

from data analysis: be on the lookout for unforeseen effects. Non-epistemic observation is a phrase that philosophers have used for the phenomenon that one may have observed something without knowing it at the time. The top category, which is the most active category, in which one performs some act of making or doing is sometimes referred to in philosophy as *verum factum*, knowing through doing.

It is instructive to take what is now commonly accepted as the iterative and cyclical nature of the scientific method and quality improvement (see the Shewart–Deming chart) and trace back the ideas several hundred years. Here are two of my favourite quotations. Claude Bernard (1865), in his book on experimental medicine, states, “An experiment differs from observation in this, that knowledge gained through observation seems to appear of itself while that which an experiment brings us is the fruit of an effort that we make with the object of knowing whether

something exists or does not exist.” And a very Baconian quote from Jevons (1874), a principal critic of Bacon himself, reads, “It may readily be seen that we pass upwards by insensible gradations from pure observation to the determinant experiment. . . . The successful investigator must combine diverse qualities: he must have clear notions of the results he expects and have confidence in the truth of his theories and yet must have that candour and flexibility of mind which enable him to accept unfavourable results and abandon mistaken views.” It is the responsibility of statisticians of whatever type to rescue the practical side of the philosophy of science, particularly as embodied in the design and analysis of experiments, and deliver it to the world. This leaves an admirable role for the academic statistician, who may have a theoretical bent, which is to try to continue to understand the dynamic nature of the whole process.

Rejoinder

David Banks

I thank all the discussants and am pleased that their spectrum of opinion confirms my belief that important controversies underlie the current practice of industrial statistics. From the comments, my sense is that statisticians with experience in manufacturing industries find broad agreement with the paper, in contrast to academic statisticians whose research is in industrial statistics. Between these extremes, traditional academic statisticians tend to be favorable, but industry statisticians in quasi-academic environments (the Bell group) are less so. If there is a latent variable that explains this ordering, it may reflect the degree to which these researchers are expected to simultaneously justify their work on two criteria: statistical merit and practical value.

There was strong consensus on statistical education. I think most agree that the best single thing academic statisticians can do for industry is to revise program requirements in the terminal M.S. degree. The current curricula contain enormously too much inference and probability, but insufficient exposure to a breadth of toolkit topics. The precise content of an ideal curriculum is debatable, but the discussants have persuaded me that it should give conceptual coverage of survey sampling and categorical data.

TQM evoked more diversity. Many discussants were uncomfortable with my claim that the TQMperor has no clothes. I concede that the ubiquitous expression of the contrary view may have seduced me into overstatement. A possible compromise is that the TQMperor has really nice underwear. Specifically, I can agree that TQM has useful but staggeringly simple ideas. Their connection to statistics is generally slight. A manager who does not incorporate what is good is doomed. Managers should assess each TQM precept thoughtfully, in the context of their own situation, and not expect that adoption of TQM is sufficient, or even primary, for their survival.

Stitching together several of the discussants' comments, TQM may be successful because it creates a corporate climate in which statistical reasoning can flourish. Insofar as statistical thinking replaces wishful thinking by factual evaluation, it can only benefit industry. In particular, decision makers should have a grasp of the principles of experimentation, the critical weighing of evidence and random variation.

Some discussants felt that the overview of industrial statistics was narrow and incomplete. Doubtless, it was incomplete. And I agree that it spoke more to conventional manufacturing than to the R&D environ-