Ocean Science in the Classroom

Using an integrated ocean science approach to chart a new course in high school science curricula

Julie Lambert and Suzanne Smith Sundburg

In one form or another, ocean or marine science courses have existed for decades. Although these courses can effectively integrate the sciences in ways that stimulate student curiosity and interest, they have not yet received formal recognition for the role they could play in improving science education for secondary students. In this article, we discuss why ocean science courses are not as prevalent in high schools and, by contrast, why ocean science courses should be taught. Finally, we present a framework and suggested resources to show teachers how they can align ocean science concepts to the national standards and become more experienced in strategies for teaching these concepts.

Why are ocean science courses less prevalent?

Ocean science courses are less prevalent in U.S. high school curricula for several proposed reasons. First, ocean science is a relatively young science compared to other traditional sciences and is not a traditional discipline-based science course. Rather, ocean science is a naturally integrated science that incorporates the biological, chemical, geological, and physical science concepts that scientists must learn in order to understand marine processes and systems. Relatively few undergraduate programs exist in the ocean sciences; therefore, few teachers have bachelor's degrees in the field. Moreover, implementing inquiry-based activities in an integrated science course requires a variety of materials and supplies.

Second, across state school systems and universities there is inconsistency as to whether a high school ocean science course qualifies as a science course requirement for graduation or college admission. This may be, in part, due to ocean science not appearing as a major theme in the *National Science Education Standards* (NRC 1996) or the *Benchmarks for Science Literacy* (AAAS 1993).

Also, ocean science is often wrongly perceived as being an "easier" or irrelevant science course focused primarily on marine biology, instead of a course that naturally integrates life and physical science concepts. In a study of the curricula and instructional practices of nine high school marine science teachers, Lambert (2006) found that most of the study's teachers focused more on teaching marine biology, indicating that even teachers often interpret ocean science as marine biology. Two explanations for this focus may be the relatively small number of appropriate high school–level ocean science textbooks and teachers' lack of ocean science content knowledge and experience.

Why should ocean science courses be taught?

Many reasons exist to promote ocean science courses at the high school level. First, ocean science is naturally integrated and addresses many of the content standards in the state and national standards and benchmarks (Figure 1). In addition to providing a broad range of content, ocean science courses also provide a way to connect science ideas in the curriculum. This provides students with an overarching context for studying basic science concepts, which may prove to be motivating to students and increase their participation and learning of science (Cognition and Technology Group at Vanderbilt 1990; Blumenfeld et al. 1991).

In Lambert's studies (2005, 2006), students of teachers who integrated biological, chemical, geological, and physical characteristics of the oceans performed higher on a science content assessment than students taking a traditional marine biology course. These results provide initial evidence that student achievement can be positively affected by teaching science concepts through an ocean science theme.

Second, the course is relevant to all students, even those from diverse backgrounds and cultures. The National Oceanic and Atmospheric Administration (NOAA 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. The ocean's living resources also provide food, recreational experiences, and new medicines to improve health and cure diseases. Oil and natural gas also are obtained from the continental shelf.

FIGURE 1

Alignment of Standards to ocean science concepts.

[Note: This table was developed by Julie Lambert to align ocean science concepts to the National Science Education Standards (NRC 1996). It has been reviewed by teachers, scientists, George DeBoer, Deputy Director of Project 2061, and Sarah Schoedinger of NOAA.]

National Science Education Standards (9–12)	Ocean science concepts
Physical Science (NRC 1996, p. 176) • Structure of atoms • Structure and properties of matter • Chemical reactions • Motions and forces • Conversation of energy and increase in disorder • Interactions of energy and matter	• Properties of water: water molecule, polar nature of water, dissolving ability of water, heat properties of water, phases of water and energy, cohesion, surface tension, viscosity, density, pressure, transmission of heat, light, and sound • Periodic table • Dissolved solids and gases • Alkalinity and pH • Biogeochemical cycles • Chemical factors affecting marine life (biochemistry): osmosis, diffusion, salinity, acids/bases, dissolved nutrients, and dissolved gases • Physical factors affecting marine life (biophysics): light, sound, pressure, temperature, buoyancy, and viscosity • Waves and wave phenomena • Tides and the Moon's gravitational effect on oceans • Ocean circulation: surface and deep currents
Life Science (NRC 1996, p. 181) • The cell • Molecular basis of heredity • Biological evolution • Interdependence of organisms • Matter, energy, and organization in living systems • Behavior of organisms	• Origins of life in oceans • Life zones in the ocean • Classification of marine organisms • Biodiversity of marine organisms • Evolution of marine organisms • Primary production: photosynthesis, respiration, nutrient availability, variation in productivity, nutrient cycling, decomposition and microbes, chemosynthesis • Energy flow: food chains, webs, and pyramids • Marine ecosystems and marine ecology

(continued on next page)

FIGURE 1

(continued from previous page)

National Science Education Standards (9–12)	Ocean science concepts
Earth and Space Science (NRC 1996, p. 187) • Energy in the Earth system • Geochemical cycles • Origin and evolution of the Earth system • Origin and evolution of the universe	• Origins of the solar system, Earth, atmosphere, and ocean • Solar energy and heat budget • Earth's seasons • Hydrologic cycle • Winds: local land and sea breezes and global wind patterns • Surface currents and Deep circulation • Atmosphere/ocean interactions: hurricanes and El Niño • Climate: currents and coastal climate, climate change • Composition of Earth, rock cycle, seafloor topography • Theory of plate tectonics, theory of continental drift, theory of seafloor spreading • Location of earthquakes and volcanoes • Sediments • Coastal processes • Tides and the phases of the Moon
Science and Technology (NRC 1996, p. 190) • Abilities of technological design • Understandings about science and technology	• Diving and exploration technologies, satellite oceanography • Fishing technologies/aquaculture and marine biomedical technology • Extraction of seafloor and chemical resources and energy sources • Transportation and recreation
Science in Personal and Social Perspectives (NRC 1996, p. 193) • Personal and community health • Population growth • Natural resources • Environmental quality • Natural and human-induced hazards • Science and technology in local, national, and global challenges	• History and culture • Marine resources: living and nonliving biodiversity and overfishing • Coastal development and Habitat destruction • Water and sediment quality • Management of the coast and oceans • Oceans and climate change • Natural disasters: hurricanes, tsunamis, El Niño
Science as Inquiry (NRC 1996, p. 173) • Abilities necessary to do scientific inquiry • Understandings about scientific inquiry	• Development of the theory of plate tectonics • Discovery of hydrothermal vents • Exploration of the ocean
History and Nature of Science (NRC 1996, p. 200) • Science as a human endeavor • Nature of scientific knowledge • Historical perspectives	• Availability of new technologies to study the ocean: ocean observing systems, ocean drilling project, computer modeling, AUV's and ROV's • Climate change and the oceans • U.S. Commission on Ocean Policy report

Oceans play an important role in cycling nutrients and crustal materials and regulating global climate.

Student responses to a questionnaire provide evidence to support the relevance of ocean science (Lambert 2006). Of 375 students, 89% said that they saw how science plays a role in their everyday life and community as a result of taking marine science, and 90% thought that the ocean affected humans who live anywhere in the planet. Of 384, 67% were interested in taking additional science courses as a result of completing a marine science course.

Frameworks for teaching and learning ocean science

One framework that can guide teachers in developing an ocean science course is the document in Figure 2, "Ocean Literacy—The Essential Principles of Ocean Sciences K–12" (College of Exploration 2005). These principles were developed from the recommendations of approximately 100 educators and scientists who participated in the October 2004 Online Ocean Literacy Workshop sponsored by the National Geographic Society's Oceans for Life Initiative, NOAA, and the College of Exploration. Fundamental Concepts (additional details that elaborate on the Essential Principles) were developed as well. Figure 3 lists some of the Fundamental Concepts for Essential Principle 7.

A conceptual framework for helping teachers design an ocean science course is presented in Figure 1, which shows an alignment of national standards to typical science concepts that may be taught in an ocean science course. This framework may be especially useful for

FIGURE 2

The Essential Principles of Ocean Sciences K–12 (College of Exploration 2005).

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

teachers who want to demonstrate how their course content aligns to national standards.

Resources for teaching ocean science courses

Many valuable resources are available to teachers interested in teaching ocean science, such as the 10 Centers for Ocean Science Education Excellence (COSEE), funded by the National Science Foundation. COSEE has a collaborative mission of promoting the development of effective partnerships between research scientists and educators; disseminating effective ocean science programs and the best practices; and promoting a vision of ocean education as a charismatic, interdisciplinary vehicle for creating a more scientifically literate workforce and citizenry.

The COSEE website (*www.cosee.net*) contains links to individual centers throughout the United States. These links provide a variety of resources for teachers, from lesson plans to professional development opportunities. The COSEE website also contains links to the National Marine Educators Association (*www.marine-ed.org*) and the "Bridge to Marine Links," which is a comprehensive collection of information, lesson plans, and professional development opportunities.

FIGURE 3

Fundamental Concepts of Essential Principle 7 "The ocean is largely unexplored".

(For a complete list of the Fundamental Concepts for this and the other Essential Principles, visit *http://coexploration.org/oceanliteracy/documents/OceanLitChart.pdf*.)

- The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.
- Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.
- Over the last 40 years, use of ocean resources has increased significantly; therefore, the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.
- New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.
- Use of mathematical models is now an essential part of ocean sciences. Models help us understand the complexity of the ocean and of its interaction with Earth's climate. They process observations and help describe the interactions among systems.

Changing course to solve a "quiet crisis"

Thomas Friedman (2005) claims in his recent bestseller, *The World Is Flat*, that we are facing a "quiet crisis" involving the steady erosion of America's scientific and engineering base.

As employees in the 14 federal agencies that oversee ocean resource management and manage our country's science enterprise approach the age of retirement, our nation's need for qualified ocean scientists is becoming even more evident. We must address this need now within our high schools by not only improving science literacy of all students, but by attracting students into the many ocean science–related careers. ■

Julie Lambert (julielambert@att.net) *is an assistant professor of science education at Florida Atlantic University, 777 Glades Road, Boca Raton, FL 33431; and Suzanne Smith Sundburg* (pro.wordsmith@verizon.net) *is a freelance writer and science editor currently working onsite at NASA Headquarters.*

References

American Association for the Advancement of Science (AAAS). 1993. *Benchmarks for science literacy*. Washington, DC: American Association for the Advancement of Science.

Blumenfeld, P., E. Soloway, R. Marx, J.S. Krajcik, M. Guzdial, and A. Palincsar. 1991. Motivating project-based learning. *Educational Psychologist* 26 (3 and 4): 369–98.

Cognition and Technology Group at Vanderbilt. 1990. Anchored instruction and its relationship to situated cognition. *Educational Researcher* 19: 2–10.

College of Exploration. 2005. Ocean literacy—The essential principles of ocean sciences K–12. *http://coexploration.org/oceanliteracy*.

Friedman, T.L. 2005. *The world is flat*. New York: Farrar, Straus and Giroux.

Lambert, J. 2005. Students' conceptual understandings of science after participating in a high school marine science course. *Journal of Geoscience Education* 53(5): 531–39.

Lambert, J. 2006. High school marine science and scientific literacy: The promise of an integrated science course. *International Journal of Science Education* 28(6): 633–54.

National Oceanic and Atmospheric Administration (NOAA). 1998. Marine education, U.S.A.: An overview. In *Year of the ocean discussion papers*. Washington, DC: U.S. Department of Commerce.

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