OBSERVATIONS ON GRADUATE PROGRAMS IN STATISTICS AND RELATED ISSUES

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Technical Report No. 383

December, 1980

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1. A Past Prospective

In a brilliant essay some 40 years ago, Harold Hotelling (1940) sharply focussed on the problem of teaching statistics at universities. He wryly described, by means of a poignant anecdote which could easily have been entitled "The rise of Jones," how statistical instruction developed and was managed in those times. Briefly, Department X, be it Psychology, Engineering, Business, or whatever, notices that some outstanding work in the field uses statistics. Deciding that its students, ignorant of such matters, would be severly handicapped, the department introduces a course in the catalogue with "Instructor to be announced." Economics dictates that someone in Department X, qualified or not, become the "Instructor to be announced." Why not assign the course to Jones, a bright young graduate student with a quantitive turn of mind? Indeed, Department X delights in this providential resolution, which combines frugality with employment for Jones and ensures that an auxiliary area will not overshadow discipline X. Hotelling proceeds to describe how Jones, earnest young scholar that he is, prepares for the assignment. He pursues "statistics" through library catalogues and, after some false leads and dead ends, eventually comes upon the leading journal of the time: Biometrika. Being somewhat ill-at-ease with the mathematics therein, he then resorts to the few textbooks available at the time, which turn out to be too abstruse for him. There is apparently nothing

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* Address to Conference on Teaching of Statistics and Statistical Consulting, Ohio State University, Novenber 24, 1980.

** This work was supported in part by an NIH-GM-15271 grant.

available that he is comfortable with. He is almost ready to give up in despair when the thought occurs to him that the market languishes for an elementary textbook. He realizes that as soon as he accumulates a little more knowledge and experience he may be in a position to provide such a commodity. His entrepreneurial spirit is aroused and soon deed follows thought. Jones, a better economist than statistician, has accurately assessed the market -- his text is a huge financial success. His promotion through the ranks is rapid, culminating in being Professor of Hyphenated-Statistics and soon becoming an officer in national and international societies and a valued consultant to various federal and private organizations. Meanwhile, his text has not only gone through several profitable editions but is used as a source for other Jones's who were tapped a bit later for a similar destiny. Hotelling then describes the most fascinating feature of the literary cycle, tracing the influence of one author upon another through parallelism of passages, the task sometimes facilitated by the accumulation of error inherent in repeated copying. Errors promulgated by the original Jones, or in papers he used as a resource, are then either perpetuated through a series of derivative texts or distinguished by the particular manner further error accrues. Hotelling, tongue in cheek, points out that such subsequent transmission of error may actually be innocuous; for, the original formulae may have been wrong or ill-conceived, and consequently future error, no matter how blatently compounded, may be no more harmful to the student than exposure to original error.

Hotelling further foresaw the possibility that inefficiency of overlapping and duplicating courses, given independently in numerous departments by perfect or imperfect clones of Jones, would eventually impel academic administrators to assign this task to the Department of Mathematics. Such a solution would prove inadequate, because the teaching of statistics would be assigned to mathematicians ignorant of the subject and with little or no interest in its applications. The cure then would be worse than the disease.

Accordingly, Hotelling strongly advocated establishing statistics as a separate and conventional university department -- conventional in the sense that participation in statistical research would be a necessary criterion for being a reputable teacher of statistics. Such a department would also have a unique feature. In addition to the customary teaching and research duties of university faculty, it would be recognized that a professor of statistics had yet another function to fulfill. Advising colleagues and other research workers on statistical methods appropriate to their investigations, was to be a highly significant regular activity for statistics faculty and provision for this should be made by adjusting the teaching load. This would provide a vital service to the university and facilitate exposure to problems presenting novel features, thereby stimulating research in statistics itself. Proper departmental organization and choice of faculty are pivotal to the mission -- the education of future professors, professional practitioners, occasional users of statistics and even those who want to gain some understanding at a level consonant with their background. A faculty must then be selected with extensive mathematical training, a thorough knowledge of theroetical statistics, an understanding of areas where statistical methodology can be applied -- and, most of all, an inquiring mind. Such a group he believed, would be sufficient to ensure that statistics as a branch of knowledge would thrive and contribute to the research efforts of other disciplines in a consultative capacity and obviate the temptation of other departments to duplicate the teaching of statistics. Unfortunately, he did not anticipate that other departments would still regard the teaching of statistics as too important or too threatening or perhaps too engaging an activity to be left preponderantly to statisticians -- even Hotelling's super-statisticians.

Hotelling read his paper at a meeting of the Institute of Mathematical Statistics on September 10, 1940. The next day, at a business meeting of the Institute, the members resolved that the ideas expressed by Hotelling in detail in his paper be implemented and given as wide a circulation as possible.

It is no exaggeration to say, as far as the teaching and the organization of statistics subsequently initiated at American universities, that no other document comes close to having the prescriptive impact of the principles Hotelling advocated. With few exceptions, most departments of statistics in the English speaking areas of North America formed after the second World War, attempted to organize and operate according to the objectives he articulated. In retrospect it would also be fair to say that as Hotelling's explicit hopes were realized so were his implicit fears. Jones in the form of his clones is still with us. Other departments duplicate courses. The tripartite function of professors is still the exception rather than the rule. The attempt to structure a curriculum which balances professional demands with intellectual aspirations induces academic quarrels that ballots do not assuage. In what follows I will address these issues.

2. Who Teaches Statistics And Why Is It Important?

With the establishment of separate and full scale Departments of Statistics one might assume that the question of who teaches statistics would be moot. But this is not so. A Department of Sociology, for example, would not dream of teaching engineering courses, and a Department of Engineering would be loathe to encumber its curriculum with sociology offerings; yet neither one would hesitate in the slightest to teach elementary statistics of one sort or another. Their attitude is puzzling and bears further examination. Clearly, statistics is offered by Department X because its students need the material. This is not sufficient reason, however, for Department X to offer the course. The need for elementary mathematics is even more crucial and yet no department would dare usurp the prerogative of the mathematics faculty. Or if that analogy is imperfect, a chemistry department clearly does not teach courses to its own students in elementary physics, nor vice-versa. Although physical and biological science departments would have no excuse whatever, social science departments offer two explanations for indulging in this activity. First, the course is used more as a sieve to weed out unsatisfactory students than as an educational vehicle. Secondly, social science students require special treatment because of their fear of statistics. We must concede that the sieve induces trepidation which in turn requires special therapy. The logic is unimpeachable, but the university and what it stands for is, figuratively speaking, stood on its head.

There is also an implication in all this that statistics is either poorly taught by statisticians or it is, as I've mentioned before, just too important to be left to statisticians -- or both. The latter part of the disjunction while commendable for generals and war has been traditionally inappropriate at the university except, for some obscure reason, with regard to statistics. If statisticians are not good teachers of elementary statistics, then certainly sociologists, engineers, economists, et al. cannot be qualified by virtue of their inferior training, lack of depth in the subject, and inability to keep abreast of the latest developments. I would maintain that the justifications advanced are merely deceptions that cloak actual economical and political reasons. Jones has tenure and presumably long ago gave up serious work in some speciality, cannot be retrained and doesn't want to be. Besides he has texbooks to peddle and resides in a department of political clout if not political science.

Budgetary stringencies imposed on universities where the scale of this year's retrenchment is measured in multiples of the previous year's, incline legislators and boards of regents to equate academic vitality with student credit hours. Obviously any transfer of this valuable currency is perceived as a potential disaster, even for a well entrenched department.

Perhaps Hotelling mistakenly assumed that the academy was a repository for intelligence, rationality, enlightenment, and good will, instead of a marketplace whose denizens are all "statisticians" busily calculating utiles in order to maximize expected personal gain. For whatever it's worth, could Jones have foreseen all this? If so, the faculty should have elevated him to the presidency of the university -- or even beyond. Unfortunately, there are not enough administrative posts at any single institution to cope with all the Jones's generated there, nor of course would such a denouement be the answer.

A more cunning statistics faculty then Hotelling envisaged might have conspired to coopt Jones, install him among themselves, and use him to teach large elementary classes thereby earning student credit hours under the auspices of a deserving enterprise.

But this solution is fraught with peril. The instruction is generally unaltered, but the course is endowed with an unwarranted stamp of approval inherent in the new sponsorship. Further, by virtue of the inclusion of Jones, opportunities for fostering excellence in a statistics department are attenuated.

3. Professordom, Studentdom and Curriculum

Graduate education in statistics is often decried, by those who deem themselves real statisticians, as deficient in exposing students to the "real world." Although there is some justification for this view, they also neglect to mention that many run-of-the-mill problems that professional statisticians consult on are ill-conceived, foolish, and dull. Sometimes the so-called "real world" is merely a figment of an investigator's overactive or even demented imagination. Not a few social science or educational projects fall into one or more of these categories. At the other extreme there are a few of our statistical colleagues who deplore the mere analysis of data and regard anything less than a total commitment to the mathematics of statistics as cookbookery and vocational training unworthy of inclusion in a graduate education. These also subscribe to the curious conceit that mathematics is what mathematicians do and thereby undermine their own argument about what statistics is.

There are mathematical results that deepen our understanding of statistical theory -- after all the foundations of the theory is mathemathical in form. There are results which shape the development of the methodology. There are results which are pedogogically enlightening. And there are results which illuminate the intellect but are not directly relevant. All of these are invaluable contributions of mathematical statistics. The concoction of artificial problems to display a solution of limited mathematical virtuosity is, however, a habit we easily acquire when our work is not informed by facing critical problems. Statisticians confronting such problems are at least in a position to contribute to their solutions. Mathematical nicety and rigor can be hacked out later. The tension between the poles of theory and application is best reconciled by faculty members engaging simultaneously in both but occasionally retreating to one or the other.

Hotelling envisaged that an accommodation could be made by a reduction of the teaching load, thus enabling each professor to engage in a consulting program. Currently, very few if any departments can afford such a luxury for its entire staff. To minimize the impact on the teaching program they assign a few members to the consulting function and attempt to have it funded by special projects. This may have the effect of too sharply narrowing the focus of application. Younger faculty, when overexposed to consulting, may tend to forget about theoretical issues and research, basking in the genuine appreciation exhibited by their consultees.

Operating lemonade stands in the Sahara Desert may be ego-rewarding but changes in the real landscape are illusory -- shifting sands not withstanding.

Even if we were all superb teachers, brilliant theoreticians and consultants par excellence -- in short super-statisticians, what proportion of our students will eventually exhibit these qualities? This is not easy to predict but I suspect it will be smaller than most would anticipate. The major difficulty lies in recruiting really capable students. Very few departments of statistics, if any, are entirely satisfied with the caliber of students they attract to their programs.

That most departments do not conduct vigorous undergraduate programs in statistics to draw from, is one reason. That mathematics programs from which we obtain most of our graduate students have decreasing enrollments, is a second reason. Indeed, data collected by the Educational Testing Service indicate that the yearly output of bachelor's degrees in mathematics is declining at an alarming rate[1]. Thirdly, we are in keen competition with computer science, a rapidly growing and attractive area at the undergraduate and graduate levels, for the remaining mathematically inclined students. Statistics finds it difficult to compete with the allure of the all-pervasive computer. It is hoped that we can appeal to the more mature student with a bright and inquiring mind who is not seduced by the superficial glamour of the computer -- but there seems to be a dearth of such students. Lastly, we will very soon experience the pinch of the great demographic trough now being encountered in primary and secondary schools, which will substantially decrease an already diminishing pool of talent.

Even if we were all super-professors and could recruit enough potential super-students, the education of the next generation of super-professors would still be a Herculean task. We have many impediments to overcome. Students with deficient mathematical backgrounds are inevitably delayed in their progress. Students trained exclusively in mathematics as undergraduates have difficulty in perceiving statistics as anything other than some inferior branch of mathematics, and many, of course, are only attracted by the employment opportunities offered. Six months in a consuting center of a statistics department should be adequate for those of the latter that are curable. There is also the possibility of overcuring -- as reflected by students who succumb to the "lemonade stand" syndrome, or who consider consulting as some inane form of psycho-therapy for consultee and/or consultant, pace Boen and Fryd (1978). This must be guarded against, especially if

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[1]See News and Notices section of The Mathematical Monthly, Vol. 87, No. 8, 1980, p. 689.

it comes too early in the course of a student's education -- even for those whose main interest is becoming professional statistical consultants. Precisely because these individuals may be engaging in this activity the rest of their careers, limits should be set on the time devoted to consulting during their graduate education. Outside the university opportunities for deepening one's knowledge about statistical theory are rarely available. We must also resist the tendency to tailor graduate education to some corporate statistician's parochial views on what the practice of statistics is about and the importance he attaches to early and extensive exposure to consulting during the graduate program.

What of the graduate curriculum then? Surely all agree that students should acquire a sufficient background (whatever this means in a particular context and here there is disagreement) in mathematics and probability. In my view the more the better as long as it doesn't detract from time spent on the main issue -- Statistics. Is this reasonable? Maybe, maybe not. Of course the student must exhibit mathematical proficiency or he will not be capable of using invaluable tools in deriving and understanding statistical theory and establishing the models from which will flow the methodology and applications. The orderly, efficient linear approach just described is certainly not the way the subject developed. Teaching it in this way, however, seems to get the material across to the student in an expeditious manner. Our scientific journals operate on this principle -- and with good reason. To attempt to teach a subject in the way it actually developed is much more time consuming, but considerably more interesting. A scenario for this would, no doubt, involve starting from an insightful particular application which spawned a method of wider ambit and which was eventually justified by a theory. Perhaps the theory then was found to be logically or empirically deficient or irrelevant and this required either modifying the old theory or devising a new one. In turn, either the old method was given a new justification or the methodology was revised.

At any rate, occasional seminars in which historical persepctives are employed to teach statistics would be a revelation to students, even more than the shock of being exposed to "real world" consulting.

It is also crucial, in my opinion, to teach the logical (or illogical) foundations of statistics in several of its existing forms. The foundations do have ramifications that extend to applications. Its study is informative with respect to the cultural heritage of statistics and leavens the current intellectual milieu. Some reckon it pretentious, if not presumptious, to occupy themselves with the philosophical underpinnings of our discipline. But without striving to maintain such an abiding interest, we cannot consider ourselves to be more than mere mechanics -- always serving someone else's scientific or technical interest.

Lastly, I would like to put forward a more parochial concern about what else should be included in a curriculum. There is an enormous emphasis on testing hypotheses and estimating parameters (misplaced, I believe) in courses in statistical inference and in applications as well. This fosters the illusion that the so-called statistical hypotheses are completely reflective of scientific (or other) possibilities and that parameters are always real entities that exist. For many situations this is simply not true. What we entertain is a set of potential frameworks and choose the one that best suits our needs, although we are fairly certain that the one chosen is not the true one. The proper term for this acitivity is "Model Selection," and quite often it is done with a particular purpose in mind -- namely, predicting future observables generated from the process under scrutiny.

Hence prediction or more generally predictivism, which views inference and decision as being directed toward potential observables, should be given at least as prominent a place in our curricula as estimation. Aside from this conceptual and philosophical attitude, a major technical difference, as I see it, is that prediction involves inference (preferably probabilistically framed but not necessarily) about a finite number of future values, whereas estimation pertains either to an infinite number of future values or to a completely unobservable and possibly non-existent entity. It appears to me that the finite number should take precedence in statistical instruction and application, since in this sense estimation is a limiting case of prediction. For a fuller discussion of these matters see e.g. Geisser (1964, 1966, 1971, 1975, 1976, 1980a, 1980b) and Geisser and Eddy (1979). Even in theoretical physics, Jaynes (1980) demonstrates the validity of the predictive inferential approach by reformulating statistical mechanics into "predictive statistical mechanics." In essence, parameters are mainly artifices introduced by statisticians to lubricate the modelling procedure. Current pedagogy mistakes the lubricant for the seminal substance.

Finally, concerns of professionalism and competency incline curricula to be extensive, highly structured and compulsory. How this is to be implemented without stifling creativity, independence and imagination is a problem which each department must resolve for itself, given the material at hand.

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