The Dogma of "The" Scientific Method

This is the challenge of science– to shed dogma and get closer to the truth.

– Rudolph Tanzi & Ann Parson (2000, p. 2)

It's altogether too easy to reduce all method in science to a simple algorithm. Hypothesize, deduce (or predict), test, evaluate, conclude. It seems like a handy formula for authority. "The" Scientific Method (expressed in this way) haunts the introductions of textbooks, lab report guidelines, and science fair standards. Yet we consider it a poor model for learning about method in science.

We endorse instead teaching about the Scientists' Toolbox. Science draws on a suite of methods, not just one. The methods also include model-building, analogy, pattern-recognition, induction, blind search and selection, raw data harvesting, computer simulation, experimental tinkering, chance and (yes) play, among others. The toolbox concept remedies two major problems in the conventional view. First, it credits the substantial work–*scientific* work–in developing concepts, or hypotheses. Science is creative. Even to pursue the popular strategy of falsification, one must first have imaginative conjectures. We need to foster such creative thinking skills among students. Second, the toolbox view supports many means for finding evidence– some direct, some indirect, some experimental, some observational, some statistical, some based on controls, some on similarity relationships, some on elaborate thought experiments, and so on. Again, we think students should be encouraged to think about evidence and argument broadly.

Consider just a few historical examples. First, note Watson and Crick's landmark model of DNA. It was just that: a model. They drew on data already available. They also played with cardboard templates of nucleotide bases (Watson, 1968). Yes, their hypothesis of semi-conservative replication was eventually tested by Meselson and Stahl–*later*. But even that involved enormous *experimental* creativity (Holmes, 2001). Consider, too, Mendel's discoveries in inheritance. Mendel did not test just seven traits, cleverly chosen in advance (as the story is often told). Rather, he seems to have followed *twenty-two* traits, hoping for patterns to emerge. He ultimately abandoned those he found confusing (Di Trocchio, 1991). Nobelist Thomas Hunt Morgan, in Mendel's wake, did not discover sex-linkage through any formal hypothesis about inheritance. He was looking for species-level mutations. When he first encountered his famous white-eyed mutant, he did not immediately frame a prospective conclusion. Rather, he probed and observed, not sure what he had found (Allen, 1978). Or consider Darwin. Darwin arrived at natural selection, of course, through synthesizing observations on biogeography, fossils, organismal design, population growth, and limited resources. Only *subsequently* did he reconstruct it as "one long argument" in the *Origin of Species* (Mayr, 1991). In their more recent and monumental work on Darwin's finches, Rosemary and Peter Grant have simply extracted significant patterns from voluminous data they collected over many years (Weiner, 1994; Grant & Grant, 2002). No hypothesis. No experiment. No control. If such great heroes of biology did not use the prescribed Scientific Method, how can anyone justifiably portray it as "the" method of science?

Scientific papers do indeed seem to follow the scientific method. But they are *reconstructed* accounts of *completed* work. They are composed to fit a standardized *publication* format. They do not describe how research always occurs in practice (Medawar, 1964; Bazerman, 1988; Knorr-Cetina, 1984).

The chief problem we see is that students come to believe that the Scientific Method *guarantees* discovery and unambiguous, reliable conclusions. Uncertainty, incompleteness, or revision are excluded. Of course, science is fallible. But *how?* The Scientific Method does not say. Bauer (1992) has nicely profiled how the mythic Method misleads. For Bauer, scientific ideas develop gradually, subjected to successive

filters. There is no unique algorithm yielding absolute truth. We believe that students need to learn how science can be limited, how some evidence can be complex, and how some questions can be unresolved. That, in turn, helps them understand how (or when) we should trust scientific claims. Such judgment is especially important as more and more public decisions involve complex and/or ongoing science (Anand, 2002).

Given that the conventional Scientific Method does not adequately describe the richness of science, we marvel at its hold on the school mindset. Why the entrenched dogma? At one level, the simplicity may be merely convenient. But the dogmas may be deeper. Those who actively defend the Scientific Method (recently in *ABT:* Lawson, September, 2000; McPherson, April, 2001) seem concerned with the privilege of science. For them, science is special. It is beyond the ordinary. It is exclusive. The Scientific Method demarcates Science with a capital 'S'. Without discipline, it would seem, no claim is any better than any other. Order seems secured by rule-following and conformism. Portrayed in this way, of course, the promise of The Scientific Method seems grossly overstated. Yet we wonder how prevalent this perspective is.

We agree instead with Albert Einstein (even though he was not a biologist!): *"The whole of science is nothing more than a refinement of everyday thinking"* (Einstein, 1954, p. 283). Accordingly, a conception of scientific method should grow out of familiar experience. It should complement and extend ordinary discovery processes. And it should highlight how to establish reliable evidence–an aim shared, for example, by journalists and judges. A physician diagnosing an illness, a mechanic troubleshooting a car, a detective tracking a crime all use the same methods as scientists, although in different contexts. Lab work should make sense. The reasoning shouldn't seem foreign. Students should see that when we apply these same methods to understanding the natural world, we call it science.

We thus encourage our colleagues to teach the suite of skills in science. *ABT* is an excellent resource. In just the past two years, articles have featured such skills as:

- framing inquiry questions (Marbach-Ad & Clawasen, 63/6),
- building hypotheses (Hoese & Nowicki, 63/3),
- designing experiments (Deutch, 63/4; Temple, 64/1), and
- integrating and assessing data from multiple methods (Singer, Hagen & Sheehy, 63/7).

In addition, we advocate historical case studies, which allow students to see biology in action (e.g., Hagen, Allchin & Singer, 1996; reviewed in *ABT,* April, 1999).

If one must characterize method in science concisely, let it be something like this:

Scientists follow hunches, clues, and questions obtained from observations, earlier claims, reading, etc. They explore how to generate relevant information. They consider possible sources of error. They engage others in interpreting evidence. Results usually lead to more questions. Ideas are refined. Some change, some are abandoned.

Yes, teach how to pose hypotheses. Yes, teach controlled experiments. As tools. And don't stop there. Viewing science as constrained by one privileged method is greatly impoverished. We do science in many ways. Let's teach the Scientists' Toolbox.

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