Using a Person as a "Human Sound Wave" to Simulate Sonar
(demonstration lasts approximately 35 minutes)

Dr. Kent M. Syverson
Dept. of Geology, University of Wisconsin, Eau Claire, WI 54702
(715) 836-3676
syverskm@uwec.edu, May 31, 2013

Course: Geology 102--Oceanography, 3 semester credits, three 50-minute lectures/week. An undergraduate-level, optional course used by many students to fulfill part of their natural science general education requirement. The course has no prerequisites.

Introduction

Oceanography is a non-lab, three-credit course taken by 150 to 200 UWEC undergraduate students per semester. The course is taught in a large lecture hall, and it is always a challenge to engage students in topics involving physics and math. To start the semester, I spend two lectures discussing how knowledge of the oceans advanced through time. History is boring to many students, so I try to use innovative methods to help students understand important events/technologies. I also try to engage students early and then keep them "hooked." As a part of this effort, I developed a "human sound wave" demonstration to illustrate the principles of sonar.

The ability to determine the depth and shape of the ocean floor revolutionized our understanding of the oceans. The Challenger Expedition in the late 1800s used one of the simplest techniques -- dropping a weight on a rope until it encountered the sea floor. The Challenger discovered water 8200 m deep in the Pacific Ocean. I demonstrate this technique in class using string with a magnet on the end. Obviously this method is very slow and inefficient. The major breakthrough in depth determinations occurred in the 1920s when Germany developed **SONAR** [**SO**und **NA**vigation and **R**anging] to determine water depths. A working sonar system requires four basic elements:

1. A sound wave source
2. A sound wave receiver
3. A timer
4. Some sort of time plotting/recording mechanism

In a working sonar system, an energy source sends out a sound wave. The amount of time required for the sound wave to travel downward, bounce off the sea floor, and return to the receiver at the ocean surface is measured. Using this two-way travel time and the velocity of sound in water, it is possible to rapidly determine the depth of the ocean. Although this is a simple time-distance relationship, explaining sonar solely using diagrams and calculations is rather mystical for many math-challenged students. The "human sound wave" demonstration simulates a sonar device and enhances student understanding of the process.

"Human Sound Wave" Demonstration

Two student volunteers are required for the demonstration. These include:

Student #1 – the Recorder. The Recorder creates a graph on the whiteboard and plots data points
Student #2 – the Timer. This person serves as the Wave Source, Receiver, and Timer. Can be any student who knows how to work his/her cell phone stopwatch.

The Recorder is instructed to make a graph on the whiteboard with time on the vertical axis (values increasing downward in increments of 2 seconds, draw horizontal lines for each time increment). As the Recorder makes the graph, the demonstration is explained to the entire class. During the demonstration, the front of the classroom represents the ocean surface, and the first obstruction toward the student seats is defined as the "sea floor." When the Wave Source says "Go," I (the Human Sound Wave) run from the front of the lecture hall until I encounter an obstruction (the first row of chairs), bounce off them, and run back to the whiteboard. My arrival time at the whiteboard (two-way travel time) is measured by the Timer, reported to the Recorder, and plotted on the whiteboard graph. Depth soundings are conducted at 1-meter intervals across the front of the lecture hall, and all arrival times are plotted with equal horizontal spacing on the graph. When I encounter an aisle, I run to the back of the lecture hall, bounce off the wall, and return to the whiteboard where my arrival time is much greater than other values for "shallow water." Thus, the aisles plot as deep valleys on the ocean floor and other areas plot as shallow water, just as a sonar printout would look.

At this point I ask the entire class to read the graph and tell me the depth of the ocean in the lecture room. (A student might say, “14,” and I ask, “14 what?” Eventually they tell me seconds.) Students recognize that the water depth is still unknown because the vertical scale is in units of time. Somehow this time data must be converted into a distance. Many students are in the problem-solving mode by this time, so brainstorming with students invariably results in a suggestion to use the Human Sound Wave velocity (V_{hw}) and the travel times to calculate the depth of the ocean.

All necessary data is available except V_{hw}. Students tell me how to calculate this velocity (measure how long it takes the Human Sound Wave to travel a known distance), so I pace off the distance across the front of the lecture hall and have the Timer measure the time it takes the Human Sound Wave to run this distance twice. This calculated V_{hw} will be used to convert the two-way travel times on the graph into water depths.

We discuss other similar examples (such as how far a person can travel in two hours at 50 miles per hour), and then proceed to analyze the "human sound wave" data set.

Two-way arrival times are used to calculate the "depth" of the classroom "ocean." Students have seen the Human Sound Wave travel to the sea floor and back again, so they qualitatively understand the concept of two-way travel time. I diagram the problem on the whiteboard, show

how the wave has traveled through the water depth twice, and from this we are able to derive the equation for converting the time data to water depth:

$$D = V_{hw} * T/2$$

where D = depth of the ocean (ft), V_{hw} = velocity of the Human Sound Wave (ft/sec), and T = two-way travel time (sec).

The calculated "depths" are then compared to actual distances as observed by students in the classroom. Generally the distances are fairly accurate, especially for greater "water depths" where stairs are not present. However, some values are obviously inaccurate. Such places include where the "actual water depth" is identical at two adjacent sampling points, yet our depth soundings indicate different water depths.

I ask students to analyze the errors associated with the human sound wave demonstration. This discussion is valuable, because many of these sources of error may occur with a real sonar system. Thus, the demonstration facilitates an intelligent discussion of errors associated with real a sonar system operating in the marine environment. These errors include:

- Velocity of the Human Sound Wave is not constant because of 1) running up and down steps, and 2) time it takes to accelerate and change directions (especially significant for short travel distances). I ask if the speed of sound is constant in the real world (no, it is not), and then using a common-sense understanding that denser water is at the bottom of the ocean (change in temperature and salinity), students infer that sound waves should speed up at they move downward to the sea floor. Unless a correction is applied, depth calculations will be inaccurate.
- Clock problems (Timer’s reaction time or inaccurate clock).
- Recorder problems.
- Improper communication between the Timer and the Recorder.
- A student comes in late and I bounce off of the student (a fish finder).

I find that students leave with a good understanding of sonar (and a good laugh as well).

Results

This demonstration is effective for several reasons:

- Observing the Human Sound Wave travel to the sea floor and return to the surface helps students understand the concept of two-way travel time. This method works well for visual learners.
- Once students see the Human Sound Wave in action, the method for analyzing the two-way travel time data seems less complicated because students can relate the concepts of sonar to common problems in their lives (how long it takes to drive to a town X miles away at Y miles per hour, for example).

- I ask students to evaluate why sonar was such a breakthrough for measuring water depth, and students recognize the method is much faster than using a rope and weight. Thus, a high-resolution map of the sea floor can be generated using sonar.
- Students better understand errors associated with a real sonar system.
- The demonstration breaks down barriers between students and the instructor early during the semester. Seeing the professor act a little crazy is appreciated by the students, and they tend to participate more when they are enjoying an activity. This establishes positive momentum for student participation during the entire semester, and I try to do other somewhat "crazy" things during the course of the semester to build on this momentum. Students comment very favorably on the human sound wave activity in course evaluations, and students remember the basics of sonar years after they were in the course!

Other miscellaneous notes

1. Run the demonstration in the lecture room beforehand so the Recorder can draw the appropriate vertical time scale for the graph.

2. Recruit a student to be the Human Sound Wave if you are not comfortable running in the classroom.

3. Stress to the Recorder that equidistant depth soundings will be made across the front of the classroom, so two-way travel data points must be equally spaced in a horizontal direction. Check the work of the Recorder for the first few points to make sure data is being plotted properly.

4. Use humor if possible (pretending to be a sprinter, showing slow motion of the Human Sound Wave bouncing off the sea floor when evaluating sources of error, telling students they will fail if they trip me while I am running, etc.).

Conclusion

I have found this low-technology teaching technique very effective in the classroom. I think that other teachers easily could use this demonstration with positive results in their classrooms as well.