GETTING MORE DATA INTO THEORETICAL STATISTICS COURSES

THOMAS L. MOORE
GRINNELL COLLEGE

TECHNICAL REPORT NO. 91-001

SLAW is supported by a grant from the Exxon Corporation
Statistics in the Liberal Arts Workshop (SLAW) is a group of educators concerned with the teaching of statistics. The workshop was initially funded by the Sloan Foundation. Continuing support has been provided by the Exxon Corporation.

Participants in the summer of 1991 are:

Donald L. Bentley  
Pomona College

George W. Cobb  
Mt. Holyoke College

Janice Gifford  
Mt. Holyoke College

Katherine T. Halvorsen  
Smith College

Homer T. Hayslett, Jr.  
Colby College

Gudmund Iversen  
Swarthmore College

Robin H. Lock  
St. Lawrence University

David S. Moore  
Purdue University

Thomas L. Moore  
Grinnell College

Norean Radke-Sharpe  
Bowdoin College

Rosemary Roberts  
Bowdoin College

Dexter Whittinghill III  
Colby College

Jeffrey Witmer  
Oberlin College
This talk represents a happy opportunity. My message today fits nicely into the 10-minute talk format. I'm not sure what I'd do with more time.

I'd like to take my time to argue for including more data and applications in the case where a college offers only one course (perhaps a 2-term sequence) of probability/mathematical statistics to its undergraduate majors. Then I'd like to say a few words on how I have given this kind of flavor to our probability/statistics sequence at Grinnell.

In a provocative 1988 article in the College Mathematics Journal [1], David S. Moore of Purdue asks (in his title) the question “Should Mathematicians Teach Statistics.” The first sentence of the article is “NO!”.

David admits that his article is intentionally polemical but his point is that statistics is not mathematics but rather a quantitative discipline that uses mathematical tools (among others) to solve problems involving real-world data. He argues that mathematicians who treat the teaching of statistics as one would teach another mathematics course rob the students of a chance to really learn statistics.

In his excellent and readable article in Technometrics [2], George Box gives ample and persuasive evidence that progress in statistical theory has throughout history most often been the result of a practical need in the scientific world revealing a novel statistical problem outside the bounds of present statistical theory.

For example, William Seeley Gosset's contribution of the $t$ statistic came out of his need for dealing with small samples obtained in experiments at the Guiness brewery from the lab and from field experiments on grain.

Before Gosset's day (before 1900) the nuisance parameter of $\sigma$ would have been estimated by the sample standard deviation and the resulting statistic would be treated as if the estimate were the true value. Although one can certainly imagine a theoretician having discovered the $t$ statistic through a seemingly natural consideration, it was the practitioner Gosset who did so.

Indeed it was Box [2] who said that, “Gosset’s derivation of the sampling distribution of ... the $t$ statistic must surely stand as the nadir of rigorous argument.” Gosset’s confirmation
of his new find required a blend of crude mathematics and simulation, and it was his friend R. A. Fisher who firmed up the mathematical analysis.

Others have written about this centrality of data to statistics and its implication for our teaching of statistics. For example, Oscar Kempthorne [3] claimed that "statistics has been enslaved by mathematics" and Robert Hogg [4] in a 1985 report of statistics education for engineers (also from the American Statistician) strongly recommends teaching for that audience with real problems and data.

Thus we must conclude that if we are to teach undergraduate majors about statistics, we must teach them more than just statistical theory or mathematics. We must teach them something about how this theory can apply to real data.

At the same time the situation at most smaller 4-year schools admits a very modest statistics curriculum. In 1987 I helped collect some basic information on statistics at such institutions through a mailed survey (see [5]). We used a convenience sample of 99 colleges from a working list of the annual Liberal Arts Library Directors Conference. We received responses from 80 schools. Of these the most common course offered was a course in probability and mathematical statistics. While 94% of those responding offered such a course for one or two terms, only 84% offered some type of lower-level introductory course. On the other hand, of the 80 respondents only 6 offered any other statistics courses that can be taken for math major credit. The reasons for this are not complex. At a small school it is common to not have a statistician on the faculty and very rare to have more than one. Practicalities make it difficult to teach a large statistics curriculum.

Thus it is clear that if we are to teach our undergraduate majors at small colleges what statistics is about we must do it in this standard course in probability and mathematical statistics.

The last two CUPM reports ([6] and [7]) have recommended that this course be more than a course in theoretical or mathematical statistics. For example, the 1971 CUPM report begins with a quotation: "... [Core mathematics] provides an excellent foundation of knowledge for potential graduate study in statistics. It does NOT, however, provide nearly enough students with either motivation to study statistics or an understanding of the extra-mathematical aspects of statistics." And from the 1980 report: "The traditional undergraduate course in statistical theory has little contact with statistics as it is practiced and is not a suitable introduction to the subject." My impression is that these recommendations, despite being quite old, have had a modest impact on the way the course is often taught. (The boldfacing is mine.)

I'd like to spend my remaining time indicating how I have made modest changes in the way I teach this course to more closely follow these recommendations.

Several years ago I chose a textbook that does a good job of using real data in a mathematical statistics text [8]. Today there are perhaps just a couple of other ones around to

2
compete. My students generally give the textbook high marks, especially for its willingness to include real applications.

The first semester is a fairly conventional coverage of the textbook from probability through properties of estimators. I could easily and perhaps more effectively rearrange some of what I do second semester into the first, but for the past few years I have not taught the first semester course and my colleagues are happy to let me do the supplementation during the second semester.

We begin with an overview of the data collection process. This is from two excellent general and nonmathematical introductory statistics texts ([9] and [10]). After discussing the collection of data I proceed through the standard topics in the text: hypothesis testing (1 and 2 sample), Chi square tests, simple linear regression, and one-way ANOVA. Along the way I supplement the course with reading and exercises from the Minitab Handbook [11] and the new book by Moore and McCabe [12] to cover data analysis and additional topics like normal plots, multiple regression, robustness, and some two-way ANOVA. Some material is inevitably covered only through lecture (e.g., some material on regression diagnostics and some on the role of linear algebra in regression). I find I don’t have to spend any appreciable class time with Minitab and the mechanics of basic descriptive statistics come easily to these students.

In the early part of my career, it was a source of embarrassment to me that my upper-level students couldn’t help their friends taking the lower-level introductory course with homework. This is rectified. Throughout the course I consistently take class time to reinforce basic principles of statistical work. With examples we discuss issues about the data: Why were they collected? How were they collected? What do simple plots suggest either about the data or about the appropriateness of applying statistical procedures? What type of analysis might we do? etc. For this reason I try to always use examples in class that are of real data. Good sources for real data examples include [8], [11], and [12], and [5] contains a bibliography of others. I use student projects from previous years for good sources of examples as well as an occasional data set from a faculty member on campus or a journal article.

Each semester I have students work in teams of two to do a project. This project requires them to pose a problem whose solution involves collecting data. The students must submit a proposal early in the semester. Once I approve the project, the students collect the data, analyze the data, and submit a final report of their findings. I may also have them present their projects orally to the class.

The student projects are, again, not an original idea with me. A number of people have suggested their use. For example, in a presentation at last summer’s (1990) meeting of the ASA [13] James Landwehr said in speaking about the introductory mathematical statistics course for majors: “... it is valuable for the students to actually do some data collection, analysis, and interpretation themselves. Experiencing the whole process of statistics, ..., is important.”
And Ann Watkins [14], who with Landwehr was a PI for the Quantitative Literacy Project, says of projects: "My students seem to enjoy this part of the course the most. I think in large part it is that they get to choose the problem. So even though there are inevitable pitfalls and stumbling blocks along the way they remain motivated."

Some examples of student projects I have received are: (1) Are bridge hands random?, (2) Are dollar bill serial numbers random?, (3) Is the college's reading lab effective?, (4) Which division of the college has the greatest textbook costs for students?, (5) What golf statistics best predict the final score?, (6) Is there a difference at Grinnell between the home court advantage for the women's basketball team versus the men's?, and (7) Has class size at Grinnell increased since the College reduced the standard teaching load for faculty from 6 courses to 5?

In summary then I have argued here for the inclusion in the traditional probability/mathematical statistics course for majors of more applications in all facets of the course. Inevitably some topics in statistical theory will be left out but the students will get a broader view of statistics. This may also encourage more students to take more statistics at a later time or, perhaps, even to go on to become statisticians.
References


