STATISTICATION: THE QUEST FOR A CURRICULUM

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I want to take the this opportunity to speak about the special problems we statistical educators face in trying to develop a suitable curriculum for statistics instruction. I will argue that we are far from successful. I will emphasize ways in which statistics is different qualitatively from other subjects in this regard.

The fundamental problems are threefold. The first is that statistics is an exceedingly young science. We have collectively little experience in statistical pedagogy. The second is that statistics, unlike, for example, probability, lacks a universally accepted foundation. To some this might seem to be an issue solely for the morning coffee break. But, in fact, it's much more serious. It not only affects what we teach but it affects how we think about our subject and this in turn reflects itself in the way we present our subject to students. The third fundamental problem is that statistics is a subject in extremely rapid transition. I will come back to these points in the ensuing discussion.

My talk will be of a very personal nature and it will tend to reflect my own experiences and my own failures, really, over 20 years of trying to come to grips with this difficult subject. I will, in particular, review the historical antecedents of the modern statistics curriculum in order to try and put our search for a curriculum into perspective. And I will talk about some current problems which we face. Finally, I'll give my impression of some of the current major trends in statistics with regard to how they impact on the problem of curriculum development.

My career began after I graduated from Stanford University and took up a post as a statistician in the Department of Mathematics at the University of British Columbia. I was enormously confident when I first stepped into the classroom. After all I'd had courses on measure theory and I'd had courses on statistics and I had learned about hypothesis testing out of Lehman's book and I knew about sufficiency as defined by the Radon Nikodym theorem and so on.

Needless to say, I was a little discouraged by the blank looks and the glassy stares I got from the students peering back at me in my first class. But of course I put this down to the fact that in a public institution you were bound to get a lot of class E students and, who knows, perhaps I had more than my fair statistical share in this particular course. As well, I supposed there were a great many students in other disciplines who were being made to take the subject as a prerequisite in their own field but who had not the mathematical skill to follow my lucid presentation. Pearls before swine!

It was not till some time later that I began to realize that I didn't understand what I'd been saying either. And that feeling has still not left me altogether.

To summarize my experiences in statistics teaching let me relate an anecdote. I had a student who came to the first lecture in a course on statistics which I was giving and who never showed up thereafter. Of course, this isn't uncommon. One often has students who appear and after a few lectures are not seen again. These students drop out. Imagine my surprise when I saw the same student writing the final examination. Imagine further my surprise when I discovered he scored 99% on the final. I was amazed. I asked him to come in to see me. He did so and sat nervously in front of my desk while I finished doing some paperwork and then finally I turned to him and I said, "You came to my first lecture, and only that first lecture. Now I've just finished grading your examination and I find that you got 99%. How do you explain this?" He replied very nervously, "Oh sir, he said, I would have done better only that first lecture got me so darn confused."

I despaired at my failures. But then I began to teach some mathematics courses and I found that the situation was completely different. I had no difficulty preparing my lectures and indeed I could even prepare them much more quickly than statistics lectures. The students did well on their assignments and on their exams. I was even nominated for the University's Master Teacher Award on three successive years. I didn't win mind you but the group of nominees was always quite small, at most 30 per year. And one year, one of my math students was so delighted that he wrote the letter in the next transparency to the editor of the student newspaper.

Transparency 1: Superteach

Even though nominations for master teacher award have been closed for two months now, I'd like to nominate, J.V. Zidek.

He is the only one of the 12 professors that I've had in my two years at UBC that hasn't put me to sleep in one of his classes.

I have also never had a prof who gets his message across so clearly. Most others, I have to sit in on another class to get the gist of what is going on.

As physics prof Frederick Kaempffer put it in Jan. 9 issue of The Ubyssey, good teaching should be expected rather than awarded for. Zidek is one of the few who have offered better than adequate teaching.

Name withheld

In time I began to realize that the difficulties I was experiencing in the statistics classroom were not entirely a result of my own failing. My interest in statistics history has in part been a search for pedagogical clues. I have spent a lot of time perusing the University's collection of statistics textbooks. I would like to share with you some of the impressions gained from statistics texts of earlier years. According to Meitzen's history (1891), statistics instruction originally referred to instruction given in general political, geographic and economic studies. It really referred to the fact that numerical quantities were used in the course of instruction. Evidently, Hermann Conring gave the first series of lectures in statistics in that sense at the University of Helmstedt in the year 1660. Although Conring was a physician and also a professor of law, his lectures were primarily about data concerning the land, its products, the government, state, resources and so forth.

In 1746, Gottfrid Achenwall first applied the name "statistics" to such a series of lectures. He was a professor at the University of Marburg. Statistics as we know it gradually emerged from this background as other subject areas crystallized and were gradually removed from this core of instruction. For example, Adam Smith segregated political economy as a separate science with his publication of "The Wealth of Nations". Geography was later established as a separate scientific field and life insurance was removed. At each stage, statistics was what remained by default in this process.

It is quite interesting to look at the early books. I want to mention three or four, in particular Mayo-Smith's book entitled "Statistics and Sociology", which was written in 1895. The book contains almost no theory and after a very brief discussion of general features such as collecting data, he goes straight into a discussion of things like demographics, births, deaths, and marriages.

Although Pearson's work on correlation and frequency curves is presented in a fairly mathematical way in a book by Elderton in 1906, by and large, the books on statistics written prior to 1925 reflect the heritage I just described. These books tend to be about what we would call descriptive statistics and statistical graphics. There are no well defined notions of independence, random sampling, population. and so forth.

King's book of 1916 actually hints at inference and he talks a lot about the need for care in the collection of data etc. His book includes polemics in favour of good statistical practice and against the abuse of statistics. He remarks that non-scientific people may be divided into two classes as regards to their attitudes towards new inventions or discoveries. One class accepts without question the wildest stories of incredibly marvellous discoveries and wonders why no one stumbled upon them before. The other class, usually possessing a little more education are skeptical of all scientific truth and label it all alike as guesswork.

I was interested in his remark that one of the shortcomings of statistics is that they do not bear on their face, the label of their quality. This reminds me of the difficulty one has even today of trying to convince clients and students of the need to invest more in sample surveys to obtain numbers of better quality.

I found West's book, published two years after King's in 1918, quite remarkable. He describes Pearson's curves. He talks about curve smoothing which is of course of great current interest and he includes a section on smoothing by inspection. He says that when smoothing a curve the first step is to study the data carefully. He says a curve cannot be reliably smoothed by a statistician who does not know the data thoroughly.

Later he anticipates robustness when he talks about the sensitivity of the arithmetic mean. He says that it is to be noted that a single increase of 50¢ in the price for one month has exactly the same effect in the value of the mean as does a 10¢ increase in the prices of each of 5 months. "Is this true statistically," he asks, "should the exceptionally high prices have so much weight?" He concludes that the value of the mean may not always be significant because "a part of its value may be due to the presence of unduly large variates". The book is unusual for the time because it contains some theorems and some proofs and its called "A Book on Mathematical Statistics" even though the proofs are often verbal and the mathematical aspects on the whole are quite perfunctory.

The last of the books I want to mention is that of Gavat published in 1925. It, like its predecessors, is quite concerned with descriptive statistics but the number of mathematical formulae is by now considerable. There's more precision as well even though we do not yet get solid definitions. For instance, when Gavat discusses the notion of "truly random" he tries to be quite precise. To draw a "truly random sample", in his terminology," the names of the 7,000 students may be written each on a card and then the cards are placed in a sack and thoroughly shaken up. A card then may be drawn at random by a blindfolded person". Although sampling is without replacement, nevertheless he requires that "the remaining cards in the sack be thoroughly shaken up again before the second is drawn and so on.

He talks about pitfalls in statistical thinking. "Some so called statisticians have been known to say that inaccuracy in the data makes no difference if there is only a sufficiently large amount of data. The old man who bought eggs at 25¢ a dozen and sold them at 24¢ was asked how he could make any money. He replied, he could not except that he has sold a very great many." Gavst is talking about bias although he doesn't use that terminology or otherwise indicate that he has explicitly recognized the concept. He says "if it be true that when a woman is asked her age she is inclined to understate it, the correct average age of women cannot be obtained by asking a very large number of women how old they are. But if it is true that some women are inclined to understate and others to overstate their ages, it may happen that one can arrive very closely at the correct average by getting a sufficiently large number of women to state their ages."

He notes that besides these types of errors there are others which might be called mistakes. "These should not be allowed to pass. A constant checking of work in every way possible should eliminate mistakes. It is not a crime to make a mistake, everybody does it, but it is at least very reprehensible to let the mistake stand."

Like all other books in this period and before, there is heavy emphasis on real data and practical applications so, for example, in a section on logarithmic graphical representation he presents a graph on the number of registrations of automobiles in the United States up to 1922. He then uses this curve for the purpose of what we would call forecasting. He says, and remember he is writing in the early 1920's, "New elements of prosperity or increase of population may create sufficient growth in demand to keep up the growth of business for a time. But it is impossible to get away from the general tendency of the eleven year period shown by the curve as a whole. This much is certain: the automobile industry is facing a probable saturation point in the not very distant future and should conduct its business with that possibility in view." As you well know, the industry did sort of reach a saturation point in 1929! An early demonstration of the power of statistics!

By now the developments in the foundations of statistics were becoming better known. Applications were becoming more widespread. Kolmogorov's axioms had established probability on a solid foundation. Mathematical theorems appeared with regularity. And so on.

A number of notable contributions began to emerge around the late 1920's. There is Rietz's book on mathematical statistics in 1927. Tippett published his book on methods in 1931. Snedecor appeared in 1934 and von Mises in 1939. This was a land mark year since in addition, Treloar was published then and so was Shewhart's classic on quality control.

Although King in his 1916 book calls Achenwall the father of Statistics, that title would now-a-days be given to Karl Pearson. Fisher is often referred to as the "Grand Old Man of Statistics." In any case it was these two authors who laid down the theoretical foundations for modern statistics. With these foundations, statistics was able to emerge as a distinct discipline quite separate from its origins in demography, social science and so forth. It was able to expand its earlier purely descriptive role to include inference based on precise definitions of population, random variation, and so.

In the transition period from purely descriptive to inferential statistics, stochastic models are viewed purely as models of stochastic variation. The notion of the "true state of nature" had not yet arrived. Thus, for instance, the negative binomial, the binomial, often called then the positive binomial, and the Poisson were simply viewed as a single parametrized family of potential models. The parameters themselves were not necessarily ascribed any real significence and so in fitting these models, negative values of the parameters were as acceptable as positive ones provided the resulting distribution fitted the observed results more precisely. The next transparency shows the formalistic relationship not much mentioned these days between the two binomial distributions:

Transparency 2: Negative and Positive Binomials

$$f(x) = \binom{n}{x} p(1-p)^{n-x} \quad \text{positive binomial}$$

$$= \frac{n\cdot(n-1)\cdots(n-x+1)}{x!}\, p^x\,(1-p)^{n-x}.$$

Let $n \to -|n|$, $p \to -|p|$, $\theta = |p|(1+|p|)^{-1}$.

Then

$$f(x) \to \frac{-|n|\cdot(-|n|-1)\cdots(-|n|-x+1)}{x!}\,(-|p|)^x(1+|p|)^{-|n|-x}$$

$$= \binom{|n|+x-1}{x}\theta^{|n|}\,(1-\theta)^x \quad \text{negative binomial}$$

UNIFICATION:

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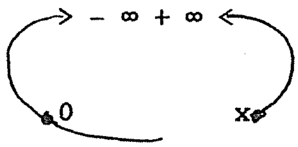
neg binomial



pos. binomial

The history of statistics and statistical pedagogy to this point might be summarized by saying that there were two somewhat over-lapping but parallel streams of development. The older, more descriptive, derived from the social sciences, demography, life insurance and so on. The other stream involved the development of the foundations of statistics. It had a heavily mathematical flavour, aimed for precision, contained notions of efficiency, and embraced the notion of optimality.

In North America at about this time in the late 1930's, and early 1940's we see the beginning of so-called mathematical statistics which in particular was contained in the seminal works of Abrahan Wald. Wald attempted in statistics what Kolmogorov had achieved in probability, that is, an axiomatic foundation. His work built on the earlier work of Neyman and Pearson. It was heavily mathematical in character, diverged from the applications base of the subject, and enshrined the notion of the "true state of nature" as an element of a statistical problem. Textbooks on statistics in North America at least, tend to reflect very heavily the legacy of Wald and his successors. These books typically have little real data and a plethora of

Greek symbols. Under the influence of statisticians like Tukey we are seeing in the late 1970's and 80's a return to a less mathematical era with much greater emphasis on applications and on the use of real data in statistical teaching.

My reading of statistical history has not eliminated my confusion about the choice of a statistics curriculum. But it has been enlightening to see current problems in the light of the great divergences and conflict in the development of statistics which have accompanied its evolution over the past one hundred years or so.

I would like to turn now to some of the reasons why the development of a satisfactory statistics curriculum has been difficult.

Let me begin with what I call the lack of a suitable foundation. There are not yet sound footings for statistical graphics, for example, nor for statistical computing and exploratory data analysis. There are no well defined directions whatsoever for curriculum development in such areas.

In the more traditional areas of inference and decision there are lots of directions but they are all different, unfortunately. The difficulties so presented are much more than mere grist for the coffee-break philosophy mill. They affect not only the choice of topics. Certain items become nonsensical. Certainly, the choice of direction affects the way we think about statistics.

Let me discuss two particularly troublesome issues. The first is the meaning of probability. Kolmogorov begged the question with his axioms but in doing so established probability, at least, on a firm logical foundation. Probability is left as an undefined object, analogous to the notion of a point in geometry. There is complete agreement about what a "point" is but unfortunately not about probability. As Doob remarked some years ago, the situation is unchanged from 1921 when he heard a statistician describe a probability as a number between 0 and 1 about which nothing else is known.

A current, increasingly popular view holds that probabilities are subjective. They are measurable attributes of the human mind. Their measurement, like all measurement, entails error. The statistical virtue of this approach lies in its use of all information, in the sample and in the background experiences of the statistician. Moreover the approach offers maximum flexibility. This point of view has made enormous inroads in fields like civil engineering, for example, where it is impossible to conceive of truly repeated sampling.

This reminds me of an experience I had some years ago as a member of a committee concerned with salary differentials between men and women at the University of British Columbia. To correct for differences in rank, age, etc., a multiple regression analysis was done. It was reported that there was a significant "sex" effect. A p-value of something like point one percent was quoted for the 1700 or so items in the database which included the entire population of all University of British Columbia faculty.

I asked a statistics colleague to explain what that p-value meant. He asked me to think of a large number of world's restocked at random, and University's with academics. This gave my imagination a workout. Even more so with the answer given by the regression analyst himself when he appeared before the Committee. He asked us to imagine the President assigning salaries with a dice! What is one to tell the students?

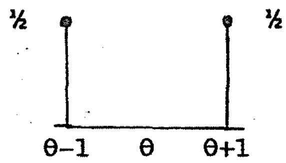
The second item I want to discuss under the heading of foundational issues is the ill-defined notion of "confidence". You have all taught students about confidence intervals and sure enough learned on the final exam that the mean is between 2 point 6 and 7 point 1 with probability .95. I can sympathize. To attempt to define confidence by long run frequency seems wrong when discussing the statistician's confidence *in a specific interval* like 2 point 6 to 7 point 1. As you well know, confidence doesn't even represent confidence even in a colloquial sense given, typically, the existence, in multiparameter problems, of so-called "relevant subsets".

Consider the example of Berger and Wolpert (1984) given in the next transparency:

Transparency 3: On the Meaning of 75% Confidence
Example (Berger & Wolpert, 1984)

X_1 and X_2 are independent r.v.'s with

p.m.f.



Smallest 75% confidence set for θ is:

$\{\frac{1}{2}(X_1 + X_2)\}$ if $X_1 \neq X_2$

$\{X_1 - 1\}$ if $X_1 \neq X_2$.

But if $X_1 \neq X_2$, $\frac{1}{2}(X_1 + X_2) = \theta$ for sure!

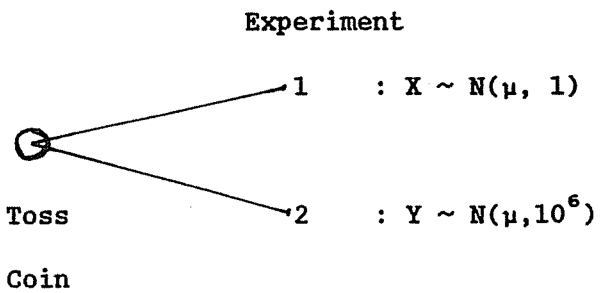
if $X_1 = X_2$, $P_{\theta X_1 = X_2} \{X_1 - 1 = \theta\} = \frac{1}{2}$!

The traditional, frequency theory of statistics abounds with such paradoxes and is altogether unsatisfactory.

Let me now turn to a second category of difficulties involved in developing statistics curriculum, what I have listed as conceptual difficulties. I will present a series of examples.

First, what is the sample space, i.e., the conditioning event underlying all the probability calculations. Hogg and Craig (1970) say the sample space contains every possible outcome. Consider the example on the next transparency, a variant of an example due to Cox (1958):

Transparency 4: What is the Sample Space?
Example (Cox 1958).



What is the Sample Space?

Conditioning on coin toss <u>seems</u>

sensible. But is it? Why?

My next example is randomization. It has been called the major advance in science in the twentieth century, a reason for statisticians to take a bow. But I always find students in my course on design skeptical of an alpha-value which is inflated by probability generated through a table of random numbers.

You have all heard I am sure the story of the industrial who told his newly appointed statistical advisor of his plan to put the four different soap powders into four successive washing machines, 1, 2, 3, 4. "You mustn't!" said the statistician explaining about possible machine effects and the need to draw the numbers out of a hat one-by-one at random to get a randomized order. The industrial drew the numbers, 1, 2, 3, 4 and on seeing the result exclaimed "I can't do that!" "Yes you must!" shrieked the statistician. How would you explain the statistician's position to the student?

Most of you have instructed your students about the likelihood function. But what is a likelihood function? Consider the unpublished example on the next transparency; it illustrates the point very nicely:

Transparency 5: What is the Likelihood Function?

$X_1, \cdots, X_n$ are independent Poisson (λ) random variables

N is unknown as is N_o = number of X_i's = 0

SOLUTION 1:

$$L(\lambda,N) = \prod e^{-\lambda} \frac{\lambda^{x_i}}{x_i} \propto e^{-N\lambda} \frac{\lambda^{N_1+2N_2+\cdots}}{(N-N_1-\ldots)!}$$

Is this correct if N is random?

SOLUTION 2:

$$L(\lambda,N_o) = \binom{N_1 + \cdots}{N_1,\cdots,N_k,\cdots} \lambda^{N_1+2N_2+\cdots}$$

independent of N_o! Is this or solution 1 correct

Finally I will turn to the notion of independence which is a very difficult concept for most students. Of course, defining the independence of random variables as the factorization of the joint density function achieves a formal simplicity and a mathematical precision. But it obscures the fact that this is really conditional independence given the population parameters.

Anyway the idea of independence is really a lot more complicated than this simple mathematical definition can convey. The next transparency illustrates this point:

Transparency 6: "Independence" is Deep

$f(x,y) = f(x)f(y)$ is "conditional independence"

- $X_1, \cdots, X_n$ independent given μ is plausible
- $X_1 - \mu, \cdots, X_1 - \mu$ independent is plausible
- $X_1, \cdots, X_n$ independent is <u>not</u> plausible!

X_1 has information about X_2 if μ is unknown

EXAMPLE

		x = −1	x = 0	x = 1
y	+1	2/25	3/25	
	0	3/25	9/25	3/25
	−1		3/25	2/25

Here $p(y|x=0) = p(y)$ so $x = 0$ is uninformative even though $x = -1$ and $x = 1$ are quite informative. "Nonindependence" here hides interesting structure. The conditional approach is more informative.

In the next transparency, I give an alternative intuitive approach which I sometimes use:

Transparency 7: Predictive Approach to Independence

LINEAR INDEPENDENCE

$E[Y-a-bX]^2 \geq E[Y-E(Y)]^2$ for all a,b

implies $Cov(X,Y) = 0$

QUADRATIC INDEPENDENCE

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FUNCTION INDEPENDENCE

$E[Y-g(X)]^2 \geq E[Y-E(Y)]^2$ for all g implies

$E(Y|X) = E(Y)$

ARBITRARY INDEPENDENCE

$E[h(Y)-g(X)]^2 \geq E[h(Y) - E\{h(Y)\}]$ for all g,h

implies $f(y|x) = f(y)$

HOMEWORK $E\, d(h[Y], g[X]) \geq E\, d(h[Y],c)$ for

all h,g ??

Another relatively recent problem in curriculum development is the emergence of enormous class sizes. On the next transparency I present some data on trends at the University of British Columbia which have led to large class sizes there:

Transparency 8: Trends in Statistics Enrolment at UBC

TYPE OF COURSE	ENROLMENT CREDIT UNIT 1971/72	ENROLMENT CREDIT UNIT 1985/86
Service	974	1670
Undergraduate	192	336
Graduate	18	54

In this regard I recently did an analysis of how my statistics colleagues spend their average work week of some 50 hours or more throughout the year. I then imputed our Departmental budget to tasks – that's hard money, not soft – by the number of hours devoted to the task. The next transparency shows the results:.

Transparency 9: Imputed % of Expenditures by Task
Statistics Department – UBC

Professional and Research Activities:		52%
Administration		16%
Teaching:		
Service:	20%	
Math Sc. Undergrad:	8%	
Graduate:	4%	32%

The most significant findings, of many, in my study were that:

- almost two thirds of the Department's teaching $'s were spent on service teaching, the highest such ratio by far of any department in our Faculty of Science.
- the $'s spent per statistics student teaching hour declined by about one fourth since 1971/72 after correcting for inflation.

The effect of decreased support levels has been a rapid increase in the size of typical sections of statistics courses. One or two hundred students is now not uncommon. This, of course, has led to an attempt to modify curriculum and teaching methods to contend with these large enrolments. Such efforts are doomed to failure. The quality of instruction cannot be maintained under such circumstances. And too much energy, which could be devoted to curriculum development, is now wasted in the futile attempt to find compromise teaching techniques which will keep the kids at the back of the room from reading newspapers while class is on.

In terms of information transfer, these dramatic increases in student-to-faculty ratios cause relatively minor problems. Finding sufficiently large classrooms with adequate audio-visual support, good seating and visibility is difficult but not insurmountably so. Greatly increased levels of teaching assistance are required to handle the grading, tutorial, and laboratory problems. But scores on "objective" exams which measure the information transferred would likely differ little between adequately equipped large and small classes.

The quality losses due to the unrestrained growth of the student-to-faculty ratio have been in skill-development rather than information transfer. The development of statistical skills needs what is no longer feasible, and that is a great deal of one-to-one student-faculty interaction through personalized grading, out of class meetings, small group tutoring, and so on. As it is, assignment grading has become perfunctory. Graders haven't time to indicate where students went wrong in incorrect solutions. Instructors cannot review the grading. His or her easier-to-grade examinations tend to measure only information transfer rather than skills. Unfortunately, the remedial and outstanding cases have suffered the most.

My survey of instructors suggests a maximum tolerable section size of 60 in lower level courses. Thirty is the figure I got for upper level courses. A recent study of the effect of class sizes at the Stony Brook Campus of the State University of New York revealed that in calculus classes under 35 student failure rates declined to 19% from 50%; the number of A's rose by 3% to 24%. So the benefits of small classes in the mathematical sciences seems clear.

Incidentally, thinking about large classes reminds me of teaching evaluation and its impact on curriculum. I will decline to discuss this here. But let me share with you comments on my teaching which I received while teaching small statistics classes:.

Transparency 10: Samples of Student Comments

Zidek:

His assignments were considered helpful, but his symbolism was different from that of the text. Typical comment: "Zidek dose the best anyone could do. He doesn't have much to work with."

The lecturer's enthusiasm and humour really made the course much more enjoyable and fun than it could have been.

We face a problem in developing statistics curriculum which is peculiar to statistics, its tendency to dissolve itself. My brief historical sketch shows our subject as the residue left behind after subjects like geography found their own foundations and moved away. These primordial roots run deep. Let me mention some manifestations:

- official statistics is being developed entirely outside of the standard statistics programs.
- factor analysis was developed by psychologists.
- partial least squares is being developed by chemists and psychologists. How many of you include partial least squares in your course on multivariate methods?

- Kriging, an important spatial method, is being developed by geoscientists and meteorologists.
- we sometimes give courses on sample survey design but leave to others like sociologists, the courses on survey research techniques.
- electrical engineers and more recently computer scientists are giving the courses on imaging, in particular, on pattern recognition. It's hard to find these subjects in programs of study in statistics.
- what about time series analysis? Again, we are typically beaten to the punch by geophysicists and oceanographers, for example.
- morphologists give the courses on morphometrics because, in part, of the reluctance of statisticians to deal with non-numerical data like shapes, for example.
- decision analysis, which was developed by statisticians like di Finetti and Savage, has gone over to the business school.

All of this leads me to suggest that there is a very realistic possibility that statistics will cease to exist. It may flow out through its primordial roots back into substantive areas where it will be developed, in a piece-meal fashion as in its past, by an army of statistical users rather than statistical scientists. It is incumbent on all of us to resist this process of dissolution, to resist defining our subject out of existence. We can begin by not defining our curriculum too narrowly.

I want to conclude my presentation by describing very recent and strong new directions and developments which are leading to even further uncertainty about what we should be teaching.

First, there is absolutely no question that the Bayesian subjectivist view is winning its war against frequency theory. At the moment it is empirical Bayesianity which is in the vanguard. Statistical scientists concerned with applications now think routinely of "borrowing from strength," as it is called. This, of course, is vital in the increasingly common multiparameter problem where there is never really enough data to apply Fisher's asymptotic theory with confidence. Why in the light of this great change in fundamental views are we not seeing Bayesian theory routinely included in our courses?

Statistical computing, exploratory data analysis, and statistical graphics are rapidly developing areas which have only barely found their way into the classroom. Rade and Speed (1985) present papers covering everything from pocket calculators to mainframes, schools to colleges. But the emphasis is on how computers can help us do better what we have always wanted to do. It is becoming obvious that the most profound major impact of computers will be felt in an entirely different direction. They are giving us a new language for statistics and hence a new statistics culture. They are replacing calculus and mathematics as modes of statistical thought. Promotions and grants committees are having to rethink how achievement in statistical research should be measured since traditional criteria like publications in refereed journals do not seem relevant in many cases. We face similarly great challenges in working out how computers should be integrated in statistics curriculum.

One obvious impact of computers has been the return of real data in statistics instruction. Another has been the decline of the "true state of nature" and the re-emergence of the "model". We are going backwards in history as we go forward.

Another important recent trend is the surge of interest in statistical quality control. This new subject will have to be accommodated as well.

Finally, statistical consulting courses are coming into fashion along with computing and real data. We now have a two course graduate sequence at the University of British Columbia. It is tied to an infrastructure for consulting which is described in the next transparency.

Transparency 11: Statistical Consulting Infrastructure

DEPARTMENT
FACULTY SUPERVISOR

FULL TIME
SYSTEMS DEVELOPER
CONSULTANT

Stat
Consulting
Courses

GRADUATE
RA's

Registered
Students

Computer

Clients

This is probably a common scheme. The key to the success of this operation is finding support for the systems developer/consultant. Much of the impetus and continuity of the operation derives from this person. And the consulting laboratory is the source of real problems, clients, and hands-on experience for students.

In thinking over what I have been saying I am reminded of Samuel Johnson's comment: "Your views are both good and original; but the part that is good is not original and the part that is original is not good."

Anyway, I have tried to argue that the curriculum of our subject is in an unsatisfactory state, exceptionally so by comparison with mathematics, for example. I have tried to present some of the underlying reasons, its youth, for instance; that much of its content is extremely deep and hard to communicate to students; that some of its concepts like confidence are seemingly meaningless. I have tried to put curriculum development into its historical context with two distinct paths, the social scientific and theoretical now converging. I have mentioned some current trends which further complicate an already difficult situation. And I have argued that our subject is in constant danger of dissolving into a myriad of other disciplines.

This conference is very welcome. Your being here is proof of your concern with issues like those I have been discussing. Many of these will be addressed in the next few days. I look forward with anticipation. Thank you for your attention.

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