Ocean Literacy Through Science Standards

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***Abstract* - Ocean sciences were idiosyncratically left out of the National Science Education Standards and most state standards, resulting in a decline in the public's attention to ocean issues. National Geographic Society, COSEE, NMEA, NOAA and the US Commission on Ocean Policy have all urgently called for the inclusion of the ocean in science standards as a means to increase ocean literacy nationwide. There has never been consensus, however, about what ocean literacy is and what concepts need to be included in standards to achieve it. Last fall, an on-line workshop on "Ocean Literacy through Science Standards" attempted to develop this consensus. This paper describes the resulting definition of ocean literacy; the essential principles; and fundamental concepts and their alignment to the National Science Education Standards.**

I. INTRODUCTION

The need for ocean literacy is simple. On our blue planet the most dominant feature is the ocean. Understanding the ocean is integral to understanding the planet on which we live. This understanding is essential to sustaining our planet and our own well-being [1]. However, for many years core curricula for grades K-12 have not included ocean topics. In fact, in some cases, the oceans have been completely ignored in formal K-12 education. The challenge facing ocean literacy proponents has been how to incorporate concepts about the ocean into accepted curricula. In the last several years, several institutions have grappled with this challenge as follows:

- National Geographic Society: In February 2002, the Geographic convened a virtual workshop to identify key ocean concepts that were then developed into an Oceans Scope and Sequence aligned to the National Geography Education Standards [2].
- National Marine Education Association (NMEA). In July 2003, NMEA established an Ad Hoc Committee to better define the important marine and aquatic science literacy concepts and to establish linkages to existing state and national standards that will strengthen science education. This committee was also tasked to make recommendations on a series of actions for the NMEA Board of Directors and the National COSEE Council to promote an ocean literacy agenda.
- Dr. Robert Stewart, Texas A&M University, Department of Oceanography. In July 2004, Dr. Stewart and his colleagues presented a paper entitled "What Every Student Ought to Know about the Ocean: a Compilation of Key Concepts" at the NMEA annual conference [3].
- COSEE-New England. COSEE-New England, a partnership between the New England Aquarium, the Wood's Hole Oceanographic Institution and the University of Massachusetts-Boston, initiated an effort to strengthen the New England region's capacity to develop and provide high-quality ocean science education. As part of this effort, they developed a draft definition of ocean literacy.

Based on these projects, it became clear that the community needed a mechanism for communication and a way to foster community consensus on ocean literacy. It was also recognized that agreement was needed on the fundamental issues of: the need for ocean literacy; the definition of ocean literacy; identification of key ocean concepts for inclusion in K-12 curricula; and alignment of ocean concepts to the National Science Education Standards [4]. In October 2004, the ocean sciences and science education communities came together in a virtual conference to develop consensus on these issues. The following sections of this paper summarize that consensus. This document describes our thinking at a particular moment in time. We continue to seek input from an ever growing circle of colleagues to achieve consensus about what is essential for students to understand about our ocean planet. For future revisions and changes to the ocean literacy concepts or to see documentation of the process used to develop this material, please visit http://www.coexploration.org/oceanliteracy.

II. WHAT IS OCEAN LITERACY?

Ocean literacy is an understanding of the ocean's influence on you and your influence on the ocean. An ocean-literate person understands:

- the essential principles and fundamental concepts about the functioning of the ocean;

- can communicate about the ocean in a meaningful way; and
- is able to make informed and responsible decisions regarding the ocean and its resources.

III. ESSENTIAL PRINCIPLES OF OCEAN LITERACY

Every ocean literate person should understand these essential principles:

1. The 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 the 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.

Please note that, by design, the essential principles are overarching ideas that do not neatly fall within a particular discipline. As a result, there are many fundamental concepts that illustrate more than one essential principle. For example, Essential Principle #4 has only two fundamental concepts listed with it, but there are several others in this document that could be. This is unavoidable and demonstrates the true interdisciplinary nature of ocean sciences.

IV. FUNDAMENTAL CONCEPTS OF OCEAN LITERACY

Below each essential principle is a series of supporting fundamental concepts, which are analogous to the fundamental concepts that underlie each standard of the National Science Education Standards (NSES).

1. The Earth has one big ocean with many features.

   a. The ocean is the dominant physical feature on our planet Earth—covering approximately 70% of the planet's surface. There is one ocean with many ocean basins, such as the North Pacific, South Pacific, North Atlantic, South Atlantic, Indian and Arctic.

   b. An ocean basin's size, shape and features (such as islands, trenches, mid-ocean ridges, rift valleys) vary due to the movement of Earth's lithospheric plates. Earth's highest peaks, deepest valleys and flattest vast plains are all in the ocean.

   c. Throughout the ocean there is one interconnected circulation system powered by wind, tides, the force of the Earth's rotation (Coriolis effect), the Sun, and water density differences. The shape of ocean basins and adjacent land masses influence the path of circulation.

   d. Sea level is the average height of the ocean relative to the land, taking into account the differences caused by tides. Sea level changes as plate tectonics cause the volume of ocean basins and the height of the land to change. It changes as ice caps on land melt or grow. It also changes as sea water expands and contracts when ocean water warms and cools.

   e. Most of Earth's water (97%) is in the ocean [. Seawater has unique properties: it is saline, its freezing point is slightly lower than fresh water, its density is slightly higher, its electrical conductivity is much higher, and it is slightly basic. The salt in seawater comes from eroding land, volcanic emissions, reactions at the seafloor, and atmospheric deposition.

   f. The ocean is an integral part of the water cycle and is connected to all of the earth's water reservoirs via evaporation and precipitation processes.

   g. The ocean is connected to major lakes, watersheds and waterways because all major watersheds on Earth drain to the ocean. Rivers and streams transport nutrients, salts, sediments and pollutants from watersheds to estuaries and to the ocean.

   h. Although the ocean is large, it is finite and resources are limited.

2. The ocean and life in the ocean shape the features of the Earth.

   a. Many earth materials and geochemical cycles originate in the ocean. Many of the sedimentary rocks now exposed on land were formed in the ocean. Ocean life laid down the vast volume of siliceous and carbonate rocks.

   b. Sea level changes over time have expanded and contracted continental shelves, created and destroyed inland seas, and shaped the surface of land.

   c. Erosion—the wearing away of rock, soil and other biotic and abiotic earth materials—occurs in coastal areas as wind, waves, and currents in rivers and the ocean move sediments.

   d. Sand consists of tiny bits of animals, plants, rocks and minerals. Most beach sand is eroded from land sources and carried to the coast by rivers, but sand is also eroded from coastal sources by surf. Sand is redistributed by waves and coastal currents seasonally.

   e. Tectonic activity, sea level changes, and force of waves influence the physical structure and landforms of the coast.

3. The ocean is a major influence on weather and climate.

   a. The ocean controls weather and climate by dominating the Earth's energy, water and carbon systems.

   b. The ocean absorbs much of the solar radiation reaching Earth. The ocean loses heat by evaporation.

This heat loss drives atmospheric circulation when, after it is released into the atmosphere as water vapor, it condenses and forms rain. Condensation of water evaporated from warm seas provides the energy for hurricanes and cyclones.

c. The El Niño Southern Oscillation causes important changes in global weather patterns because it changes the way heat is released to the atmosphere in the Pacific.

d. Most rain that falls on land originally evaporated from the tropical ocean.

e. The ocean dominates the Earth's carbon cycle. Half the primary productivity on Earth takes place in the sunlit layers of the ocean and the ocean absorbs roughly half of all carbon dioxide added to the atmosphere.

f. The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon and water.

g. Changes in the ocean's circulation have produced large, abrupt changes in climate during the last 50,000 years.

4. The ocean makes Earth habitable.

a. Most of the oxygen in the atmosphere originally came from the activities of photosynthetic organisms in the ocean.

b. The first life is thought to have started in the ocean. The earliest evidence of life is found in the ocean.

5. The ocean supports a great diversity of life and ecosystems.

a. Ocean life ranges in size from the smallest virus to the largest animal that has lived on Earth, the blue whale.

b. Most life in the ocean exists as microbes. Microbes are the most important primary producers in the ocean. Not only are they the most abundant life form in the ocean, they have extremely fast growth rates and life cycles.

c. Some major groups are found exclusively in the ocean. The diversity of major groups of organisms is much greater in the ocean than on land.

d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.

e. The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.

f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy". Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, methane cold seeps, and whale falls rely only on chemical energy and chemosynthetic organisms to support life.

h. Tides, waves and predation cause vertical zonation patterns along the shore, influencing the distribution and diversity of organisms.

i. Estuaries provide important and productive nursery areas for many marine and aquatic species.

6. The ocean and humans are inextricably interconnected.

a. The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and over half of Earth's oxygen. It moderates the Earth's climate, influences our weather, and affects human health.

b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.

c. The ocean is a source of inspiration, recreation, rejuvenation and discovery. It is also an important element in the heritage of many cultures.

d. Much of the world's population lives in coastal areas.

e. Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (such as point source, non-point source, and noise pollution) and physical modifications (such as changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.

f. Coastal regions are susceptible to natural hazards (such as tsunamis, hurricanes, cyclones, sea level change, and storm surges).

g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

7. The ocean is largely unexplored.

   a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.

   b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.

   c. Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.

   d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.

   e. Use of mathematical models is now an essential part of ocean sciences. Models help us understand the complexity of the ocean and of its interaction with Earth's climate. They process observations and help describe the interactions among systems.

   f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

V. CONCLUSION

Educational standards provide the leverage to change the content and delivery of science education. Our current K-12 education system is defined by the goal of alignment. In most states, curriculum content, instruction and assessments derive from accepted standards. If the ocean sciences continue to be excluded from state and national science standards, they will remain marginalized and efforts to incorporate them into curricula will be stymied. However, education standards are not developed and adopted easily; nor are they revised frequently. Those who are concerned about science education and about the future health of our ocean planet must actively promote the development of science standards and assessments that include ocean concepts by local educational agencies such as school boards and districts, state departments of education, and professional societies and associations. By agreeing upon and documenting the essential science content and processes related to our ocean and coasts, the ocean sciences and science education communities have provided a powerful tool for influencing state and national standards and assessments when the opportunity arises.

Additional information relating to ocean literacy and ocean resources can be found at:
http://www.ngsednet.org/oceans
http://www.marine-ed.org
http://www.cosee.net
http://www.education.noaa.gov

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