About a month ago, I got a flyer in the mail advertising software to aid in three-dimensional visualization of geologic structures. “Reduce your uncertainty!”

I’m not sure that’s what my students need.

My department (at a public liberal arts college, with no graduate students) teaches students how geoscientists do science by getting the students involved in collecting and interpreting data, starting with class projects as freshmen and culminating in senior theses based on independent research projects. My introductory Earth Systems Science class collects and interprets data on a small local river. My sophomore mapping class writes a report that accompanies their final mapping project. My junior Structural Geology class writes reports that separate their observations from their interpretations for every field lab. Our seniors propose research projects during their junior year, collect their own data, and present their work as papers and professional talks at the end of their junior year. And my colleagues take similar approaches in their classes.

This semester, I taught Advanced Structural Geology, an upper-level elective taken by about ten junior and senior undergraduates. It’s the one course in which I can teach nearly anything I want, and this semester, the course was inspired by a pair of articles by Clare Bond and colleagues at Midland Valley, a structural geology software company. Clare had shown a synthetic seismic section to geologists at conferences and asked them to interpret it, and found that only a fraction of people with related experience had interpreted it correctly. The most successful approaches involved thinking about the sequence of events that formed the structures, rather than simply identifying the geometry. Midland Valley creates software that allows testing of structural geology hypotheses through various kinds of modeling, and at conferences, I’ve seen Clare argue that their software can be used to improve geologists’ understanding of hidden structures. I decided to focus my course around their software, and around the use of modeling in structural geology in general, in part because I thought Clare’s arguments were compelling, and in part because I was concerned that our undergraduates don’t give a lot of thought to what they are trying to accomplish when they use specialized software. But I didn’t just want the students to learn to use software – I wanted them to make a habit of thinking about the tools that they use to solve particular problems, to think about the underlying assumptions, to think about whether the software was testing the students’ conceptual models of their structures, or whether they were using the software to confirm things that they were already certain were true. The final project for the class was to apply the software (or another type of modeling software) to a structural geology problem, and to write a paper that discussed both their results and their assumptions.

I graded the final papers for both Advanced Structure and my introductory course last week, and as I read them, I wondered whether the process of collecting and interpreting data really helped them understand how science works. In paper after paper, the intro students told me that the river behaved exactly in the way that they expected (even though there were several strange results in the data – for instance, an unusually high discharge measured at one site, paired with surprisingly low turbidity). In paper after paper, my Advanced Structure students told me that the software worked because it reconstructed their cross-sections correctly, and that their cross-sections must have been right because the software said so. All of the students, intro and upper-level, were so *certain...* without good reason to be.

It made me think that maybe this whole process of science is just plain *hard* for humans. Not because we have to do math or physics or chemistry or scale shear cliffs while carrying thirty pounds of rocks, but because we don’t like uncertainty. We don’t want to look for those things that might show us that the world doesn’t work the way we think it does. It’s scary. It’s stressful. And we’re rewarded for being right, not for questioning ourselves.

And yet it’s that questioning that makes science a valuable way to understand the world. If science brings us closer to an understanding of the natural world, it’s because science tests its assumptions.

But if doing the kind of work that scientists do isn’t enough to create a habit of open-mindedness, a willingness to examine one’s assumptions and be aware of how those assumptions shape our results, what should we (as teachers) do?

I don’t know. Here’s an example of something else that I did, something that I thought worked, but which probably wasn’t enough:

I took my Advanced Structure class on a field trip over spring break. In the middle of the field trip, I had them map in an area where they knew there could be normal faults, thrust faults, strike-slip faults, folds, overturned stratigraphy – almost anything possible at shallow levels of the crust. They had seen the basic stratigraphy, and they had aerial photos and compasses. I sent them out to figure it out.

After about an hour, I went looking for the groups. Some of them thought they had figured out the answer. Most of them were wrong, and I tried to get them thinking about what observations they needed to make to test their models and think about other possibilities. Other students were just confused, and frustrated, and needed coaching to start brainstorming possibilities. I sent them all off again with sketches of possible cross-sections and predictions that each cross-section implied.

In the van at the end of the day, I told them that being confused is part of the field geologic method. “Go outside. Walk around. Get confused. Sketch possibilities for what might be going on. Walk around some more and see if those possibilities match what you see.”

But I think that in the end, they really wanted to be certain that they were right, whether the evidence was strong enough for their certainty or not.