Teaching Statistics Algorithmically or Stochastically Misses the Point: Why not Teach Holistically?

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"It takes judgment, brains, and maturity to score in a balk-line game, but I say that any fool can take and shove a ball in a pocket... you've got Trouble..."
—"Professor" Harold Hill (*The Music Man*)

We agree with Professor Cobb on the need to reconstruct the undergraduate statistics curriculum. But if we are to "preach what we practice," we must first examine what we practice. Viewed as a whole, the practice of statistics hasn't really changed, although methods continually evolve. We should not allow debates about methods, whether algorithmic or stochastic, to distract us from teaching a holistic understanding of what statisticians actually do. The challenge of sound statistical practice has been discussed for decades, but apparently with less impact on statistics education than we might hope for. Consider, for example, these two wise comments, each decades old.

Feinstein (quoted by Zahn 1985) said nearly 50 years ago:

> A clinician is taught to identify and formulate patients' problems in a carefully structured manner; but he is then left to develop diverse tactics of "judgment" for managing the outlined problems. A statistician is taught a carefully organized set of mathematical structures for managing an outlined problem; but he is left to develop diverse judgmental methods for identifying and formulating the problem. The clinician may emerge able to express the right questions but unable to find the answers; the statistician may emerge with the right answers but unable to select the questions.

William Hunter (1981) advocated a solution to this challenge: Statisticians should work as *colleagues* with scientists and others with whom we consult. In that role, we must comprehend the entire enterprise. Hunter pointed out that the first step in collaboration is for the statistical consultant to work with the client to formulate the best question.

> Therefore, it is of the utmost importance that in each new situation the consultant try to discover what the real problem is. To avoid the mistake of solving the wrong problem ... (p. 73)

Kimball (1957) called finding the right answer to the wrong problem a Type III error. We must teach our students to avoid such errors.

Online discussion of "Mere Renovation is Too Little Too Late: We Need to Rethink Our Undergraduate Curriculum From the Ground Up," by George Cobb, *The American Statistician*, 69. Richard De Veaux, Department of Mathematics and Statistics, Williams College. Paul F. Velleman, Department of Statistical Sciences, Cornell University (Email: pfv2@cornell.edu).

Undergraduate statistics education often focuses too much on methods rather than taking this holistic view. It matters little whether the analysis tests the equality of two means with a classical t-test or with a resampling approach if the conclusions of the test are invalid from the beginning. Rather than debating the choice of t-test versus a decision tree, shouldn't we first ensure that the comparison is a scientifically valid one?

To follow Hunter's advice we must ask questions such as whether the data allow generalization to a larger population, whether their structure can be meaningfully described with the models we wish to fit, and whether important subgroups or individuals were excluded from the data. In the decades since Hunter's article, we have seen the development of graphical and diagnostic tools that make it even easier for the statistician probe data to see whether a model is appropriate and to identify unusual or influential groups and cases.

The answers to these questions (or, of greater concern, the violations of the naíve assumptions our methods have been making) often emerge *during* a careful statistical analysis. Because of this *it is essential that the statistician participate in the analysis*. It is statistical malpractice to turn the data over to an automated algorithm, to, as Professor Hill would say, simply shove the data into the pocket of a particular analysis.

Exceptions, anomalies, outliers, and subgroups are best recognized and understood in the context of the question being addressed. That is why the statistician must be, as Feinstein would want, fully conversant with both the right question and the statistical methods being applied. And that is why fully automated methods cannot be trusted to produce statistical analyses on their own; computers don't (yet?) understand the real world sufficiently to take a holistic view of the analysis. But the trained human mind and eye are remarkably effective tools for spotting unanticipated patterns and exceptions and understanding what they might mean in the context of the question being investigated. So that training is essential.

Rather than focus on the methods used to solve the problem, we must teach the entire process by which the statistician probes for the correct problem formulation, translates that problem into a statistical question, finds an appropriate method to solve that problem, and then communicates the result back to the scientist. The methods themselves are important. Indeed, as the American Dental Association Seal of Acceptance says (to paraphrase), they "have been shown to be of significant value when used in a conscientiously applied program of [data] hygiene and regular professional care." But conscientious application is the requisite element. Simply replacing a stochastic method by an algorithmic one will not help. We believe that the current statistics curriculum focuses too much on the method rather than on the conscientious application of methods in the context of the question to be addressed, and that "data science" exacerbates this trend.

It is certainly wise to provide our students with a full quiver of methodological arrows. But (to mix our sports metaphors a bit) we must not ignore the target. We must teach the entire process of developing a question that can be addressed with the available data and examining the data before, during, and after an analysis in nearly every undergraduate course we offer. By the time statistics majors come to the capstone course, typically during their final year, the approach should be second nature, not something they see for the first time.

This process requires "judgment, brains, and maturity." Perhaps that is why after decades, our statistics courses still have not moved sufficiently in this direction. We should try to teach judgment, and our students certainly have fine brains, but maturity comes only with experience. We must take the time to give students practical experience in data analysis.

Ignoring the more difficult parts of this process and concentrating only on the algorithmic part (as the worst practices of data science do) is an abdication of our responsibility as statisticians and educators.

References

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