Abstracts and Short Presentations

State Space Models for Time Series Forecasting

M Akram - Isa Town, Bahrain

The last two decades have witnessed a significant advancement in Markovian or state space models. These models are frequently constructed and applied by modern stochastic controllers in engineering disciplines, but not commonly used by the time series analysts and forecasters, though the behaviour of many systems can be conveniently and effectively described by the dynamics of these models. This is perhaps due to lack of familiarity among statisticians, either of the models themselves, or of the nature of their construction. The paper briefly reviews a common state space model for time series analysis and forecasting and then describes a simple procedure to construct it.

In recent years, numerous state space models have been introduced by stochastic controllers and statisticians to analyse time dependent systems. These models, dynamic in nature, consist of two equations, such as:

$$Y_t = f\theta_t + v_t \quad \text{and} \quad \theta_t = G\theta_{t-1} + w_t$$

called observation and state equations respectively, where, for $t = 1,2,...,n$, f is a $(1\times n)$ vector of some known functions of independent variables or constants; θ_t is a $(n\times 1)$ vector of unknown stochastic parameters, called a state vector; G is a $(n\times n)$ known system or transition matrix with eigenvalues $\{\mu_i\}$ for $i = 1,2,...,n$; and v_t and w_t are Gaussian white noise processes with mean zero and variances V and W respectively.

For the construction of these models, various methods have been proposed by Aoki (1987), Harvey (1981), Harrison and Akram (1983) and others, but, generally, these are difficult to follow. Here, a simple and straightforward procedure is described which may be easily employed by modellers and academics to construct state space models for both practical and teaching purposes.

Suppose a time series $\{Y_t\}$ at time t is modelled as:

$$Y_t = f_t\theta + \delta_t$$

where $\delta_t \sim N[0,\sigma^2]$ and $f_t = f\,G^t$ for $t \geq 0$.

The vector f and the matrix G jointly describe the discrete time system. The characteristic equation of G, defined by $g(\mu) = |G - \mu I| = 0$, where I is an identity matrix, is closely related to the auxiliary equation of the corresponding difference equation model of the system, the roots of which determine the form of G. For canonical form of models the vector f and the matrix G are defined as: $f = (1,0,...,0)$ and $G = \{g_{ij}\}$ for $i,j, = 1,...,n$ where

$$g_{ij} = \begin{cases} \mu_i & \text{for } i = j \\ 1 & \text{for } j = i+1 \\ 0 & \text{otherwise} \end{cases} \quad \text{and} \quad f = (1,0,...,0).$$

For example, a simple linear regression model

$$Y_t = a + bt + \delta_t$$

where at time t, a is the level of the process, b is growth, and δ_t is as defined earlier, can be converted into a second order state space model by defining D as a difference operator and writing the second order difference equation of the noise free term of the above model as:

$$D^2 Y_t = Y_{t+2} - 2Y_{t+1} + Y_t \doteq 0.$$

Solving this equation we get the roots $\mu_1 = \mu_2 = 1$. Considering these roots as the eigenvalues of the matrix G as

$$G = \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix}$$

and writing $f = (1 \quad 0)$ and $\theta = (a \quad b)'$ we see that a system that satisfies this difference equation is

$$Y_t = f\theta_t \quad \text{and} \quad \theta_t = G\theta_{t-1}.$$

Considering the noise δ_t as a linear combination of the noises v_t and w_t, and adding into the system equations, we obtain

$$Y_t = f\theta_t + v_t \quad \text{and} \quad \theta_t = G\theta_{t-1} + w_t.$$

If, instead of the canonical form, a diagonal form is desired, this may be achieved by applying the transformation technique of Akram (1988).

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Teaching Industrial Statistics in an Australian University

Tim Brown - Perth, Australia

Australian industry is becoming more aware of the benefits that statistical methods can have in improving quality and enhancing competitiveness. Correspondingly, there is a growing demand for statistics graduates in industry. Traditionally, quality control has usually been a small part of undergraduate statistics curricula in Australia, and the emphasis has been on detection of failures rather than prevention and design. Good curricula exist (such as that of Vardeman and David (1984)), but these have not been designed with the Australian education system in mind, and require fine-tuning. As well, the graduates will not be useful unless they are good at communicating statistical ideas to non-statisticians, can work as part of a team, and are able to extend their knowledge where necessary. As with other courses in applied statistics, these requirements mean that an industrial statistics course must use quite different teaching methods.

This talk described some of the methods used at the University of Western Australia, outlined the technical content in our course, and discussed computing in this context. Some of the points which emerged are more widely applicable.

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Development of an Introductory Statistics Unit for a Multi-Disciplinary Class of Students

Henry T Eastment - Toowoomba, Australia

Prior to 1990, the University College of Southern Queensland offered three introductory units in statistics in degree courses. These units had many topics in common although there were some specialist topics in each and problems and discussions of statistics were discipline-oriented.

In 1989, to increase the efficiency of the offerings of courses within an environment of reduced levels of funding, a statistics unit, to be taken by all students whose course of study required an understanding of the fundamentals of statistics, was developed. At the same time, the effectiveness of the teaching programme had to be maintained.

In this paper I outline the development of the so-called corporate statistics unit.

Development of the unit: The unit was designed for students from Science, Engineering, and Business Studies courses. Although these students have varied mathematical backgrounds, it was necessarily assumed that they would have minimal calculating skills.

A unit team was formed consisting of people from Engineering, Science, and Business Studies, who had some experience of statistics within their own area so that the aims, objectives, and contents of the unit would, and could be seen to, be developed by an interdisciplinary group with each area's requirements being considered.

After surveying the needs of each area the major topics decided upon as core were Scientific Method, The Role of Statistics, Data Types and Properties, Data Reduction and Pictorial Presentation, Numerical Description of Data, Elementary Probability, Binomial and Poisson Distribution, Normal Distribution, Sampling and Statistical Inference, Correlation, and Regression. In addition, students would study either Statistical Inference for two or more samples or Decision Analysis, depending on which was more appropriate for their course of study.

Next, the team selected three textbooks, one for each area of study. The selection of three textbooks meant that students had to be provided with study material that would:

(i) contain general statements about statistics and general examples and explanations;
(ii) not have to deal with particular sources of data, since students could see these sources in a text relating statistics to their own field of study;
(iii) have suitable referencing to all three texts.

The selection of three textbooks had the potential to create several difficulties for students if not handled correctly.

To assist students in studying the unit, a Learning Package consisting of an Introductory Booklet and a Study Guide were produced.

The Introductory Booklet contained information relating to the study of the unit externally, including unit specifications, assignments and due dates, telephone tutorial times, and a study schedule.

The Study Guide has a section on each of the eleven topics. Each section gives objectives, references by chapter to textbooks, further information or more detailed explanation of textbook material, worked examples, a list of key concepts and terms, student activities, self-assessment questions with answers, and a glossary of terms. This learning package was provided free of charge to students studying the unit externally. Students studying on-campus were expected to purchase it.

Students were advised to buy a suitable "scientific" calculator at a cost of \$30-\$40 and told that they were expected to learn to use it efficiently and effectively.

Presentation and administration of the unit: For on-campus (internal) students, the unit was taught using two one-hour lectures per week and one two-hour tutorial per week for fourteen weeks.

By providing a learning package supported by lectures and tutorials, students could be directed to read appropriate material prior to attending classes so that they will be better prepared. This was the approach taken in the unit; lectures consisted of an overview of material, highlighting major points and discussing examples.

Students were given problems selected from the appropriate textbook to discuss in tutorials and were also given ample opportunity to discuss problems on an individual basis.

For off-campus (external) students, a telephone was manned twice a week to enable students to contact staff directly regarding difficulties they encountered while studying the unit. Three times during the semester a telephone tutorial (whereby several study centres are linked via conference telephones to the university) was held to discuss problems in a group situation with students. Tapes of these sessions were distributed to students on request. In addition, students could contact the Distance Education Centre and have a message passed on to the lecturer who would usually respond within 48 hours.

Students in the unit were assessed on the basis of three assignments, each worth ten percent, and one three-hour open book examination worth seventy percent.

All students did the same three assignments, each of which contained questions on the core material. The additional material was examined in the final examination which also contained questions on the core material.

The Unit Teaching Team, consisting of the lecturer and five tutors, met weekly to discuss tutorial activities, assignment marking, teaching techniques, problems identified by the students or staff, and general administration of the unit. These weekly meetings were essential for the administration of the unit and were very useful as a feedback medium.

In conclusion, I would like to say that I feel that the unit team has succeeded in giving the students a sound, well-balanced, introductory statistics course.

In the first offering of the unit there were approximately 250 full-time students and 350 external students. In the second offering a total of 1300 students are expected.

I would also like to thank all members of the Unit Team and the Unit Teaching Team for their active support and participation in the development and presentation of the unit. My thanks also to Pam Surman and Mike McFarlane of the UCSQ for helpful comments on drafts of this paper.

"With Cat-Like Tread" - The Emergence of Statistics at the University of Sydney

Ann Eyland - Sydney, Australia

This paper traces the development of the teaching of statistics at the University of Sydney from a course on surveying at the end of the last century, to the present degree programmes in biometry, economic statistics, and mathematical statistics. This development has not been well-ordered. Rather, it can be likened to a cat stalking its prey, the prey changing significantly from time to time. Some of the factors associated with developments (or lack thereof) are found to lie within and without the statistics profession as well as within and without the university. They are related to staff and resources, intellectual ideas, and as the official historian of the university says, the personalities involved in the internecine wars of the university.

Communicating with Scientists : Experiences with Fission Tracks and Radial Plots

Rex Galbraith - London, England

Statistical ideas are not always well understood, even in the scientific community, and the important ideas are not always those that receive emphasis in statistics textbooks. I discuss some experiences in communicating statistical ideas in the context of fission track dating. These include a controversy about correlation and precision, and the use of radial plots - a graphical method for comparing estimates that have differing precisions. Radial plots have other applications - for example to inter-laboratory studies, to meta-analysis of clinical trials, and to the display of Bayes' estimates.

Improving Student Learning : Using Computer-Generated Data Sets to Individualise Student Assignments

Michael Glencross - Transkei, South Africa

At tertiary level, the traditional methods of teaching and assessment that are often employed tend (i) to encourage competition rather than cooperation among students, and (ii) to promote a passive learning role, both of which are detrimental to effective learning. Further, a perennial problem in the teaching of statistics is that of finding suitable examples of data whose structure contains the necessary simplicity or complexity for analysis and discussion. This paper describes a recent development intended to improve student learning by using the standard features of a computer software system to generate individualised student assignments, together with the matching solutions. The resulting benefits to students and lecturers are discussed.

Some Information about the Activities at the Department of Statistics, Stockholm University, Sweden

Jan Gustavsson and Per Nasman - Stockholm, Sweden

This paper briefly describes the activities at the department, particularly with reference to basic education. Topics that are dealt with are study programmes, courses, type of teaching, and use of computers. Special interest is given to a new local study programme in statistics.

Survey on Statistics Education at Colleges and Universities in Japan

Masayasu Murakami and Masakatsu Murakami - Tokyo, Japan

As of April 1, 1989, there were 490 universities in Japan, with 1190 faculties. 132 were established by the national and municipal organisations with 449 faculties and the rest were by the private ones.

To the request for materials addressed to deans, 94% of universities contributed materials which piled up to more than 10 metres in height!

All the materials were checked by members of the committee for statistical courses. The titles of the courses alone were not enough for this purpose, and course descriptions and related information were studied. In some cases, the information was not sufficient to decide that it was a statistical course. This phase of the work required several months. For this and other reasons, it was decided that summaries should be done separately for the national and municipal universities, and for the private universities. What follows refers to the former only.

To determine statistical courses adequately, joint study of the courses by more than a single member was considered relevant. Thus, the first summary pertains only to those cases where the courses could be judged clearly statistical by the title. In other words, only the courses having the titles of "statistics" or "specialised statistics" were included.

Altogether, 1247 such statistical courses were offered, classified by title, as shown in Table 1.

TABLE 1
Statistics courses offered by national and municipal universities

Course Title	No of Courses Offered	Course Title	No of Courses Offered
Mathematical Statistics	208	Educational Statistics	36
Statistics	197	Agricultural Statistics	32
Probability and Statistics	133	Special Statistical Topics	29
Quality Control	94	Psychological Statistics	21
Social Surveys	67	Management Statistics	20
Applied Statistics	60	Data Analysis	15
Economic Statistics	59	General Theory of Statistics	15
Experimental Design	53	Statistical Engineering	14
Probability	47	Gymnastic Statistics	13
Biostatistics	40		

At the general education level of freshmen and sophomore 69, or 56%, of the universities offered statistics courses and 55, or 44%, of universities had none. Out of the 69, 36 universities are for natural science, and 28 are for social science.

Over all education levels, freshmen to seniors, the numbers of courses offered by faculties were as shown in Table 2.

TABLE 2
Numbers of statistics courses classified by faculty

Faculty	Total Number of Courses
Engineering	440
Education	224
Agriculture	164
Economics	164
Science	88
Literature	46
Home Economics	34
Culture and/or General Science	33
Medicine	28

Teaching Order Restricted Multivariate Statistical Inference

Peter E Nuesch - Lausanne, Switzerland

During the past thirty years, order restricted inference has been a central theme of research for statisticians. It all started with a handful of papers in the second half of the fifties, particularly with the two *Biometrika* papers by Bartholomew in 1959. A first monograph (Barlow, Bartholomew, Bremner and Brunk) with a reference list of 236 titles, appeared in 1972 in the Wiley series in probability and mathematical statistics. The revised edition, by a new set of authors (Robertson, Wright and Dykstra) appeared in 1988, with a reference list of 948 titles.

During the same period, a considerable number of multivariate statistics texts appeared on the market, all of which ignore order restricted inference. (Some books like Miller's *Beyond ANOVA - Basics of Applied Statistics* contain fleeting references to the field without really treating it.)

It is the purpose of this paper to find the reasons for the fact that a vigorous research theme with an undeniable appeal for the practitioner has never been put into user-friendly form for the applied statistician. We then list the steps necessary to do so, and report on some experiences with teaching order restricted multivariate statistics at an introductory level.

Teaching Statistics in Colombia : Problems and Potential Solutions

David Ospina - Colombia, South America

Historical review: Statistics in Colombia was practically unknown as a discipline and as a profession before 1960. The statistical courses of the different universities were taught by engineers, mathematicians, economists and other professionals. It was not until 1958 that the National University started the undergraduate programme in Statistics (Comite Carrera de Estadistica Universidad Nacional, 1985). It was a three year programme which emphasised some topics not directly related to statistics, like geography, accounting, technologies, etc. Four years later (in 1962) the University of Medellín opened its own programme. This was a five year programme but as diversified as the one at the National University.

The reduced number of statisticians or professionals devoted to statistics was probably one of the main reasons why these programmes were poorly oriented. Most of the classes were lectured by people who did not have the required statistical background or did not have enough interest in statistics. The teaching was very theoretical and the practice was reduced, in most cases, to textbook exercises.

Several reforms to the programme at the National University have been carried out (Comite Carrera de Estadistica Universidad Nacional, 1985). The fact that the studies are under the direction of the Department of Mathematics and Statistics has increased the mathematics level and has made it look like a branch of mathematics. This has affected, to some degree, the employment opportunities (Morettin et al., 1985).

This absence of contact with actual applications of statistics created confusion amongst the students about the actual role of statistics. In 1977 there was an important statistical meeting at Bogotá supported by the American Statistical Association and DANE (Departamento Administrativo Nacional de Estadística). Its main goals were to found a strong statistical society in Colombia and promote the joint work between statistics and other disciplines. Unfortunately, despite the initial success, the situation did not change. The Society was created but it did not work. Today nobody knows about it. The people attending the meeting did not continue working and the objectives were soon forgotten. Boroto and Zahn (1989) must be right when they say that the source of the main problems lie within the profession.

Two Associations, although a little more restrictive, have been founded and are active. One of them (ACESTA) groups the statisticians from Medellín, and the other one (Asociacion de Estadísticos de la Universidad Nacional) the statisticians from Bogotá. It is estimated that more than 70% of the statisticians are associated to one of them. Today the total number of undergraduate statistical degrees conferred is close to 800.

The relatively low success that statisticians have had in Colombia has been reflected by the lack of interest in our profession amongst the student population. The average number of registered students for the first semester in the statistics programme during the period 1979-1981 was 15 (Comite Facultad de Ciencias Universidad Nacional, 1983). The private sector is not generating many job opportunities for statisticians in Latin America (Morettin et al., 1985), and that applies to Colombia specifically. The low industrial development and the high dependence on multinationals seem to be the key for that.

Today there are only two five year undergraduate programmes in statistics (National University and University of Medellín), one master's programme at the National University, and one programme of specialisation on Data Analysis at the University of La Salle. The graduate programmes seem to be more successful than the undergraduate ones. I think the reason for this is that professionals from other areas usually acknowledge the importance of statistical methods when they have to face statistical problems in their jobs. This seems to motivate them to study statistics because the kind of problems they analyse are not approached during their undergraduate studies.

Reform of 1990: The last reform of the statistics undergraduate studies at the National University has been carried out this semester (Comite Carrera de Estadística Universidad Nacional, 1986). It took into account most of the opinions in the academic and non-academic sectors. The new programme consists of three parts. At first there is a basic cycle joined with mathematics, then a disciplinary cycle, and finally the specialised one. The basic cycle which gives the opportunity of selecting more than one discipline can produce better results than the original rigid programme. Once the student has finished the basic cycle he/she will choose between mathematics and statistics. If he/she prefers statistics he/she will follow a disciplinary cycle which will provide him/her with the fundamental knowledge in statistics (statistical methodology, statistical theory, non-parametric statistics, sampling, linear models and computation). At this stage the student will be able to decide which specialisation he/she desires. These are: Data Analysis, Probability, Econometrics, Experimental Design, Administration, Sampling and Population Studies. After the three cycles the student must do some consultation work and elaborate a paper.

The advantages of the reform are evident. The different choices will motivate the students to pursue the programme. The basic cycle will help to use the resources in a more useful way, joining the students from both programmes - mathematics and statistics. The specialised cycle considered the opinions of the Asociacion de Estadisticos de la Universidad Nacional.

The consulting semester is also very important. As Carter et al. (1986) say: "... simple exposure to real problems is not adequate". However, this part of the programme has to be considered seriously because statistical consulting usually requires a lot of specialised knowledge that can be obtained only at the Doctoral level. The people in charge of this consulting orientation to the students must have enough academic and practical background to prevent this experience from failing.

There are a couple of gaps in the programme from my point of view. The first has to do with the poor communication skills that our graduates usually have. One course semester in technical writing should be required. This problem, already analysed by two American Statistical Association Committees (Committee on Training of Statisticians for Government, 1982; Committee on Training of Statisticians for Industry, 1980), seems to affect us equally. The second point is related to the proficiency in at least one computer language and one statistical package which has not been clearly established within the programme.

Potential solutions: Besides the changes that the new reform considers, there are some suggestions which should be taken into account.

(i) The selection procedure to admit students to the university must be modified. There is a waste of resources because the number of accepted students is much smaller than the maximum allowed. The change involves a revision of the entrance tests and the general policy of acceptance. In a developing country it does not seem a good idea to leave empty seats in the classrooms when there are hundreds of students who would be very pleased to occupy them. Not everybody should be admitted, but to those with a decent score, who did not qualify for their favourite choice, an opportunity to enrol in other programmes with an insufficient number of students, should be given. Mathematics and statistics are two of these cases.

(ii) The ties between the Department of Statistics and the Associations should be strengthened. Not only with Statistical Associations, but with other Professional Associations. A promotion campaign must start soon with talks and seminars about the impact of statistics in the different knowledge areas.

(iii) The statistics programme must be divulged in high schools by people with enough experience in statistical applications, not just statistics teachers. We can only gain recognition and status if we can provide the people with what they want and need (Boroto and Zahn, 1989), and only people who have the experience can tell the story.

(iv) There must be strong cooperation with other faculties and programmes. It is important to undertake joint research and publishing. It is only through this kind of work that the statistical profession gets credit. Interdisciplinary projects must be one of the priorities.

(v) An industrial semester where the student can apply some of the main statistical techniques and write a report on it, should be considered as an alternative for the last semester.

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Teaching Introductory Statistics for Future Citizens at Liberal Arts Colleges

Rosemary Roberts - Brunswick, Maine, USA

Liberal arts colleges are undergraduate institutions that are unique to the United States. The liberal arts philosophy is to provide a general education that prepares students for lifelong learning and good citizenship. This philosophy affords the opportunity to give statistics education a prominent role at liberal arts colleges. We discuss this opportunity to teach statistics for future citizens.

Statistics Education of The Graduate University for Advanced Studies

Giichiro Suzuki - Tokyo, Japan

The Graduate University for Advanced Studies was founded on October 1, 1988 as one of the national universities of Japan. The fundamental idea of the university is to develop a new system of postgraduate education in Japan. The characteristic features are as follows:

(i) The university provides a PhD course of three-years' duration.
(ii) Research and education are carried out in close cooperation with the seven Inter-university Research Institutes (parent institutes). They are:
  (a) School of Cultural Studies: Department of Regional Studies and Department of Comparative Studies;
  (b) School of Mathematical and Physical Science: Department of Statistical Science;
  (c) School of Mathematical and Physical Science: Department of Accelerator Science and Department of Synchrotron Radiation Science;
  (d) School of Mathematical and Physical Science: Department of Structural Molecular Science and Department of Functional Molecular Science;
  (e) School of Life Science: Department of Genetics;
  (f) School of Life Science: Department of Molecular Biomechanics;
  (g) School of Life Science: Department of Physiological Sciences.
(iii) A wide, integrated and international vision is fostered by enhanced interchange

between the schools and departments and with other universities in Japan and abroad.

The Inter-university Research Institutes provide Japanese and foreign scientists with opportunities to perform high-grade joint research in various branches of science.

The Graduate University itself consists of three graduate schools, i.e.

(i) School of Cultural Studies;
(ii) School of Mathematical and Physical Science; and
(iii) School of Life Science.

The schools comprise a total of ten departments. There is a Department of Statistical Science which belongs to the School of Mathematical and Physical Science.

The academic staff of the department consists of 13 professors and 12 associate professors of the Institute of Statistical Mathematics, Tokyo. Most of the research and teaching is carried out at the Institute, making full use of its facilities and equipment.

Deep expertise in specialised fields is cultivated by teaching and research guidance tightly consolidated with the high-level research performed in the parent institute.

Inter-departmental functions of the university, such as joint seminars and lecture courses, provide the students with opportunities to broaden their scientific interest and international awareness through contacts with faculty members and students of other schools and/or departments of the university, as well as with those of other universities in Japan and abroad.

The requirements for graduation are:

(i) Study for at least three years. However, the period may be shortened for those students who have achieved outstanding records.
(ii) Acquisition of required credits in the department.
(iii) Preparation of a dissertation under the guidance of academic advisors and a successful defence of the dissertation in a final examination.

The degree to be awarded is "Gakujutsu-Hakushi" or Doctor of Philosophy.

Courses are grouped in four lines, namely Statistical Bases; Research, Experimentation and Analysis; Prediction and Control; and Applied Statistics. The first line treats basic notions of statistical science, e.g. randomness, likelihood, entropy, etc. It includes statistical inference based on probability theory. Courses in the second line comprise methods pertaining to data collection like sampling survey and experimental design, data analysis of spatial events, multi-dimensional analysis, pattern analysis and so forth. Courses included under the next line are prediction, control, optimal decision based on information criteria, statistical models, and also statistical calculation for handling large-scale statistical models. The last line takes up research on the methods for the analysis of phenomena with the treatment of variation in fields such as Biology, Medical Science and Engineering, as well as statistical methods for the measurement and analysis of human action and behaviour.

On Teaching Linear Statistical Models

Kathleen Trustrum - Brighton, England

This paper discusses the content of a course of 27 lectures plus 9 exercise classes given to final year undergraduates majoring in mathematics and statistics. The course includes topics from multiple regression, experimental design, and generalised linear models. The problems of demonstrating the use of appropriate statistical packages during the lectures are also discussed.

A Report on the Hogg Workshop in Statistics Education

Jeffrey A Witmer - Oberlin, Ohio, USA

A group of 39 statisticians met at a workshop at The University of Iowa from 18 to 20 June 1990 to discuss statistics education in the United States. This workshop was organised with the goal of improving undergraduate instruction in statistics - an area that is widely held to be in great need of improvement. Introductory courses in statistics are perceived by many students as being dry, boring, and not relevant to their lives. Moreover, at many institutions statistics teaching is adversely affected by the view that statistics is a branch of mathematics, rather than a separate discipline.

The statisticians in attendance represented large universities, small colleges, and industry. Most of the workshop time was spent in meetings of four teams, each of which included members from each area. The conversations centred around beginning courses for non-mathematical students, but many of the points raised can be applied to the teaching of mathematical statistics.

(i) *We need to state our goal:* Stating the aim of the course is an important, and often overlooked, step toward successful teaching. After considering skills and knowledge to impart to students, as opposed to a list of methods to cover, one team came up with the following:

> "Our aim in a first course is to develop critical reasoning skills needed to understand our quantitative world. The focus of the course is the process of learning how to ask appropriate questions, how to collect information effectively, how to summarise and interpret that information, and how to understand the limitations of inferences. [Statistical reasoning] is central to education."

Unfortunately, the common introductory statistics course does not meet this goal. A typical textbook example begins with a question that has been formed to address one feature of data that have already been collected. Students gain little insight into how and why data are collected, how experiments are designed, and how analysis of one set of data leads to new questions, new experiments, and subsequent analyses in a continuing cycle of scientific inquiry. Statistics is presented as a formal ritual, rather than a dynamic study of processes.

Every team agreed that the typical introductory course should change by giving more attention to graphical techniques, to simple topics in the design of experiments, and to the scientific method, and *much less time to hypothesis testing.* Most introductory textbooks devote too much space to this.

There was some agreement that there should be a single introductory course for students of all interests. Undergraduates interested in mathematical statistics, who are the largest pool of future graduate students in United States' statistics programmes, should depart from standard current practice and take an additional introductory course in statistics that features data analysis and applications.

(ii) *Analyse data:* There was widespread agreement that students should encounter more data from real problems and work more with graphs. Many advocated projects in which students collect their own data and analyse them in written reports. Such projects combat apathy by allowing students to work with data that they find interesting. Moreover, projects give students experience in defining problems, formulating hypotheses and operational definitions, designing experiments and surveys, collecting data and dealing with measurement error, summarising data, analysing data, communicating findings, and planning experiments that are suggested by their findings.

(iii) *To compute or not to compute:* Properly used, the computer can be a powerful and effective tool in teaching students about variability in data, particularly through graphics. Most participants strongly support the use of the computer. Having a computer available during class facilitates "on-the-spot" analyses of data, which teach students that there are often many analyses that can shed light on a problem and that simple graphics can tell one a great deal.

However, a few participants saw obstacles, including lack of equipment, lack of adequate projection systems, and lack of staff to operate statistical computing laboratories. Moreover, teaching students to use the computer can shift attention away from statistical ideas.

(iv) *Lecture less, teach more:* Lecturing is but one way to communicate ideas to students. Classroom demonstrations and data collection add variety, as do experiments that are run in class. Much effective learning takes place when students work together in teams. Student projects can be done in small groups, as can some experiments that are conducted in class.

Of course, some teachers are faced with very large classes. Two ways to make a large class seem small are to emphasise project work and to lecture to a small, random,

(v) *What can the profession do to help?* It was suggested that a "First Course Corner" or "Activities Corner" be added to *The American Statistician*, in addition to the existing "Teacher's Corner", which deals mainly with issues that are only of interest in teaching graduate level courses. Such a new section would provide a place to share interesting sets of data, experience with projects and classroom experiments, and other ideas to improve the introductory course. It would also signify a commitment on the part of the profession to improve the situation.

Other suggestions included short courses at meetings to teach teachers about such topics as process improvement (which few current statistics teachers studied in graduate school) or the effective use of student projects in the introductory course.

Of course, it would be quite helpful if universities rewarded excellent and innovative teaching. More directly, some participants in the workshop are developing sample syllabi to share with other teachers. This idea has already been used successfully in the calculus reform movement in the United States.

University Statistics Training in a Government Statistical Agency

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The Department of Statistics employs university graduates in its Mathematical Statistics Branch. This branch provides technical support and advice on surveys run within this department and by outside clients.

What statistical training have these graduates had and how is this training applicable to the work they find themselves doing? What, if anything, is missing from this training, and should these gaps be covered by universities?

In order to answer the questions posed we administered questionnaires and interviews to our colleagues within the Mathematical Statistics Branch.

Our conclusions are that a breadth of statistical training and a familiarity with statistical concepts is important. The detail of techniques can be learnt or revised when it becomes necessary for a project. The higher the level of statistical training undertaken at university, the more techniques a student is likely to have encountered. We identified a lack of exposure to sampling theory for those people whose degrees had been obtained at New Zealand universities. Many people expressed a desire for the practical component of courses to be increased.

Three elements that we identified and feel are deserving of emphasis are:

(i) A greater emphasis on the use of resources such as journals, and encouragement for students to do background research to get a wider view of a problem.

(ii) A greater emphasis on good oral and written communication. Good communication skills were seen as essential for any statistician.

(iii) The use of more real-world problems in which the technique to be used is not clear-cut. Our respondents expressed the view that finding a suitable technique for a problem is a skill that needs to be learned.

It is our opinion that students are not encouraged sufficiently to practice and develop these skills and that these skills are important for all statisticians.