Ocean Literacy
An In-Depth Top Ten

BY TOM GARRISON

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What concepts should be emphasized in ocean education? This central ocean literacy question arises at every meeting of marine educators, lies in the heart of every teacher who sits down to plan a course outline for his or her general oceanography course, and bedevils people like me whose professional life is teaching and writing about the ocean.

Most of the lists I've seen include what might be called "the standard five," a concept set derived from students' responses to questionnaires or cursory glances at texts. The list usually looks like this:

- How deep is the ocean?
- What lives in the ocean?
- What makes waves?
- What causes tides?
- What seafood should I eat?

Student-generated lists rarely include multi-layered questions:

- Why does any land stick up out of the ocean? Mountains seem really heavy—why isn't Earth just flat and covered by water? (And how can anything be strong enough to support vast mountains to high altitudes?)
- Why is it cool near the ocean but very hot (or cold) inland? (And why does it take so long for water to boil?)
- Where did heavy elements like iron or gold come from? (And is the inside of Earth made of different stuff than the outside?)
- Are there oceans on other planets? (And must an ocean always consist of water?)
- Where did the ocean come from? (And how old is it?)

We teaching professors prefer lists like the second because they allow us to do what we like best: integrate disparate parts of the story of the ocean into a dynamic whole. You would have no problem coming up with 25 or 30 more multi-layered concepts, each worthy of a week's discussion in a general course.

But I have been working on another set of organizing concepts, and am moving toward basing my always-flexible course to them. I haven't worked out all the kinks, but on the opposite page is a list of ten large sequential ideas around which a general oceanography course might be planned.

"But where," you ask, "is my favorite topic?" You want to talk about sediments and diatoms and the carbonate compensation depth? They're in there. But these are the pivotal points that we need to cover—the pegs onto which our students can hang their knowledge. The list of topics you believe to be important can be distributed within this larger framework.

What purpose does an exercise like this serve? (And remember, this list is tentative and unconventional.) It helps to focus the teacher's attention on the truly important points he or she would wish students to remember four or five years downstream. It brings us to the central question of ocean literacy: how can one guide students to use knowledge for the greater good, use information to make intelligent decisions, and use data to teach others?

And so we try, with changeable lists like these.

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A Changeable List for General Oceanography Course Topics

1. Scientific inquiry works as a continuing chain of questioning, testing, and matching theories to observations. A theory is strengthened if new facts support it; if not, a new explanation is sought. This procedure is based on the assumption that nature "plays fair"—that the rules governing natural phenomena do not change capriciously as our powers of questioning and observing improve. We believe that the answers to our questions about the natural world are ultimately knowable.

2. The origin of Earth and ocean is a long and wonderful story. Most of the atoms that make up Earth, its ocean, and its inhabitants were formed within stars billions of years ago. As they died, some stars ejected these elements into space during cataclysmic explosions. The sun and the planets, including Earth, condensed from a cloud of dust and gas enriched by the recycled remnants of exploded stars. Our ocean is not a direct remnant of that cloud, however. Most of the ocean formed later, as water vapor trapped in Earth's outer layers escaped to the surface through volcanic activity during the planet's youth. The vapor cooled and condensed to form an ocean, now distributed in temporary basins.

3. Life originated in the ocean soon after the ocean formed, developing and flourishing in the ocean for more than 3 billion years before venturing onto the unwelcoming continents. Earth and a *single type* of life (carbon based, DNA/RNA coded, protein constructed) have evolved and grown old together. The great message of biology is unity, not diversity.

4. It has taken a long time for people to appreciate the nature of the world, but we're a restless and inquisitive lot, and despite the ocean's great size, we have populated nearly every inhabitable place. Clearly the ocean did not prevent the spread of humanity. The early history of marine science is closely associated with the history of voyaging.

5. Earth is not uniform throughout. The rigid, brittle surface of our planet floats on a hot, deformable layer of partially melted rock. Over long spans of time, movement in and below this layer carries continents across the face of Earth, splits ocean basins, and shatters cities.

6. Water is anything but ordinary. Liquid water has an important thermostatic effect—an oceanless Earth would be much colder in winter and much hotter in summer than the moderate temperatures we experience. Sea ice in the polar regions contributes to Earth's moderate surface temperatures in a different way. Because water expands and floats when it freezes, ice can absorb the summer warmth of the sun, melt, and then refreeze in winter, giving back to the atmosphere the heat it has stored. The *heat content* of the water can change through the seasons; its *temperature* may remain the same.

7. The large-scale movement of the atmosphere and ocean is driven by uneven solar heating, friction, gravity, and Earth's rotation. The waters of the world ocean are layered. Surface currents driven by the wind affect the upper layers, and circulation in the deeper layers is driven by the force of gravity. Currents near the seafloor move as slow streams in a few places, but the greatest volumes of deep water flow through the ocean at an almost imperceptible pace. The ocean mixes every million years. The whole ocean slowly falls, rises, and creeps from place to place.

8. Atmosphere and ocean are intimately connected. Heat and molecules shuttle back and forth, a meter of water evaporates from the sea and returns annually, waves travel and expend their energy. Few natural events underscore human insignificance like the rise and fall of a great storm. Powered by stored sunlight and released as frontal storms or tropical cyclones, the combination of atmosphere and ocean can do fearful damage.

9. All living and nonliving ocean systems are invariably intertwined. Alter one thing and all else changes.

10. Resource consumption cannot be sustained. Since 1961, human demand on Earth's organisms and raw materials has more than doubled, and now exceeds Earth's replacement capacity by at least 20 percent. Growth cannot continue. Our cities are crowded and our tempers are short. Times of turbulent change lie before us. The trials ahead will be severe.