Issues in Earth Science
"Topics for Debate"
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Hypothesis, Theory and Law:
Discovery Through Questioning

by
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My attention was caught recently when, at a professional conference on the geology of North Dakota, a presenter posed this question:

"Why don't we find coal from the Cretaceous period in North Dakota? Here, commercial deposits of coal don't appear until post dinosaurs. The swamps and vegetation were surely here with the dinosaurs. A scientist in California has a theory that the dinosaurs ate too much of the vegetation not allowing it to be deposited in great enough quantities. Post dinosaur-demise, more vegetation was deposited and hence led to coal forming in the Williston Basin after 50 mya."

I thought to myself, "At best, that is a hypothesis, not theory. If an industry professional cannot use the terminology of hypothesis, theory and law correctly, science teachers have an even bigger job to do than I thought!"

I next considered what other explanations might account for the absence of large minable deposits of coal in North Dakota prior to the extinction of dinosaurs. What additional evidence indicates that dinosaurs eating too much vegetation is a reasonable explanation? Was it even true that similar swamps and vegetation were present in North Dakota before and after the extinction?

The session wrapped up, and I made sure not to waste the valuable awkward silence after, "are there any questions?" I asked for an alternate hypothesis. Unfortunately, the presenter had never really thought about it. The idea put forward made sense to him, so he accepted it. I asked another question on the vegetation present in North Dakota during the reign of the dinosaurs.

I thought it was similar to a savanna not a swamp/wetland so I was curious as to what evidence or data indicated wetlands. He was not sure once again and thanked me for great in-depth questions. The session ended with no additional questions and the majority of people hurrying to the soda and snack table.

Upon reflection, I decided the most frightening thing I saw in that room was 120+ people, many of them in science, who never questioned what the presenter said. Did they accept all of the information presented as fact? The industry professional accepted the information because “a scientist from California” had an idea. Did he consider the evidence for himself or even examine that scientist’s credentials?

Students across the country are asked to “define” scientific hypothesis, theory and law as part of state and national standards. Teachers often have students classify examples into one of the three definitions. They stress to students that theories are widely accepted fundamental explanations of natural phenomena. However, despite this memorizing, classifying and listening to explanations of terms, students often fail to understand that a theory is linked to underpinning evidence.

Students generally can classify plate tectonics as a theory because they are told it is a theory. They accept it as theory just like the presenter accepted the scientist’s 'theory'. However, students should examine and question the evidence. Some questions could be: “How can earthquakes occur inland away from plate boundaries?”, “Why does the depth of earthquakes get deeper as you go inland at ocean-land boundaries?”, “What are alternative explanations for the same species of terrestrial reptile fossils being found in South America and in Africa?” As students question the evidence and look for alternatives they gain appreciation for what a theory is and can truly start to see how a hypothesis is different from a theory. The downside to this approach is that it takes time. The upside is you are instilling higher order thinking in your students. To improve science ability, one must question and think. Is it possible that the presenter would have offered a more convincing case, and avoided embarrassing errors, had he first questioned the material he presented?

I get feedback from my students each year. One question I ask is: what was your favorite unit, and why? Most students respond that their favorite unit was the one on evolution. Their reasons are similar: “never learned it before”, “everything was on the table for discussion”, and “did not shy away from controversy”. They seem to engage with this more controversial topic because they want to 'disprove' the evidence. They examine misconceptions and offer arguments which lead to counter arguments. This type of engagement and questioning leads to actual learning. By testing students on retention of facts instead of thinking, is it inhibiting teachers to teach affectively and actually training students to just accept what they are told?

You can probably tell from my writing that I am in favor of teaching how to examine, test, and question theories, rather than teaching the definitions of theory, law and hypothesis. The first method leads naturally to an understanding of the second. By coaching and practicing thinking in your classroom you are changing the culture from memorizing the standards to understanding, questioning and making connections related to the big picture.

I leave you with one last thought to ponder. Autumn, my 3 year old, is full of questions and is constantly asking why. She is bursting at the seams to learn more. Why is this desire lost as we age? How can it be re-instilled in a group of 25-60 year old people at a professional conference, or is it too late for them? Most importantly, how can the desire to learn through questioning be resurrected in students—tomorrow's adults?

Patrick Schuette holds college degrees in geology and biology. He teaches high school science in the Dassel-Cokato school district in Minnesota and is the proud father of two budding explorers, Autumn and Briella.

Credit: Photo by Mary Colson

Seed Thesis for Issue 4: Theory in the Classroom

by Russ Colson

Most of us are aware that the word 'theory' is used differently in common conversation than it is in science.

For example, as we approach the highly-anticipated release of Star Wars VII, one might say "My theory is that Yoda will come back from the dead and save the day!" On the other hand, in science, the word 'theory' refers to a conceptual synthesis of observational data that has been extensively tested in the lab and field. It is not someone's idle speculation subject to casual challenge with limited data.

The misunderstanding of the meaning of scientific theory has led some people to think that alternative 'theories' should be presented in the science classroom, such as ideas arising from religious beliefs. Although religious ideas are an essential part of the human experience and should be included in a well-rounded education (in the view of this writer!), most scientists and science teachers don't believe those ideas belong in the science classroom because they do not arise from the methods and practices of science, nor do they meet the scientific criteria to be considered a theory.

However, do we teachers, in our eagerness to emphasize the well-tested nature of scientific theories, present theories as the goal of learning? Instead of teaching the processes of questioning, testing, and reasoning that provide the foundation for theories—what the Next Generation Science Standards (2013) call the 'Practices of Science and Engineering'—do we jump to the theories themselves as the end product of education? Do we sometimes even treat the theories as 'facts' to be memorized instead of a synthesis of observations derived through the practices of science?

It seems to me that even the Next Generation Science Standards--despite their goal of encouraging more practice of science in the classroom--emphasize theories a bit much, especially theories that are politically controversial. Consider for example the importance placed on teaching the theory of evolution in the life sciences or the importance placed on telling students that climate change is real in the earth sciences.

In placing so much emphasis on the theories that have been derived by the practices of science, we short-shrift the practices of science. Students then arrive in my college classroom without the ability to distinguish between theory and the evidence for it. In fact, sometimes students even get confused on which is more foundational, the theory or the observation that supports it. One student wrote "Some people don't understand that (an observation) can't be true if it goes against scientific theory."

Yikes.

So what are your thoughts? What is the best balance in the classroom for teaching theories versus teaching the methodologies by which we have figured out and tested those theories?

Dr. C.

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