sequence, which is full of arbitrary judgment. Sherlock Holmes must decide whether his time will best be spent questioning the one-eyed ticket collector at Baker Street Station or looking for the tell-tale footprint under Lady Cynthia's window. Similarly the investigator of the poor quality process who decides to run a designed experiment must answer questions such as: Which variables should we study? Over what ranges should we vary them? In what metric should we consider them? What type and how complicated a model should we use? What sort of experimental design should be employed? The (arbitrary) answers must be arrived at by good judgment and this determines success or failure much more than the calculation, for example, of an "exact" confidence interval, and again underlines the necessity for the iterative approach.

Judgmental questions of this kind arise in every application of statistics. But, our budding statisticians and future teachers of statistics—graduate students, post docs and junior faculty—can, I believe, only learn good judgment in the same way as does the medical profession. They must in effect serve an internship in which they are involved with real ongoing investigation and gain the experience of working with real investigators. The present policy of university departments and granting agencies produces exactly the opposite result. Only doctoral theses concerned with mathematical theory and single authored mathematical papers bring acceptance and eventual tenure. Joint investigations with subject matter specialists and the resulting publications, which should be mandatory, are in fact discounted and discouraged.

I once likened this process to teaching swimming by lecturing the students on the theory of buoyancy and the advantages and disadvantages of various strokes with the expectation that at the end of three or four years of such training they could all jump in the pool and swim. But it is actually worse than that. While many of the students taking Masters degrees are eventually allowed to get in the pool and those that do not first drown can perhaps teach themselves to swim, our greatest ambition for our Ph.D. students is that they never get wet. Instead we hope they will become professors and teach the next batch of students what they have learned.

Comment

W. Edwards Deming

This paper by Dr. Roberts is meritorious, in my opinion. I hope that many statisticians will read it, though nonstatisticians need it even more.

Dr. Roberts, as I understand it, takes the point of view that the aim of statistical reasoning in business should be pursuit of company goals. There is another point of view. In my own work and teaching, the business of statisticians is to transform the company goals—not to help the management to pursue theirs, but to change those goals. It is company goals that for three decades have put this country on the decline. Nothing short of transformation of company goals will halt this continual decline.

The aim of business should be optimization of the whole system of production and service. The statistician can contribute to optimization more than anyone. A system consists of four parts: appreciation for a system, some knowledge of the theory of variation, theory of knowledge and psychology.

A system must be managed. The aim of the system must be stated by the management thereof. Without an aim, there is no system. The components of a system are necessary but not sufficient of themselves to accomplish the aim. They must be managed.

I propose that the aim for management should be for everybody to gain—stockholders, employees, suppliers, customers, community, the environment—over the long term.

If psychologists understood variation, they could no longer participate in continual refinements of instruments for rating people.

If statisticians understood a system, and they understood some theory of knowledge and something about psychology, they could no longer teach tests of significance, tests of hypothesis and chi-square. Statistical theory is helpful for understanding differences between people, interactions between people, and interactions between people and the system that they work in, or learn in.

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If economists understood cooperation, and the loss and damage from competition, they would no longer teach and preach salvation through competition. They would, instead, lead us into optimization through cooperation.

A school of business has an obligation to prepare students for management in the future. Why should a school of business waste the student's time by teaching him how business is carried on today, and how to swim to the top in the present system? This kind of teaching will neither help our students in their future careers, nor help our balance of trade. The teaching of statistics should make it possible for students to prepare themselves for the future, not for the past.

There is heavy demand for positions and for consultants that possess the required knowledge. The demand increases, while the supply lags.

The country is being ruined by best efforts, not guided by the theory of management for optimization. There is no substitute for knowledge.

Comment: A U.K. Perspective on Applications in Business and Economic Statistics

Peter G. Moore

THE UK SCENE

Commenting fruitfully on Professor Roberts' interesting paper from a U.K. standpoint makes it necessary to outline the U.K. educational scene, highlighting some of the more important differences between U.K. and U.S. educational policies.

The basic structure of the U.K. system is highly elitist. Only about 15% of children enter tertiary education (mainly at universities or polytechnics), with relatively few staying in full-time education after the minimum school-leaving age of 16. Virtually all boys and girls who stay on at school after the age of 16 and complete their education to age 18 enter tertiary education. This creates a marked schism between leavers at age 16 on the one hand, and the graduates who enjoy full-time education to age 21, or even later, on the other hand. One consequence of the system is a shortage of craftsmen/technicians, so that graduates have to carry out basic industrial tasks that would be done by technicians or craftsmen in other countries.

There is substantial pressure in the U.K. to increase the number of entrants into tertiary education. Achieving this depends critically upon increasing the number of schoolchildren remaining at school after the age of 16, a task that has not yet been energetically tackled. One of the major constraints is the "GCSE" (General Certificate of Secondary Education), and "A" level examination systems, the examinations being taken at 16 and 18 years old, respectively. Most pupils aim to take five or six GCSE subjects and then, if they continue in education, work for their A levels. These are normally taken in three subjects (occasionally only two and, rarely, four), drawn principally from the subjects studied at GCSE level. These subjects then dictate the programme of studies entered upon at university. Hence, for example, unless the "A" levels include mathematics and physics, it is unlikely that a student could enter university for a degree in engineering, mathematics, physics, etc. This process forces subject choices to be made at around 14 for the GCSE subjects which, in turn, dictate the A level choices. Thus the needs for specialist bachelor degrees are felt right down the educational system as far as the 13 year old.

A recent government-appointed committee on sixth form (i.e., 16–18 year olds) education recommended a change in the A level system to give a broader educational base up to age 18 (say five subjects), a change which was rejected by the government. There is nevertheless a strong feeling, amongst educationalists and employers, that reform along these lines is essential to enlarge the pool of 18 year olds possessing a good quality broad education.

MATHEMATICS VERSUS NUMERACY

In the U.K. literacy has received considerably more attention than numeracy, and indeed is seen to have greater standing. A distinction can be made between mathematics and numeracy. While the amount of mathematics required in those working in business or commerce is relatively modest, unless they are

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