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Leveraging Student Experience with Water for Active Learning in a Large Introductory Oceanography Classroom

By Rebecca Freeman

My 100+ "Blue Planet" introductory oceanography students and I file in as the Human Nutrition class files out of our auditorium-style classroom, typical for general education courses at our large state institution. About three weeks into the semester, this noisy and disorganized changing of the guard occurs as meal plans are turned in at the back of the room and an impromptu question about tides leads to a diagram on the whiteboard at the front. Students are in my classroom twice a week for two reasons. First, they must take a science class despite the tenuous connection between science and fashion merchandising. Second, they are possibly avoiding sciences that they have decided are "hard" (physics and chemistry), and they think oceanography might be interesting. After all, they always enjoy Shark Week on the Discovery Channel, and have even watched some of that BBC Blue Planet series for which the class is named. Easy A, with dolphins and sharks, right?

Alas, wrong! Introductory oceanography integrates more of the other sciences than any other science class a hapless student might choose. But, if the goal of requiring at least one science class for all college graduates is to ensure that they understand the interconnectedness of the natural world around them, then congratulations, first year students! You inadvertently picked the ideal class for you!

Research (e.g., Freeman et al., 2013) demonstrates that students like mine learn best when they are doing so actively, that is, engaging with the material on their own, making observations or solving problems. Oceanography classes, often through associated laboratory sections, have long given students the opportunity to engage in hands-on learning. Indeed, the back issues of *Oceanography* are filled with elaborate laboratory activities (see https://tos.org/hands-on-oceanography).

But what should I do with a class like mine? By this point in the semester, we've covered the physical features of ocean basins and how the basins formed through plate tectonics. Now we need to learn about water itself. Would the Human Nutrition professor let me install tanks of water in the front of the classroom while she explains vitamins? Could I get them uninstalled in the 15 minutes before Calculus class starts? Do math professors really need setup time? Or maybe we could manipulate data online. Maybe the business majors could learn MATLAB! But, regrettably, we don't have bandwidth for 100+ students on their laptops at once, and I am sure that introducing MATLAB to nonscience majors would torpedo the all-important teaching evaluations.

Classrooms like mine are the reality for many of us who teach introductory oceanography. General strategies for active learning in large classrooms are well known and effective (e.g., McConnell et al., 2017). But the pedagogical literature of our discipline is bleak on specific activities utilizing this strategy for large introductory courses.

One solution lies in the students themselves. They may have never seen the ocean (usually at least half at my landlocked state university have not), but they have been observing the water-filled world around them their entire lives. Can we harness their life-long observation of water and apply it to the ocean? Before we can get to the eagerly anticipated "dolphins and sharks," we must understand the chemistry of seawater (Clarke, 2017). And here the students start to feel that they have been duped—after all they took my class to *avoid* chemistry, not to learn it and apply it.

And how *should* we learn chemistry? Should I repeat everything they've forgotten from high school chemistry for a 75-minute breathless (for me) and boring (for them) class period? And is it necessary for them to remember all the details, or might we understand just enough to apply the concepts to the ocean?

Another trend in the broader pedagogical community is the "flipped classroom" (e.g., Herreid and Schiller, 2013), in which students are assigned introductory material to assimilate before class. I record a video (see online supplementary material, with accompanying PowerPoint) that introduces the students to the concepts they need to know about water. I remind them of some basic chemistry from high school, but I try to keep the language as simple as possible. Hyperlinks to online review material fill in gaps for those who have truly forgotten everything about chemistry, or perhaps never had it at all. The video is quite short because a scripted me rambles less than an impromptu me.

In class I put up a summary of what we have learned about the water molecule:

Water has the following unique combination of qualities:

A. H_2O molecules form hydrogen bonds with each other. They are *cohesive*.
B. H_2O molecules like to bond with ions or other charged molecules. They are *adhesive*.
C. Because water bonds easily with other ions, it is the "universal solvent."
D. Water has a high specific heat.
E. Water has a high heat of vaporization.
F. Water's greatest density is at 4°C. Above or below that temperature it becomes less dense.
G. Water has a low viscosity.

We begin by discussing what we still don't understand about the water molecule. One troubling issue is the how the cohesiveness of water molecules causes a surface membrane to form. "Raise both arms," I tell the students, "you are now water molecules. Now find two other water molecules to bond with, using your arms to point to them." Empty seats in the middle of the auditorium ensure that the structure takes on a realistic randomness as students are forced to bond with molecules in all directions. But in the back row, with every seat reliably filled, and with no one to bond to behind them, the students have formed a perfect example of a membrane.

I give the class a scenario: *It is a hot day at an outdoor concert. You walk through a misting booth, and for a few minutes afterward you feel much cooler.* (See online supplementary materials for worksheet, PowerPoint, and teaching guide.) Which of the concepts (A–G) is being illustrated here, I ask? We take time to break into discussion groups. I wander around the classroom and listen to their discussions. Some google on their cell phones, others put their headphones in to listen to the relevant part of the video again, while others go "old school" and break out the textbook. As students arrive at an answer, disagreements lead to both parties backing up their answers by explaining the science to each other. All around the classroom, learning is noisily and actively happening with nary a saltwater tank in sight.

When we move on to discussion of the answer (E), I ask for a volunteer to state and defend his/her answer. Occasionally a student answers incorrectly, prompting my gratitude. "Thank you so much for identifying a major misconception that I am sure that many of your classmates share! [Applause.] Let's discuss how you arrived at this answer, and then I am sure that everyone will understand this concept better for the mid-term!"

Later, when discussing the condensation of water droplets in Earth's atmosphere, I remind students that this is the opposite process as described here and ask them to predict how condensation would affect the temperature of the surrounding atmosphere.

We move to another scenario: *You're on a road trip through the desert. You stay in a hotel with a swimming pool. Even though it's been scorching hot all day, you dive in without fear.* Two answers (D and E) are correct, but I enjoy wandering the classroom again while Camp D argues with Camp E, concluding that the professor has given them a "trick" question. A student tentatively volunteers that this scenario possibly has two answers. "Congratulations," I say! "You understand this material well!"

And they do. The mid-term includes similar scenarios. The students see connections between class activities and the exam. It seems "fair" and suddenly science isn't so bad after all. When we move on to bigger-picture oceanographic concepts, like thermohaline circulation, we relate back to these everyday scenarios of how water behaves.

We would all like to teach small classes with meaningful laboratory activities on an unlimited budget. But facing limitations means identifying and creatively using the resources that we *do* have available. We who teach large introductory courses under less-than-ideal circumstances put as much time and effort into designing active learning for our students as the design of any elaborate lab exercise might require. We should be proud of our efforts and disseminate them to the broader oceanographic community, starting with outlets such as tos.org.

SUPPLEMENTARY MATERIALS

The following material is available online at https://doi.org/10.5670/oceanog.2018.423: PowerPoint lesson, video lesson, worksheet, PowerPoint paper-free worksheet substitute, and teaching guide, including ideas for modifications for various educational settings.

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