old-world manner that was entirely natural to him and free from guile."

We can always be thankful for scholars whose influence, foresight and inventiveness are combined with such a character.

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Comment

Robert V. Hogg

I welcome the opportunity to comment on Harold Hotelling's articles on statistical education, particularly because many of us are concerned about our directions in this area, even to the point of asking seriously "Are we really doing it right?" Certainly, as statisticians, we know that we must be willing to experiment and make changes (at least small ones) in striving for optimality. Hotelling recognized this and states that "no syllabus in use today can be expected to survive a few more years of research." As new statistical methods and ideas develop, changes *must* be made even though we know that the optimum will never be achieved. However, we must continue to chase it for if we do not, our programs will dry up and fossilize.

One major issue he addresses in both articles is "What sort of persons should be appointed to teach statistics?" He makes it clear that it should be someone who has "a profound and thorough knowledge of statistical methods" and "a genuine sympathy and understanding for applications." At the university level, he emphasizes that publication of scholarly research has always been accepted as the best proof of an understanding of your field. Because a good teacher of statistics must be familiar with recent advances (even if outside his or her specialty), we need even more good expository articles today (as compared to the 1940s) written by some of the leaders in research in those areas.

To illustrate the importance of research to the teaching of statistics, I will use myself as an example (not that I am a great researcher). I like to think I know *a little* about M, R and L estimation, and this knowledge helps me add a little excitement to teaching a nonparametrics course, either beginning or advanced. For example, at a very early stage of an elementary course (not necessarily nonparametrics), many textbooks (including my own) suggest that $\bar{x} \pm 2s/\sqrt{n}$ serves as an approximate 95% confidence interval for the population mean μ provided the sample size n is reasonably large. Of course, if the underlying distribution is normal, there is no problem; really there is no problem if the underlying distribution is almost symmetric with reasonable tails. But suppose we have a very skewed, heavy-tailed underlying distribution. Then we have a different story and, in some cases, that confidence coefficient might be as small as 65 or 70% because $\bar{x}$ and s are then highly correlated (they are uncorrelated in symmetric cases). How many teachers of statistics really know that? In particular, at that point in the course, the students really should be informed that something else should be done in this case (e.g., transforming the data or using robust methods) even if the details cannot be explained at the level of the course.

Hotelling argues (and rightfully so) that most mathematicians will not be very good teachers of statistics; and those that are asked to do it should be given "a furlough for a year or two" to obtain proper training. That is, mathematicians *and* statisticians should experience some good applications before being asked to teach statistics. I can really speak with some experience here because I earned my PhD in mathematics in 1950. Although I wrote my thesis on a statistical topic under the direction of Allen Craig, I really knew very little in the way of statistical applications. I taught some great courses in mathematical statistics in the 50s; but is wasn't until the 60s—or even the 70s—that I truly saw the importance of some of the methods, like those in design of experiments. That is, while I knew all that theory about those quadratic forms, I really could not design a good experiment. A

Robert V. Hogg is Professor of Statistics, Department of Statistics and Actuarial Science, University of Iowa, Iowa City, Iowa 52242.

furlough would have been good for me in the early 1950s.

He goes on to say that it is possible for psychologists or agricultural experimenters to do a better job than mathematicians because they can sense "the difference between important and unimportant questions." That is, "appointments by departments of application are not all bad" and today we find more and more persons with good statistical backgrounds in fields like psychology, sociology, business and economics. However, Hotelling notes that it is hard to do psychology (for example) and statistics at once, and the statistician's excursions into other areas should be temporary or very limited. Thus we "should have full time professors engaged in teaching of and research in statistical theory and methods, without spending time over applied statistical problems excepting insofar as such problems might present novel features calling for the development of new statistical methods beyond the immediate case." The statistical courses in other departments should be confined to applications of theory and methods to that field and should follow general courses given by the Department of Statistics.

Every university professor should do some research and yet there are some that do little or none; "this is usually regarded as deplorable." I cannot agree more. We have opportunities to do so many different things at the university level that it is difficult for me to see how someone could essentially waste a life. If I had 10 more hours each day, I could find worthwhile projects to fill the time, assuming I had the energy. Yet many cannot find enough to do.

Consulting does cause problems for a statistician and yet presents opportunities. Substantial applied problems can suggest good research that should be published in statistics journals or else good statistical ideas can be "buried in connection with obscure special applications." Perhaps a second publication can result in a journal from that field. In any case, a balance (or weighted average somewhat in favor of the statistical theory) must be achieved. Most departments of statistics have a consulting service and activities in it must be taken into account in adjusting the teaching load. Perhaps we still do not weigh the consulting as much as we should in promotion and tenure, but consulting cannot substitute for good research in statistical theory and methods.

He argues more strongly for starting a basic course with probability theory (with or without calculus) than I would. In his scheme, this is followed by "statistical theory and applied statistics, in this order." The older I get, the more I think that students should see some data related to their field early in the course. Such presentations are highly motivational, and I find that it works, for example, with engineers. I truly believe that it is a mistake to write engineering and business statistics books as if they were *baby mathematical statistics* books, spending a great deal of time on probability and basic distribution theory. Clearly, I like mathematical statistics and think it extremely important, but there is a time and place for it. Students in other areas should see the applications sooner, maybe simple ones right at the beginning, and this is one advantage of the exploratory data analysis approach. Students, without calculus, can understand the important concepts and useful statistical tools. These should be explained by instructors "familiar with the mathematics of statistics and the task of leading the blind must not be turned over to the blind." The big advantage we have today in these courses is the computer, and I'm 100% certain that Hotelling would insist upon its use in an applied statistics course today.

The main content of a graduate program is the theory. However, graduate students should see some applications, possibly acquiring "knowledge of a field of application and contact with practical statistical work." However, the latter should *not* dominate the graduate curriculum.

There is a brief discussion of a university department (center) going into the marketplace and engaging in service to business, industry and government. There are dangers here because it is often the case that "he who pays the piper calls the tune." But despite these dangers, I believe that some government-industry-university interaction is good and should be encouraged. This is one way that we can help America regain some competitive advantage in the world marketplace. Moreover, by insisting that faculty members publish in good journals, we still have that safety valve that protects us from too much commercialism.

Having said that publishing is very important, I must admit that I believe that we carry it to more of an extreme than was done when I began in 1950. One of Ed Deming's 14 points is *Drive Out Fear*. We certainly do not do this among our nontenured faculty members today; as a matter of fact, we do just the opposite. When I started in this business, I worked hard but *never once* did I think that I would not be a tenured professor some day. Certainly the University of Iowa did not lose by dealing with Bob Hogg in this manner, and yet I believe that I had a much more relaxed and enjoyable period as an assistant professor than they do today. I suppose that there is a compromise position to be taken, but I cannot completely agree with today's position about promotion and tenure. Allen Craig and I agreed that we would first be the best teachers possible, working on interesting research problems as time permitted; but we found that

time by working many extra hours. This latter included directing theses; and if only very little of our work (or that of our students) was published, then we better get out of the business. Fortunately for us (and, we hope, for our students), this did not happen.

As in Hotelling's day, there is still a great need for statisticians. Somehow as I read his list of uses of statistics and his note that "the business and manufacturing possibilities of statistical methods has only begun," I feel as if statisticians (including me) have failed to live up to his expectations. Certainly we did not continue to use and improve upon W. A. Shewhart's quality control methods. Accordingly, American industry is far behind much of the competition. I guess statisticians cannot share all of the blame, but we must accept some of it.

In that regard, he envisioned statisticians helping lawmakers to set up definite formulae for carrying out the general policies aimed at in Acts of Congress. I'm not certain that has happened either. In recent years, I have taken the position that to get the biggest bang for our profession, we, the statisticians, should become legislators, governors, senators, managers, CEO's, etc. As a group, we are a collection of rather smart people, and the general public could do a lot worse than having us in some of those offices (they have already proven that with some of the recent selections).

For more understanding of numerical arguments, possibly we have not done enough in developing good *liberal arts* statistics courses, ones that deal with concepts rather than a lot of techniques. It was interesting that last summer a group of liberal arts professors, interested in teaching statistics, met at Grinnell College for 3 days. They were joined by David Moore of Purdue's Department of Statistics; so you can imagine that some of his ideas from *Statistics: Concepts and Controversies* entered into the discussion and their conclusions. Certainly we must do something to prevent situations like the following scenario: 1% of the population has a certain disease. There is a test that is 95% accurate (say both ways: rejecting good and accepting bad—each has a 5% chance). Certain legislators say "let's run the test anyway" not realizing that the error in the testing will swamp out the small percentage that have the disease. Without worrying about conditional probabilities, cannot someone explain the following to them? Of 100 typical persons about 1 will have the disease. If these 100 are tested, let's say that the 1 is found (actually 0.95 of 1) and about 5 of the other 99 are said to have the disease when they don't. Hence, it is reported that 6% of the population have the disease, instead of the correct 1% figure.

That brings us down to Hotelling's opinion that "A thorough-going reform of school mathematics is greatly need." About 40 years later *A Nation At Risk* notes the same thing, but Hotelling and others knew it a long time ago. The joint ASA/NCTM committee charged with getting statistics and probability into the kindergarten through 12th grade curriculum has been somewhat successful through their quantitative literacy program. That is, good materials have been written, and some teachers have been given additional statistical education. *However, much more needs to be done!* Our leaders have simply not paid too much attention to the recommendations in *A Nation At Risk.* In truth, we need another intervention, like Sputnik, to make people of this country realize how serious the situation actually is. It is difficult for us to accept our secondary position in mathematics and science education, and we (at least some of us) go on with our comfortable living as though nothing has changed in the last 30 years. It's still "happy days."

Let's face the truth that, as a nation, we are clearly living beyond our means, creating a bigger and bigger gap between the haves and have-nots in doing so. Substantial improvements in science, mathematical and statistical education could help the economy of this country. Each of us individually should ask, "What can I do about this problem?" The answer is, of course, the best that we know how; but let's do something. After all, Harold Hotelling was only one individual, and he did have some impact. We thank him, and the Editor of *Statistical Science* for giving us the opportunity of reviewing two of the "Golden Oldies."

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