Vision or Bad Dream?

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And afterward, I will pour out my Spirit on all people. Your sons and daughters will prophesy, your old men will dream dreams, your young men will see visions. (Joel 2:28)

I thank George Cobb for a thought-provoking and prophetic paper. The following are a few thoughts that occurred to me as I read the paper.

To begin, by the undergraduate curriculum I mean the entire body of courses and programs we offer for undergraduates, from introductory service courses to programs for majors. By statistics department I mean any department that employs faculty with advanced degrees in statistics to teach courses and offer programs in statistics. I will use "the science of data" (a phrase used by Moore (1992)) to include bioinformatics, data mining, data analytics, data science, and big data. Not everyone agrees that these are part of statistics and I use the terms "statistics" and "the science of data" to emphasize this discrepancy.

1. Arguments Concerning Change

1.1 Arguments Against Rethinking our Curriculum from the Ground Up?

- Most departments already periodically rethink (and even formally assess) their curriculum. Are we really in dire straits?
- Graduate programs and employers expect a basic level of competency, but prefer to provide training in additional skills. Perhaps all we need do is provide a basic level of competency, something far less ambitious than what George Cobb proposes.
- We teach (but do not always practice) that extrapolation from the present into the future is dangerous. Will changes we make now be outdated tomorrow?

If statisticians taught all courses in the science of data, George Cobb's case might be less compelling. Unfortunately, the growing popularity of the science of data and the increase in courses taught by faculty not trained as statisticians, makes this both the best of times and the worst of times for statistics departments.

1.2 The Best of Times?

Reports about the science of data appear regularly in the media. Success stories abound. The "internet of everything" will generate massive amounts of data to be mined. The science of data is suddenly "sexy." Students are flocking to our courses and majors. STEM initiatives and employers seeking people with skills in the science of data, increase the chances of funding for statistics departments. Responding to this growing interest in and demand for people who can extract information from data will force us to reexamine our undergraduate curriculum.

1.3 The Worst of Times?

There is a great deal of confusion about exactly what is the science of data. Researchers in many disciplines claim expertise, and hence the right to offer courses and programs in the science of data. Has Breiman's stochastic culture dominated the way we teach and practice statistics, so that Breiman's algorithmic culture is not regarded by outsiders as statistics? If so, it is not surprising that others do not believe they are encroaching on our turf. To quote George Cobb, "do we really want to cede to them all methods that do not rely on a probability model?" To address this, we need to seriously rethink our undergraduate curriculum.

Others have noted that this is both the best and worst of times in statistics. See, for example, Wasserstein (2015), who provides a more thorough discussion of why it is a great time to be a statistician, as well as challenges facing our profession.

2. Miscellaneous Thoughts

2.1 All Curriculum is Local

No department can be all things to all people. Graduate programs vary from one department to another, reflecting the strengths and interests of the faculty. Should the undergraduate curriculum exhibit similar flexibility? For example, in spite of claims that Bayesian inference is an advanced topic, Bayes methods are discussed in all the introductory service courses at Duke University. Dalene Stangl offers a short course in teaching Bayesian methods for teachers in secondary education. Descriptions of courses taught by Mine Çetinkaya-Rundel can be found at *https://stat.duke.edu/~mc301/teaching*. Not all departments will want to emulate Duke, but I hope we avoid overprescribing what the undergraduate curriculum should look like.

2.2 Practice What We Preach

Many of my colleagues insist that all, or nearly all, courses about statistical methods should be taught by faculty in a statistics department. However, in an era of scarce resources, we cannot meet demands for new courses while accommodating growing enrollments in existing courses.

We preach the interdisciplinary nature of statistics, but do we practice it in our curriculum? Should we pursue collabo-

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. William I. Notz is Professor, Department of Statistics at The Ohio State University, 1958 Neil Avenue, Columbus, OH 43210-1247 (Email: win@stat.osu.edu).

rative teaching with faculty in other departments, or more radically, encourage faculty in other departments to teach courses in the science of data? Such a suggestion is controversial, and if George Cobb is to be identified with Martin Luther, I may be regarded as an Anabaptist, despised by Catholics, Lutherans, and Reformed. A more cooperative approach to the undergraduate curriculum could involve the following.

- At The Ohio State University, general education courses in data analysis must be approved by a committee. Any department can propose to teach a general education course in data analysis, but must meet guidelines (developed by the Department of Statistics) regarding the content (see *https://asccas.osu.edu/files/ASC_CurrAssess_Operations_Manual.pdf*). At institutions where there is a process for approving new courses, faculty in statistics departments could suggest basic standards that all courses in the science of data must meet to insure some level of quality (see the GAISE guidelines for introductory courses at *http://www.amstat.org/education/gaise/GaiseCollege_Full.pdf* and the ASA/MAA statement on qualifications for teaching statistics at *http://www.amstat.org/education/pdfs/TeachingIntroStats-Qualifications.pdf*). With the growing emphasis on assessing courses and curriculum, statistics faculty could develop the rubrics for assessing courses in the science of data.

  Faculty in statistics departments could provide workshops for or informal gatherings with faculty in other departments to discuss the teaching of courses in the science of data, share ideas, syllabi, resources, or provide training in the use of statistical software. One of my colleagues in the Department of History told me that such workshops were held annually at Grinnell College when he was a faculty member there.

  Faculty in statistics departments could offer to mentor those wishing to teach a course in the science of data. This might involve helping draft a proposal for a course, guiding such a proposal through the approval process, suggesting resources, helping develop a syllabus, or even providing evaluations for the faculty member.

  Faculty in statistics departments could offer to team-teach courses. This would bring together statistical and subject matter expertise.

- Should we consider dual majors and minors for which we share responsibility? For example, at Miami University one can major in statistics as well as in data analytics (the latter is a co-major shared by Information Systems and Analytics, and Statistics).

- What about multiple programs? Rather than a single major, departments could offer multiple majors with different prerequisites, different core competencies, and different objectives.

2.3 Challenges

- Can our faculty agree on what is fundamental? Not too long ago undergraduate majors in statistics were rare. Requirements for acceptance into a graduate program are much less stringent than the requirements for an undergraduate major. What is essential for an undergraduate planning to pursue a PhD is different than what is essential for a student seeking a job upon graduation.

  Even for introductory service courses, what is essential is not clear. One recommendation has been to minimize the discussion of probability. However, to introduce Bayes thinking, students need to know something about probability distributions, conditional probability, and Bayes theorem.

- Most introductory courses in statistics are taught by people without advanced degrees in statistics (for example, instructors in secondary schools and community colleges). We must train such teachers how to incorporate the changes we propose in their teaching. Failure to do so will be a failure to institutionalize change.

  As an example of potential problems, many introductory statistics textbooks begin with exploratory data analysis. One reason is to expose students from the outset to the experience of exploring data in order to learn what the data are saying (see Moore (1992)). This motivates later discussions about the pitfalls that can occur when drawing conclusions from data and how these pitfalls might be avoided. Unfortunately, many instructors teach the sections on data analysis as descriptive statistics, perhaps because this is what they experienced in their first course. They emphasize the process of calculating numerical summaries and making graphical displays, rather than using these as tools to explore what the data are saying. How many instructors expose their students to exploratory tools such as brushing and slicing or linked displays? Introducing algorithmic methods could suffer a similar fate without training others to teach these methods.

  What resources are needed for teachers to teach effectively? Can one introduce students to computationally intensive methods when one is unable or reluctant to require students to use computers? Can one simply rely on graphing calculators? How do we examine students on computer intensive methods when we fear the use of computers on exams will encourage cheating? Shouldn't our methods of assessment match the material we emphasize in class?

- I like George Cobb's suggestions for disseminating changes. Publication of innovations (new courses, new teaching methods, new curricula) in journals, exposing innovations to testing and refinement by the larger statistical community, and eventually institutionalizing change is an excellent strategy. The challenge is finding journals willing to publish such papers. As a former editor of the *Journal*

of Statistic Education, I suspect that the journal would be receptive to a teachers' corner section.

3. Conclusions

Do we need to rethink our curriculum from the ground up? I believe we do. This will be challenging, but there are both faculty and programs already thinking about and engaged in this exercise who can serve as resources for the rest of us. I again thank George Cobb for his call to arms. Others will decide whether his is a vision for the future or just a bad dream.

REFERENCES

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