

Why I teach my students about scientific failure

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With class about to start, I print 14 Western blot images for my students to discuss. The 3-hour lab is supposed to be the culmination of a weekslong research project in my undergraduate biology course, the day my students determine whether their experimental results support their carefully crafted hypotheses. But the images are all the same—and all full of nothing but background bands. My students are about to have a hard lesson in scientific failure and how to be resilient in the face of it. It's a lesson I wish I'd learned before starting grad school.

As a Ph.D. student, I went through many frustrating cycles nurturing hypotheses that would later wither because of technical failures or ambiguous experimental results. When I graduated, I thought I would never do bench research again. I wasn't willing to sacrifice so many hours away from my young children with so little to show for it. Instead, I embraced my love of teaching by working as a lecturer.

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A decade later and with my kids in school, my scientific curiosity came out of hibernation and I restarted my research career. After a stint as a postdoc, I secured a position at a liberal arts college, where I established my own small lab. In my undergraduate classes, I asked my students to complete lab experiments that were virtually guaranteed to yield interpretable data. But after a few years, I grew uncomfortable with the gap between those picture-perfect experiments and my own research projects. Yes, my students left lab sessions with results, feeling their time had been well-spent. But I worried I was deceiving them about the actual experience of practicing science, which rarely produces data on the first try.

I decided to develop a new course that would give our students experience performing real experiments, ones that had the potential to fail. Using my own research interests as a framework, I gave the students a collection of papers to read. During group brainstorming sessions, they identified new questions that arose from what had already been done and collectively came up with their own hypotheses. After spending time learning lab methods required to test their hypotheses, they got to work performing their first experiment.

On the day of data analysis, I handed them the Western blot printouts and asked them to look over the images and discuss their findings. Most assumed their blots were correct—that the background bands they saw represented the proteins they had hoped to detect—and jumped immediately to interpreting the data. But I refused to let the students move on.

After a solid hour of struggle and some leading questions on my part, one student finally spoke up. “It doesn’t make sense. The bands look the same size, but the proteins should be different sizes.” Hallelujah! A student had stepped back from seeing what they expected to see and described what the data actually showed. Their breakthrough helped their classmates start to look at the results with more objective eyes. Within minutes, they were overflowing with questions and ideas about what could have gone wrong. We spent the next 2 hours covering the chalkboard with plans to troubleshoot the experimental procedures. My students were thinking like scientists—a development no amount of advance planning could have created.

Afterward, I reflected on how we train future scientists. Should we talk more openly with students about failure? When I quietly left research, frustrated at what felt like my lack of accomplishment, was this a typical experience? How often do we inadvertently discourage students from persisting in science, simply by omitting honest descriptions of the failure inherent to the research process? Research is messy and full of failed attempts. Trying to protect students from that reality does them a disservice.

My class never did generate data to test their hypotheses. Instead, we finished the semester reading about and discussing scientific failure. I hope the handful of students who go on to graduate school will learn from the experience and bring an awareness with them that success doesn’t always come easy. I trust this knowledge will help my other students as well, wherever they go.