taking a marine science course made you want to learn more about other sciences, such as earth science, biology, chemistry, and physics? [67% answered yes. $n = 461$ ]	Applying the marine world to a science class makes it much easier to comprehend, and much more fun to learn. It opens up the whole science world to you and allows you to see it all in action. Prior to the course, I was still unsure of what my goals would be, but I found that the vigorous study in the course is actually very enjoyable and I find myself hungry for more knowledge each day
<b>Enjoyment of science</b>	
What science class in high school did you enjoy the most? Why? [56% chose marine science. $n = 358$ ]	Integrated Science III with the marine approach—I have never enjoyed or learned as much as I have in this class

(Continued)

Issue	Student response
<p><b>Relevancy</b></p> <p>Do you think oceans affect humans who live anywhere on Earth, even in the middle of a continent? [90% answered yes. <math>n = 488</math>]</p>	<p>Oceans affect climates. The Indian Ocean provides rains for monsoons. El Niño causes climate changes throughout the United States and middle and South America. Also fishing and mining affect those people in the middle of a continent. Frozen and fresh fish are shipped all over the world. Offshore oil drilling contributes to the world supply, making gas and oil cheaper. Minerals are mined from the ocean floor. Phytoplankton make a lot of the oxygen we breath</p>
<p>As a result of this class, do you see how science plays a role in your everyday life and community? [89% answered yes. <math>n = 375</math>]</p>	<p>Science is all around. It affects the weather. For example, I went to San Diego and the weather was cooler there and I knew it was because of the California current. It is an Eastern boundary current, which is cooler and weaker. Before this class I didn't realize how important marine science is and all its impacts on everyday life and how it affects us in the future. In the Cape Florida Project I realized how exotic plants could be such a deadly threat to our natural environment</p>
<p>Do you think all high school students in Florida should be encouraged to take a marine science class? [76% answered yes. <math>n = 354</math>]</p>	<p>Marine science teaches you how all the environments work together. It combines all other sciences in explaining how the ocean environment functions. It is useful knowledge. We have two planets in one. We should all know more about our neighbor—the ocean</p>

disasters). Almost 90% of the students also said that, as a result of taking a marine science class, they now thought science played a role in their everyday life and community, and over 75% of the students thought all Florida high school students should be encouraged to take a marine science course.

Discussions on STS interactions help students to develop insights into their values as well as motivate them to apply their skills and participate as citizens on a local and global scale. While this study did not measure students' actions, 70% of the students said they had changed some aspect of how they live as a result of their marine science course. Most of the students' responses were related to pollution prevention; conservation and recycling efforts; respect for animals, plants, and habitats; and knowledge and interest in local environmental issues.

## Discussion

Considering that most of the research in science is strategic or mission-oriented and focused on multidisciplinary problems, science curricula and instructional practices need to be modernized to reflect current research (Hurd, 1997, p. 32). Based on the findings of this study, marine science courses appear to be able to provide a new curriculum and instructional approach that integrates multiple sciences and deals with relevant problems faced by students in a changing society. There are, however, challenges to implementing successful marine science curricula and instruction at

the high school level. These issues need to be considered in helping high school students become scientifically literate citizens.

Even with the Florida Department of Education marine science course requirements, the teachers' curricula and course content varied. In Florida, marine science teachers have a course description to guide them in their planning, but not a specific list of standards or a curriculum guide—such as New York's marine science curriculum guide, which outlines what specific geology, chemistry, physics, and biology content standards and instructional practices should be included in a marine science class. Only two of nine teachers taught geological, chemical, physical, and biological characteristics of the ocean proportionately, whereas the remaining teachers incorporated more biology-oriented content.

Marine high school teachers have few choices of inquiry-based textbooks. The University of Hawaii's *The Fluid Earth: Physical Science and Technology of the Marine Environment* (Klemm, Pottenger, Speitel, Reed, & Coopersmith, 1990) and *The Living Ocean: Biology and Technology of the Marine Environment* (Klemm, Pottenger, Speitel, Reed, & Porter, 1995) are the only inquiry-based marine science textbooks available for high school-level courses. In this study, the students of two teachers who did not issue a textbook improved the most on the content assessment, which may indicate that the university-level or marine biology-oriented textbooks used by the other teachers were not effective or these two teachers developed creative instructional practices to teach marine science content or had more content expertise. Cohen, Raudenbush, and Ball (2003) review and discuss the complexity of conducting research on educational resources, instruction, and student achievement; and indicate that conventional resources (i.e., textbooks) are weakly related to student performance. However, textbooks remain the leading source of resource materials used by National Marine Science Educators Association members (Walker, Walters, & Allen, 2003).

A model for integrating marine STS-related issues (Figure 1) was developed to provide educators with a framework for incorporating content standards and teaching practices outlined in the *NSES* and *Benchmarks* into a marine science curriculum or program. The water molecule serves as an appropriate metaphor for this model; with the oxygen atom representing the marine science curriculum (including biological, geological, physical, chemical, and meteorological concepts); one hydrogen atom representing the interactions between society and the ocean environment; and the other hydrogen atom representing technological benefits of marine science.

Despite the variations in curricula and instructional practices among the nine teachers, the high school students, as a group, significantly improved on the science content assessment, expressed increased confidence, and provided an extensive list of concepts that they had learned during their marine science courses. The differences in curricula and instructional practices used by individual teachers may have affected students' science learning, as indicated by scores on the post-SAIL assessment of general science knowledge. Students of the two teachers who used a more integrated approach improved the most on the SAIL assessment.

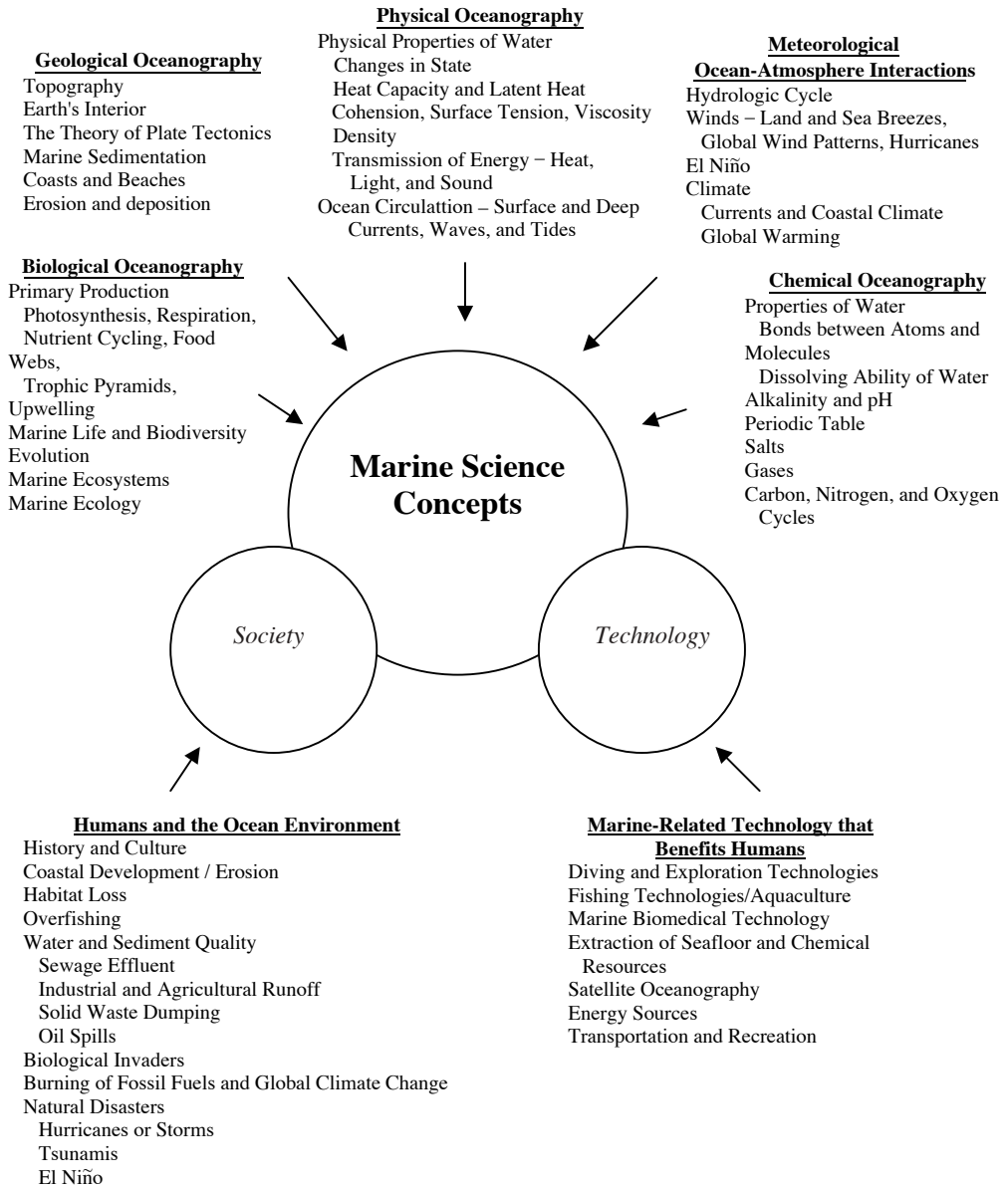


Figure 1. A model for integrating marine STS-related issues

Marine science is a very complex systems-based field of study requiring teachers to have deep content knowledge, not only of marine science, but also of biology, chemistry, geology, physics, and meteorology. All of the teachers had undergraduate education and teaching experience predominantly in the field of biology. One teacher was an exception, having a bachelor's degree in marine biology, a master's degree in science education with a minor in geophysics, and having taken several courses in a science education doctoral program. He had also taught all the basic

sciences throughout his 15-year teaching career and was probably very able to integrate biology, chemistry, geology, physics, and meteorology into a marine science context.

The findings of this study suggest a need for teaching content of multiple science disciplines to improve preparation of marine science educators. Additionally, several states have combined high school science teacher certification areas—teachers could be eligible to teach earth and space science, biology, chemistry, and physics with one general science certification. Integrated science curriculum and instruction in fields such as marine science will become even more important in teacher preparation and professional development programs.

Marine science curriculum and instruction requires that the teacher enables the students to reflect on the difference between science and technology, the importance of the marine environment, the impact of technology on the environment, and the interactions of STS. Results of the MASTS survey showed that students maintained self-perceptions of their understandings that were relatively reflective of STS-related standards and benchmarks as they participated in a marine science course. Responses on the SWIMS questionnaire revealed that students had understandings of marine science and STS-related issues. Students were able to identify many ways marine science is related to economical, technological, and environmental issues.

The results indicate important implications for STS-related issues in marine science courses. First, goals of a STS program should include increasing students' career awareness and interest in learning. A relatively high percentage (31%) of students in the study were positively influenced to consider future careers in science. Second, learning science through an STS approach is an experience students are encouraged to enjoy, which differs from traditional science classes where students are expected to acquire a body of information (Yager & Roy, 1993). Almost one-half of the students in this study enjoyed marine science more than their other science classes. Third, STS-based education provides a framework for the teaching and learning of science in the context of students' experiences, representing an appropriate science education context relevant to all learners. After participating in a marine science course, most of the high school students thought that the oceans affected humans living anywhere on the Earth and that science played a role in their daily life. Finally, the major goal of STS education is the production of scientifically literate citizens capable not only of making decisions about current issues, but also of taking personal action. Over two-thirds of the students in the study said that they were more motivated to learn science and more likely to take action based on their knowledge.

### **Limitations and Future Research**

This research provided a description of existing curricula and instructional practices used in a sample of Florida's marine science classrooms. While this study described existing marine science curricula and instructional practices used by a small sample of teachers and students' science knowledge and understandings of STS-related issues, initial evidence indicates that marine science courses can help students of

diverse backgrounds become more scientifically literate, meeting the goals of science education reform. Conducting in-depth case studies and including a control group were impractical because of the great distances across the seven counties and the variability among the high school students' science backgrounds. The results of this exploratory study, however, can help design more focused investigations on marine science curricula and instructional practices and students' knowledge of science and STS-related issues.

Further research is necessary if marine science is to be accepted as an effective high school integrated science course. First, marine science curricula need to be aligned to the national standards and benchmarks (NRC, 1996) before student learning of general science concepts can be assessed adequately. One possibility is to develop a standards-based curriculum, provide professional development opportunities for marine science teachers, and measure the effect on students' understandings of science knowledge and STS-related issues.

Second, marine science instruction also needs to be aligned to the national science teaching standards (NRC, 1996). All teachers in the study used more traditional instructional practices. One exemplary teacher in this study, who had extensive science content knowledge and graduate studies in science education, was able to orchestrate discourse among students about scientific ideas through his "interactive lectures." Further research can be conducted in exemplary teachers' classes using more structured observation guidelines. The effective instructional practices, along with curriculum materials aligned to the standards, could then be incorporated into a professional development model to promote marine science education.

Not only were the teachers' curricula and instructional practices varied, but they also were not aligned to the instruments measuring students' outcomes. The development of the three instruments was a major component of the research due to the lack of existing instruments to measure student learning of the national science standards and benchmarks. The SAIL assessment was constructed using a multiple-choice format because of the large number of students. Additionally, marine science is integrated, encompassing multiple science disciplines, thus requiring a lengthy assessment of students' knowledge of general science. Revisions of the SAIL assessment may include the incorporation of two tier multiple-choice items, in which one tier involves a content response while the other involves a reasoning response (Treagust, 1995). Performance items that integrate key concepts from multiple sciences may also be incorporated in future revisions. The MASTS survey was based on a Likert scale in order to assess understandings of STS-related issues by a large number of students. Revisions of the MAST survey may include opportunities for students to write comments about items and explanations for their choices. Finally, the SWIMS questionnaire was developed to provide qualitative data to explain relationships between curriculum and instruction and students' perspectives of changes in their understanding of science content and STS-related issues. SWIMS may continue to be used in future studies, both as a written questionnaire and as a guide for interviews with students.

In response to the national and state testing of all the sciences, further research on the teaching and learning of integrated science is necessary. With Third International Mathematics and Science Studies results indicating that U.S. curriculum covers a large number of topics superficially and the majority of U.S. teachers attempting to cover these topics very briefly (Valverde & Schmidt, 1998), curriculum reform is important. The “mile wide, inch deep” coverage of so many topics does not allow students time to concentrate and learn key science concepts. While the field of marine science is broad and covers many topics, it does so using a naturally integrated and coherent approach. Given the paucity of research on marine science education, this study is significant as an initial description and analysis of existing high school marine science curricula and instructional practices and students’ scientific literacy. The results of this exploratory study indicates that a broad but coherent theme, such as marine science, can provide a model for promoting students’ understanding of many biological, chemical, and physical science standards and STS-related issues if teachers can integrate these fields of science in their curriculum and instruction.

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## Appendix. Instrument sample items

### Science Assessment in Literacy (SAIL)

- Item 1 Water is referred to as “the universal solvent.” The dissolving ability of water is related to its \_\_\_\_\_.  
a. Ability to attract both positive and negative ions    c. High boiling point  
b. Ability to exist in solid, liquid, and vapor phases    d. High heat capacity
- Item 12 What determines how atoms of elements in the same group or family of the Periodic Table will react with atoms of different elements?  
a. Neutrons    c. Outermost electrons  
b. Protons    d. Energy levels
- Item 43 Which of the following groups of organisms would be more closely related?  
a. Fish, jellyfish, starfish, crayfish  
b. Spider, crab, insect, mouse  
c. Human, cat, dog, manatee  
d. Alligator, shark, bony fish, pelican
- Item 63. Phytoplankton (microscopic plant-like organisms) play an important role in balancing Earth’s climate by  
a. Absorbing ozone from the atmosphere  
b. Using carbon dioxide and producing oxygen  
c. Using nitrogen and producing carbon dioxide  
d. Using oxygen and producing carbon dioxide

### My Attitudes toward Science, Technology, and Society (MASTS) Items

- Item 26 In addition to its benefits, technology may have negative side effects.
- Item 27 Scientists from different fields work as a team to study many problems.
- Item 28 Scientific investigations do NOT depend on inventions of new technology.
- Item 33 Results of scientific research alone can solve most local, national, or global issues.
- Item 37 Scientific research is mainly conducted in university laboratories.
- Item 38 Scientists are NOT influenced by their personal, societal, and cultural beliefs and ways of viewing the world.
- Item 39 Science and technology influence history.
- Item 40 Today’s scientific knowledge is NOT subject to change.

### Students’ Worldviews and Interest in Marine Science (SWIMS) Items

- Item 7 What other fields of science have you learned about during your marine science course? Give a few examples.

- Item 8 Has taking a marine science course made you want to learn more about other sciences, such as earth science, biology, chemistry, and physics? \_\_\_\_\_ Yes \_\_\_\_\_ No Why or why not?
- Item 9 Has this class helped you become more aware of careers in marine science or science in general? \_\_\_\_\_ Yes \_\_\_\_\_ No Has your marine science class affected your career plans? \_\_\_\_\_ Yes \_\_\_\_\_ No Explain.
- Item 10 As a result of this class, do you see how science plays a role in your everyday life and community? \_\_\_\_\_ Yes \_\_\_\_\_ No Explain. Will you change any aspect of how you live based on what you have learned in this marine science course? \_\_\_\_\_ Yes \_\_\_\_\_ No. Explain.
- Item 15 As a result of your marine science class, do you feel more confident in the field of science? \_\_\_\_\_ Yes \_\_\_\_\_ No Explain.
- Item 16 What science class in high school did you enjoy the most? Why? Which high school science class will be the most useful in your future? Explain. During which science class throughout high school did you actually learn the most science? Explain.