Interactive Examples - Randall M. Richardson

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#1: Hypothesis testing, a sense of time, and conversion of units:

I break the class into groups of about fifteen. I have them calculate their ages in seconds, write it down on a piece of paper, and put it in a bag. I add my own age in seconds to the bag. We hypothesize that they can tell when my age is drawn from the bag. We pull one out. It may be some number like 599,184,000 seconds. I ask them, "When you tell someone hold old you are, how many significant digits do you use?" The typical response is something like, 'two' (in this case, the student was 19). We talk about giving your age as 19.4397 (also six significant digits), and they typically laugh. Then why is the answer given to six significant digits? "Because that's what the calculator said when I took 60*60*24*365*19". Thus, we learn about significant digits. Then I ask if the number drawn is mine. Most say it is not. "How come?", I ask. "Because it's too small". I use this to help them see that they have an expected result in mind when they collect the data. Then we continue pulling numbers until mine is pulled. They are all very happy when they can distinguish mine (it is at least a factor of two bigger in a first year class; if there are older students in the class we sometimes modify the hypothesis). Then we draw the rest and in most cases there is at least one mistake. Sometimes the mistake is enough to make it difficult to distinguish the 'noisy data' from my age. We then talk about the quality of data, and how noise in data can lead to erroneous conclusions.

Students gain experience working with large numbers, significant digits, hypothesis testing, & data quality.

#2: Building a concrete sense of geologic time:

After having talked about the geologic time scale (Precambrian: prior to 570 Ma; Paleozoic: 570-245 Ma; Mesozoic: 245-65 Ma; Cenozoic: 65 Ma - Present), I ask for two volunteers from the class to hold a rope that is about 15 feet long. I say that one end is the beginning of the Earth (4.6 billion years ago), and the other is today. I then give out about 10 clothes pins and ask various students to put a cloths pin on the 'time line' at various 'geologic times'. For example, I ask them to put one where the dinosaurs died out (end of the Mesozoic). They almost invariably put it much too old (65 Ma is less than 2% of Earth history!). Then I ask them to put one on their birthday (they now laugh). Then I ask them to put one where we think hominoids (humans) evolved (~3-4 Ma), and they realize that we have not been here very long geologically. Then I ask them to put one at the end of the Precambrian, where life took off in terms of the numbers of species, etc. They are amazed that this only represents less than 15% of Earth history. Finally, I ask them to think of the time line as their own age, and think about how long ago, on a comparable time scale, the dinosaurs died. It is only about two 'months' ago! The exercise is very effective at letting them get a sense of how long geologic time is, and how 'recently' some major geologic events happened when you consider a time scale that is the age of the earth.

#3: The Wave:

I have the class leave their seats and form a circle around the edge of the classroom (if necessary, they could make a double loop). I then ask them to do The Wave, as seen at football games, starting with a volunteer student. Then I ask them how long it took. To get data, they do it again, and measure the time (let’s say 10 seconds). I ask them how many cycles they completed in the 10 seconds (one). “So, it’s ‘one cycle per ten seconds’. What was the frequency of your wave?” They work together and come up with 0.1 Hz. I ask them the distance around the circle (i.e., the wavelength; let’s say it’s 30 m). “So, how fast did the wave go?” Again, in groups, they figure it went 30 m in 10 s, or 3 m/s. I ask them to do The Wave again in 5 seconds. They do, almost invariably laughing at the effort to speed it up. I ask them what frequency the wave had this time, and they figure out it is 0.2 Hz. “How fast did the wave go?” 6 m/s, or twice as fast when the frequency is doubled. I ask them to work out a relationship between frequency (Hz, or 1/s), velocity (m/s), and wavelength that works out unit-wise and is consistent with their observations of the velocity doubling when the frequency is doubled (vel = wavelength x freq).

An important concept for students to learn is the difference between longitudinal (or compressional) waves and transverse (or shear) waves. I ask them to do The Wave again, and ask them to notice how their hands move as the wave passes. They realize that The Wave moves horizontally from person to person, but their hands only move up and down, at right angles to the motion of The Wave. This is a transverse (at right angles) wave. Then I ask them to generate a longitudinal wave. They usually come up with something along the lines of stepping left or bumping shoulders, or (gently!) pulling on each other. They do this kind of a wave, and realize that their motion is horizontal, or aligned with the direction the wave moves. Then I tell them that sound waves are longitudinal waves and that water waves have a transverse component (an oversimplification). Longitudinal and transverse (P and S) waves in the Earth travel at different speeds, and hence give us different information about Earth structure.

Another concept I want them to learn is that energy is transported in waves without the medium actually moving the distance the wave travels. In their longitudinal wave I ask them if any student went all the way around the circle. “Of course not!” But it’s clear that the energy did!

Finally, I play with waves reflecting off of boundaries by having one student ‘bounce’ the wave back when it gets to him/her, so that they can see it ‘reflect’ off a boundary and travel in the other direction. I also let part of the wave be transmitted through the boundary and part reflected, and they have a lot of fun trying to have the wave go both ways.

This is one of the most effective activities I've ever used. Before using it, students had a difficult time understanding the difference between longitudinal (P) and transverse (S) waves, which made it difficult to communicate that P and S waves give us different information about the Earth. Not only do students really learn the difference, they discover the relationship between wavelength, frequency and speed, applicable to all waves.

#4: Stripes on the Sea Floor

Students often have trouble understanding the origin of magnetic stripes on the sea floor associated with spreading at mid-ocean ridges. We have already discussed that the Earth's magnetic field reverses polarity from time to time.

I have the class assemble into a large mass at one end of the classroom. I tell them that they are the magma chamber beneath a mid-ocean ridge. I pick two students to stand at the top of the magma chamber and represent continental crust above a future mid-ocean ridge. I have the continent rift apart by asking the two students to each take one step sideways and allow out two new students who are oceanic crust. These two new students, the first ones out, face forwards because they formed when the Earth's magnetic field is in its normal polarity. Now all four students outside the magma chamber again take a step sideways letting two new students out. Since I haven't reversed the polarity of the Earth's magnetic field, these students also face forwards.

All six students take a step sideways and let two new students out. This time, however, I tell them that the Earth's magnetic field has reversed, and the two new students come out facing backwards. Typically, the four students representing oceanic crust already out try to turn and face the other direction, but I tell them that they have already cooled and locked in the Earth's normal polarity. Only the new ones face backwards.

I let the process continue, sometimes reversing the magnetic field, but in the end producing 'stripes' of students facing opposite directions representing crust that was created during normal and reversed polarity times. We continue until the students run into a wall or until I feel that they understand the process.
An added benefit of this demonstration is that students can see why the oldest sea floor is next to the continents and farthest from the mid-ocean ridge (they were the first ones out). Finally, it also leads naturally into a discussion of recycling of oceanic lithosphere when the students run into the wall at the edge of the classroom.