

The Gap Between Statistics Education and Statistical Practice

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As I write this response to George Cobb's call to rebuild the statistics curriculum, I am returning from a symposium, "Statistics in the 21st Century," aimed at helping to define goals of a new center for statistics at MIT (which has been an outlier among premier U.S. universities in not having a statistics department). To me, the most striking aspect of the symposium was the consistency among its speakers in their admiration for the discipline of statistics, which focuses on the foundation of science and engineering: the use of data to provide information about the world. Maintaining this foundation as technology advances is a noble endeavor and, in the past few years, partly due to the advent of Data Science and Big Data, the importance of statistics has become much more widely appreciated.

The teaching of statistics has evolved more slowly than statistical practice. In diagnosing the problem with undergraduate statistics education, Cobb returns to Leo Breiman's "two cultures" article and makes some important points. I completely agree with him when, consistently with Breiman's earlier sentiment, Cobb warns against ceding to others "all methods of analysis that do not rely on a probability model." Tukey's profoundly important emphasis on the distinction between exploratory and confirmatory (inferential) methods, including the corruption of operating characteristics due to exploratory preprocessing, remains central to modern statistics. Furthermore, Cobb rightly suggests that computation should play a big role throughout the curriculum.

In Brown and Kass (2009, B&K hereafter), after criticizing our profession's lag in adapting training programs to contemporary statistical sensibility, we tried to move things forward by focusing on the highest level goal: to help students think more like expert statisticians. Our understanding of the way statisticians think was based on our experience in neuroscience. We said, "In the course of perusing many, many articles over the years . . . we have found ourselves critical of much published work [in neuroscience]. Starting with vague intuitions, particular algorithms are concocted and applied, from which strong scientific statements are made. Our reaction is too frequently negative: we are dubious of the value of the approach, believing alternatives to be much preferable; or we may concede that a particular method might possibly be a good one, but the authors have done nothing to indicate that it performs well. In specific settings, we often come to the opinion that the science would advance more quickly if the problems were formulated differently, formulated in a manner more familiar to trained statisticians." We asked ourselves, What is it that differentiates expert statisticians

from other mathematically and computationally sophisticated data analysts? Our conclusion was that, roughly speaking, "statistical thinking uses probabilistic descriptions of variability in (1) inductive reasoning and (2) analysis of procedures for data collection, prediction, and scientific inference." It was not our intention to confine statistical education to those topics that involve statistical models, and I again agree with Cobb (as we argued also in B&K) that there is too much emphasis on the subtleties of mathematics-based statistical logic in many statistics courses. However, I would not back off the B&K formulation of what differentiates statistical approaches to data analysis, and I continue to advocate it as an overarching guide when considering what curricula can accomplish. In fact, my continuing experience as an active member of the Machine Learning Department in Carnegie Mellon's School of Computer Science has only strengthened my conviction on this point, and deepened my feeling about Breiman's article: Breiman coupled some valid concerns with the bad advice that we should all think much more like 20th century practitioners of artificial intelligence.

An anecdote may be helpful. Some years ago, in the process leading up to Carnegie Mellon's creation of its Machine Learning Department, from the outset a joint enterprise of statistics and computer science, we held a retreat to explore shared interests and develop a vision. At one point, a computer science colleague said, "I've figured out the difference between statisticians and computer scientists: statisticians attack problems with 10 parameters and want to get it right; computer scientists attack problems with 10 million parameters and want to get an answer." This was a telling remark. Yet, in the intervening time, the two perspectives have largely merged, as we are all trying to do the best job we can with very large data sets, and complex models; in fact, the statistical perspective has been largely victorious in the sense of being fully integrated into every major machine learning conference and journal. At Carnegie Mellon, our Department of Statistics has incorporated computation extensively across our undergraduate offerings, as well as requiring students to engage with real, complex data sets, and we have just started a new major in statistical machine learning. I will urge my colleagues to distribute details about their laudable efforts.

Cobb is concerned exclusively with the undergraduate curriculum. But the biggest challenge in statistics education arises from the difficulty humans have in accepting ambiguity and acting reasonably in the presence of uncertainty. Together with cognitive psychologists, we should devise educational strategies for helping people grapple with this predicament, beginning at an early age. In addition, we should recognize the extraordinary expectations we place on those who teach elementary statistics, especially in high school. To teach the process of "thinking with data," one must not only comprehend the basics of statistical reasoning (which is notoriously difficult) but also have some experience with the way such reasoning is used in drawing con-

Online discussion of "Mere Renovation is Too Little Too Late: We Need to Re-think Our Undergraduate Curriculum From the Ground Up," by George Cobb, *The American Statistician*, 69. Robert E. Kass is Professor, Carnegie Mellon University, Department of Statistics, Machine Learning Department, and Center for the Neural Basis of Cognition, 5000 Forbes Ave., Pittsburgh, PA 15213. Support for this work was provided by NIMH grant R01 064537 (Email: kass@stat.cmu.edu).

clusions from data analysis. I fear we have not penetrated far into schools of education, where teachers are trained, and I hope we can find creative ways to do better in the future.

I presume this special issue will offer many constructive suggestions for advancing statistics education, which is a very good way for committed teachers to share ideas. I am less clear about the impact of the hand-wringing by both B&K and Cobb: we wrote, “The concerns we have articulated above are not minor matters to be addressed by incremental improvement. Rather, they represent deep deficiencies requiring immediate attention.” And Cobb frames his plea for reform with the “tear-down” metaphor. My guess is that, despite our undeniably compelling arguments, which undoubtedly convinced the vast readership of these articles, change across the country as a whole will continue to evolve incrementally, and often more slowly than at institutions such as Carnegie Mellon (where our Department of Statistics has a pretty unified view of our teaching

mission, a substantial campus presence, and a great deal of autonomy within our institution). I strongly endorse efforts to create modern, forward-looking online materials that can be used by statistics teachers everywhere. Meanwhile, those of us in Ph.D.-granting departments must remain vigilant as we train the students who will populate diverse environments, and will shape statistics education in the future.

References

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