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PROCEEDINGS of the FOURTH INTERNATIONAL CONFERENCE ON TEACHING STATISTICS

VOLUME 1

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Sponsored by
The International Statistical Institute
and
The National Institute of Statistics and Applied Economics, MOROCCO

IMPRIMERIE EL MAARIF AL JADIDA-Rabat

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FOURTH INTERNATIONAL CONFERENCE ON TEACHING STATISTICS

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- *Les communications relatives à la session 5C et aux groupes de travail n^{os} 3,4,5,7,8 ne sont pas parvenus au secrétariat de la Conférence à la date d'impression des actes de la conférence.*

PAPERS
COMMUNICATIONS

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An Introductory Mathematics Course Called CHANCE

A group of six colleges in the United States: Dartmouth, Grinnell, King, Middlebury, University of California-San Diego, and Spelman have developed and tested a new introductory mathematics course called CHANCE.

CHANCE treats issues that are reported in the news: statistical problems related to AIDS, the possible dangers of electromagnetic fields, the use of DNA fingerprinting in the courts, maintaining quality of manufactured goods in the face of variation, effectiveness of mammogram testing for prevention of breast cancer, reliability of political polls, and so forth. Students study the newspaper accounts of these topics as well as articles in general science magazines, such as Chance, Science, Nature, and Scientific American, and the original research papers when appropriate. The necessary probability and statistical concepts are developed in the context of the topic under discussion.

We have taught several different versions of the CHANCE course and have experimented with new methods of teaching, such as group learning and using activities. This project is supported by the National Science Foundation's Undergraduate Development Program with additional support from the New England Consortium for Undergraduate Science Education.

Material to help in teaching CHANCE is maintained in our Chance gopher: chance.dartmouth.edu. In addition, we put out a bi-weekly chance-news by e-mail abstracting articles in current newspapers and journals that deal with probability or statistical concepts. This chance-news is available by request from chance.dart.edu.

This talk will describe our experiences and evaluations of the CHANCE courses that have been taught in the past two years.

Glimpses of Statistical Literacy
The Experience of Statistics New Zealand

Len Cook
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In providing information to the community a Central Statistical Office forms a view of how effectively quantitative information is used by different segments of the user community.

This paper describes how in presenting information, assessing user needs and conducting training outside the organisation Statistics New Zealand has to address the changing needs of the different parts of our user community.

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and

Adnan Awad
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University of Jordan
Arman, Jordan

Statistical Literacy of Citizens: The Case of Jordan

This paper discusses two topics, namely, the past and present status of teaching of statistics in Jordan, and the Jordanian public's views of statistics.

The public's views will be collected through questionnaires distributed to a stratified sample of the population, including students, teachers, administrators, public and private employees, and ordinary people.

The data will be organized and analyzed by suitable methods.

It is expected that there will be a positive view towards statistics in Jordan, and there will be differences among the views of the strata of the population.

The Statistics of Poverty and Inequality

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ABSTRACT

The project described in this paper uses a real-life data set taken from the U.N.E.S.C.O. 1990 Demographic Yearbook.

Students at Chester College use this data set as a case study through which they can explore the use of various simple E.D.A. and graphical techniques to investigate various problems and questions.

Is the world's wealth distributed evenly?

Do people living in different countries have similar life expectancies?

Do men and women have similar life expectancies?

Are birthrates related to deathrates?

Students are able to generate and investigate their own questions, alsoand are enabled to make inferences without the use of formal hypothesis tests.

The paper also discusses the types of statistical skills required by the citizens of the future.

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The Citizen's Duty to Understand and the Statistician's Duty to Ensure Understanding: Statistics in a Litigious Society.

Life or death or at least a lot of money can depend upon how well statisticians for one side or the other in a criminal or civil case can "teach" statistics to the triers of fact, judge or jury. This paper will present some of the ethical and scientific issues surrounding the role of statistical experts in litigation. Illustrations of how statistics are presented and perceived will be given. The introduction and reception of DNA evidence, employment discrimination statistics, death penalty investigations, and epidemiological studies are among the examples to be discussed. Although the primary focus will be on United States cases, there will be some comparison with the evidentiary role of statistics in other common law and civil law jurisdictions.

THE EFFECT OF USING A VIDEO ABOUT STATISTICS ON THE ATTITUDE OF STUDENTS TOWARD STATISTICS IN A COMMUNITY COLLEGE

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KEY WORDS: Student attitudes, Pre-post testing, Video

An investigation was conducted at Community College of Philadelphia with students in 6 sections of an algebra course. The treatment group watched the video, "Decisions Through Data, What is Statistics?," (Comap,Inc., 1993). The control group read the brochure, "Careers in Statistics," distributed by the American Statistical Association. The data analyzed were derived from the Statistics Attitude Assessment (SAA), which assesses perceived usefulness of statistics. The SAA was developed by the investigator and administered as both pre-test and post-test. A chi-square analysis was performed investigating the effect of the video on the number of students who would consider taking a statistics course before and after viewing the video. There was an association between watching the video and changing attitudes toward taking a statistics course (X^2 =4.28, df=1, p<.05). After viewing the video more students considered taking a statistics course.

"Decisions Through Data, What is Statistics," Video 1, Unit 1. Lexington, MA, 1993.

LA STATISTIQUE ET L'ENSEIGNEMENT SECONDAIRE EN ALBANIE

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1. Depuis 20 ans l'enseignement de mathematiques en Albanie est en perpetuelle evolution, a l'image de ce qui s'est passé dans les autres pays. L'exemple de l'ecole francaise surtout a été étudié et suivi de près. Apres des années d'experimentation, depuis 1988 le programme du premier niveau scolaire (1-8 classe, age 6-14), a été entièrement renouvelé. Dans ce programme on trouve pour la première fois de la statistique (5e, 6e, 7e, 8e classe): les représentations graphiques, la frequence, le mode, la mediane, la moyenne, les probabilités (vues du point de vue frequentiel).

2. Dans le cycle secondaire (9-12 classe, age 15-18), des 1981, la Statistique et les Probabilités ont été introduits (avec la Logique) sans que les programmes aient été entierement renouvelés.C'etait un premier effort vers un enseignement moins traditionnel et plus moderne Le programme en Statistique et Probabilités était cependant trop ambitieux et le formalisme trop élevé. De plus il n'avait pas de prolongement au dela de la 9ème classe.

En 1990, un nouveau programme provisoire entre en vigueur, le but étant de s'adapter aux changements opérés dans le cycle obligatoire (1-8 classe); le programme definitif sera appliqué en 1996, lorsque le premier contingent du cycle obligatoire arrivera au niveau secondaire. Pour le moment, la Statistique et les Probabilités sont enseignés a tous les niveaux d'études, les sujets vont des représentations graphiques au calculs des probabilités.

3. Au vu des programmes, ces dix dernières années, la Statistique a gagné du terrain, mais en realité on est loin encore d'une situation satisfaisante. Le traditionalisme, l'attitude et l'impreparation des enseignants y est pour beaucoup. De plus par manque d'information et aussi de moyens materiels, l'enseignement de la Statistique utilise peu, voire pas du tout, les moyens offerts par la microinformatique.

Invited Lecture

Title: Handling data systems in the curriculum for General Basic Education

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Abstract: The need to introduce techniques of data collecting and graphing, descriptive statistics, and elements of probability theory in the general curriculum for grades 1 to 12 is now no longer under discussion: the average citizen is required to decode averages, ranges, dispersions, graphed data, survey results, weather prediction, etc., and to make decisions based on those numbers. The discussion now is no so much on 'how much' (there are enough lists of proposed minimal requirements to get a relatively large intersection) but on 'when' and 'how'. In this paper the author explains the decisions made about statistics and probability for the new mathematics curriculum for grades 1 through 9 designed under his supervision in the Colombian Ministry of Education, and now being introduced grade by grade since 1985 in all Colombian schools.

The first conceptual decision was to start not from statistics and probability, but from the handling of data systems. The concept 'data system' is explained, contrasting it with 'data set' and 'data structure', in the light of the version of General Systems Theory used to structure the global mathematics curriculum in Colombia. The ways data systems are integrated with other contents of the mathematics curriculum, and the proposals to integrate them with other areas, especially social studies and natural sciences, are described. The distribution of contents in the different grades is displayed, and the key proposed methods and activities are listed.

Title: Handling data systems in the curriculum for General Basic Education

Author: Carlos E. Vasco (Colombia)

1. Introduction

The need to introduce techniques of data collecting and graphing, descriptive statistics, and elements of probability theory in the general curriculum for grades 1 to 12 is now no longer under discussion: the average citizen is required to decode averages, ranges, dispersions, graphed data, survey results, weather prediction, etc., and to make decisions based on those numbers (see for instance Burrill, 1992). The discussion now is no so much on 'how much' (there are enough lists of proposed minimal requirements to get a relatively large intersection) but on 'when' and 'how'.

In this paper, I shall attempt to explain the decisions made about statistics and probability for the new mathematics curriculum for grades 1 through 9, designed under my supervision in the Colombian Ministry of Education, and now being introduced grade by grade since 1985 in all Colombian schools.

The first conceptual decision was to start not from statistics and probability, but from the handling of data systems. Therefore, the first part of this paper (Section 2) attempts to explain the concept 'data system', contrasting it with 'data set' and 'data structure', in the light of the version of General Systems Theory used to structure the global mathematics curriculum in Colombia. The second part (Section 3) deals with the specific way I address systems in the mathematics curriculum. The ways data systems are integrated with other contents of the mathematics curriculum, and the proposals to integrate them with other areas, especially social studies and natural sciences, are described in the following section. In the remaining sections, the distribution of contents in the different grades, and the proposed methods and standards are briefly treated.

2. Why data systems?

There is no such thing as an isolated piece of information. If it is really isolated, it contains no information. The key concept for statistics and probability comes from the vague notion of an information package. It has

something in it, something which is quite complex. You can do something to it: you can put in more data, or you can extract something from it.

One thing is sure: an information package is not a set of data. A set is unordered, its elements are loose and flat. A set contains no repeated items. Look at the sets {2, 4, 6} and {2, 4, 6, 6, 6, 6}. According to mathematicians, those two sets are identical: {2, 4, 6} = {2, 4, 6, 6, 6, 6}. But if you are a statistician, you know your n's are different: 3 and 6; and your averages are different: 4 and 5. Sets are practically useless for statistics.

Are then data structures the key elements for statistics? Not quite. They are too abstract, to empty of meaning. Lists, FIFO- and LIFO-stacks, and other abstract data structures are just the structures of useful data systems. A data system has components at different levels; it supports many internal and external operations, and has many internal and external relations.

Most data systems have three components at the first level of resolution: a head, a body and a foot. If you wish to be fancy, say header-corpus-footer. In turn, each one of those components may have folders and documents, or records and fields. Fields may have fixed or flexible lengths, and they may be full or empty. You must master many of these schemes, and have clear mental maps of their layout.

On those internal components, many operations or transformations are possible. Internal operations, like sorting and recoding, and external, like deleting and inserting. Among components, many relations are possible. Internal components, like dependence, or adjacency, and external, like sharing or origin.

Students do not face data sets; they face data systems. But this distinction forces us to go deeper into the notions related to systems.

3. Why systems?

The Colombian mathematics curriculum has a theoretical underpinning based on General Systems Theory (see República de Colombia, 1991; Vasco, 1986,

1990). According to this theory, any topic in mathematics can be addressed as a system with components, transformations and relations. The components supply the 'statics' of the system; the transformations provide the 'dynamics' of the system, and the relations conform the 'structure' of the system. More formally, a given mathematical system, **Syst**, can be described as a triplet of sequences: a sequence of sets, **Set**; a sequence of transformations or operators, **Op**, and a sequence of relations, **Rel**:

$$\mathbf{Syst} = \mathbf{(Set, Op, Rel)} = ((C_1, C_2, \ldots), (\mu_1, \mu_2, \ldots), (R_1, R_2, \ldots)).$$

Given any mathematical topic, the first challenge is to determine it in such a way that its components, its operations, and its relations become apparent. The main stress is on the transformations or operations, because they provide activity, dynamics to the system.

But this version of general system theory also allows another type of analysis: Every mathematical system seems to split into three levels of systems, like a ray of white light going through a prism. The bottom level is composed of those concrete systems which are familiar to students, and from which they can construct the conceptual systems we are interested in. Once they have constructed them up to a point (which can be surmised by everyday speech, gestural and pictorial communication attempts), they are prompted to propose symbolic sytems to express their conceptual sketches, and those attempts are compared to standard symbolic systems for clarity, efficiency, universality, and other characteristics of viable symbolic systems. Of course, the main stress is on the construction of the relevant conceptual systems.

4. Finding, creating, assessing, representing, and using data systems

The starting point for statistics and probability at any grade is provided by the real-life encounters students have with data systems: Batting averages of their favorite teams; prices of goodies in the school co-op store; football scores of the first half-season; grades of the first six months of the school year, etc. You either find those data systems, look for them, or build them up (don't make them up!). Counting bikes, motorcycles, cars, and busses

while you look out the window for five minutes, if you have a purpose for it, will provide you with a data system you have built yourself. Asking for prices of toys at the local toy store, in order to see which and how many you can afford with your savings, yields another data system you have constructed. It is not the same to give students a list of prices and ask them to add them up; that is a routine 'problem'. But if they have to make decisions on the real data system, things are different. They must add many times, discarding or including items, to see if their allowance is enough to buy what they want. They are operating on the data system; they are being made aware of relations among its data, and constructing new relations among them.

Data systems have authors, and authors have purposes, interests, failures. Who built this data system? How good is their data? Should I trust the data, or is it better to check some of those numbers? What did they do it for? What else can I use it for? How can I make a summary of it for my purposes? What decisions could I support using this data system? Those are key questions in life, not only in school, like: What is the range? What is the mean and standard deviation? Those questions come later; much later. And if the given data system is composed of category- and ordinal-level data, they never arise (compare with Bell, 1978-1979; Russell & Friel, 1989).

5. Integration across the curriculum

This approach through data systems jolts the mathematics teachers out of their routines. The personal and social needs data systems satisfy are beyond mathematics, and the harder questions about those systems involve social studies, psychology, sociology, political science, ethics, epistemology and research methodology. But at the same time, this challenge offers teachers multiple opportunities to connect with other areas of the school curriculum. The systems language offers parallels, analogies, and hints to other systems in mathematics, in the natural and the social sciences.

6. Curricular topics

When you look at curricular contents judging only by the keywords present in them, you might think they are more or less the same everywhere. Shift

here, add there, omit this and that, and once you have seen one, you have seen them all. The same happens to people, when they look at the data systems column with the contents of the Colombian mathematics curriculum in the area of statistics and probability. The topics look familiar; too familiar, indeed. But you must look twice: at the chart, and at the suggested activities and methods. Then you should see the difference the data systems framework makes. And if you don't see the difference, don't reject things too fast: The very fact you can judge that the suggested activites or methods fall short of the theoretical basis, is enough to recommend the latter. And perhaps enough to rebuild the former.

Let us take up an example: Grades 1-3. You see only: Bar graphs; data collection; tabulating and otherwise representing data. That is all for those three grades. But if you look twice, the idea is to build, assess, use, and represent data systems your students have obtained themselves (see República de Colombia, 1991).

The primary grades in Colombia are only five. Let us look at grades 4-5: Data collection; tabulating and otherwise representing data; introduction to data analysis; frequencies; mode; average of a small numeric data system.

The secondary school grades go from the 6th to the 9th. There are two more middle-school grades, 10th and 11th (non-mandatory). Let us look at the proposed topics for grades 6-7: Absolute frequencies; relative frequencies (percent and fraction representation); bar and pie charts; normal or point frequencies; accumulated frequencies; measures of central tendency: mode, mean, median. For grades 8-9: Measurement; sampling; disposition and representation of data; scales or levels of measurement; measures of central tendency: mode, mean, median, quartiles, deciles, percentiles; measures of dispersion: max-min, range, interquartile range. Invent other measures!

For grades 11-12 (Middle School): Statistical inference; decision-making about and on the basis of data systems. Doesn't look like much, does it? But remember to look twice. Those two lines provide enough hard stuff for the whole Master's degree coursework in Graduate School.

7. Methods and activities

The methodological principles guiding the teaching of data systems agree with those in other fields of the Colombian mathematics curriculum: start from concrete systems, familiar to students; try to construct conceptual systems related to those familiar systems; once you have good hints your students are catching on, let them try different symbolic systems, compare them, and make decisions about preferred representations.

For probability and statistics in particular, games with a degree of randomness are very attractive to children, and provide oppartunities for constructing the conceptual systems needed for decision making and for further study of probability and statistics. Data collection for well-stated purposes and needs of students is really a start in research methodology. Interpretation and critique of tables and graphs, taken from the daily paper, T. V. shows, news and other sources are the center of key activities.

Concepts are not taught via definitons, or via formulas. The idea of making short but powerful descriptions of large data systems will prime students to talk and think about minimum and maximum values, range, centrality, dispersion, etc. Through the attempts to measure centrality and dispersion, students are being prepared for a critique of the usual statistical wisdom, a reinterpretation of the usual formulas, and perhaps the invention of new proposals for measures of centrality, dispersion, skewness, etc.

The preferred symbol systems are of course graphs and tables (see SLO, 1987; SLO, 1989). Talking about decisions, needed information, statistics, measures, and instructions to calculate them, gets you to formulas.

8. Conclusion

This is a short synthesis of the approach used in Colombia to design the Data System Units of the national mathematics curriculum. Perhaps these straightforward ideas will motivate educators, curriculum designers, and textbook writers to defy traditional statistical wisdom, and be bold, creative and daring in their proposals to introduce or reform the teaching of probability and statistics in the elementary grades.

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Data Analysis Activities in the Elementary School Curriculum

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Mathematics educators in the United States have regularly reaffirmed the importance of incorporating data analysis activities into the elementary mathematics curriculum. The rationale for this incorporation often includes statements to the effect that such activities better prepare students for the information-rich society in which they live. Moreover, the consensus of pedagogical opinion is that elementary school students need to be given the opportunity to engage in realistic mathematical problems.

We have found that data analysis provides students an engaging context in which they may investigate real-world phenomena. Students' participation in developing the initial questions, collecting and organizing the data, choosing the analysis methods, interpreting the results, and summarizing the process are all essential components of the investigation.

In our presentation we discuss and illustrate several data analysis activities appropriate for an elementary school setting. These activities are part of a series of workshops for our students who are both prospective and practicing teachers.

The activities deal with growing plants, describing pets, evaluating medical tests, assessing whether a game is fair, Monte Carlo simulations, and evaluating weather reports based on temperature data. These activities use real data and are designed to model the process utilized by researchers. Throughout the data analysis process, students perform analyses which help them to understand how mathematics can function as a significant tool in describing, comparing, predicting, and verifying results.

We conclude that experiences in collecting, organizing, graphing, and interpreting results are one of the best means for introducing children to applications of mathematical understanding through data analysis techniques. We further conclude that implementing these activities have enabled children to explore interesting questions, form conjectures, make decisions, and express their ideas in settings that value each child's opinion rather than searching for one correct answer.

Using Data Desk and Projects in Teaching Probability and Statistics

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The U.S. Coast Guard Academy is one of five federal service academies. All cadets are required to take a calculus based probability and statistics course and also purchase a Macintosh computer in their freshman year. In 1989, the department introduced assignments into the Probability and Statistics course using the Data Desk software. The computer assignments are of an exploratory nature and ideally suited for learning the material. Insights about structures, patterns, and anomalies of the data help lead the student to conjectures concerning the information. Simulation and exploratory data analysis makes experimenting with various models necessary and a valuable learning experience. The computer assignments satisfy the following conditions: (1) Assignments would illustrate how theory is used in practice and emphasis would be on problem solving. (2) The projects would be relatively short and would reflect real situations that need statistical formulation. In addition to the computer assignments, a major computer project is required. This project is continuous and on going throughout the semester. The project involves analyzing data from Coast Guard Search and Rescue Stations located in Maine and requires using a majority of the material from summary statistics to ANOVA. Formal reports by students on this project will be shown.

Workshops for Mathematicians who Teach Statistics

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Among four-year colleges and universities in the USA, there are almost five times as many sections of introductory statistics taught in departments of mathematics as there are sections taught in departments of statistics. A disconcertingly large percentage of the teachers of these courses have little or no formal training in statistics.

In an effort to help these mathematicians, the Mathematical Association of America, with support from the National Science Foundation, is sponsoring a series on nine week-long workshops. Each workshop features four days of presentations by leading applied statisticians, together with hands-on computer exercises based on the presentations. The other three days of the workshop are devoted to projects that emphasize data production. The twenty four participants, in six teams of four, plan and carry out an observational or experimental study of their own design, assisted by consultations with the presenters and a project coordinator.

After the workshops, participants remain linked to each other and to the workshop leaders by electronic mail, and come together for a one- day reunion at some point during the next year to discuss their projects and their statistics courses.

In my talk I shall discuss (1) the relationship between our pedagogical goals and the structure and content of the workshops, and (2) our process of evaluation and evolution using feedback from leaders and participants.

A Modular Laboratory and Project-Based Statistics Curriculum

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We describe our experiences in developing and testing a new curriculum for introductory statistics for engineering, science and management students. The goals of the curriculum are to get students to think critically about data, and to demonstrate the role of statistics in scientific investigation. The curriculum features a number of one-week modules each keyed to project and laboratory experience. The modular structure offers flexibility in course design and gives students the ability to tailor the course to individual needs. The learning environment is problem-driven and alternative modes of delivery, such as cooperative learning, are emphasized.

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Parallel Evolution in Statistical Education? A Comparative Study of Practical Experiences for Undergraduate Students

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The purpose of this paper is to compare and contrast the experiences of two universities in different countries with respect to practical experiences for undergraduate students. One university is Winona State University in Winona, Minnesota which is located in a predominantly rural area in the Northern Central part of the United States. The other university is Sheffield Hallam University in Sheffield, England which is the fourth largest metropolitan area in terms of population in England. Both universities require two experiences of each student–a work experience to the university and a project under the supervision of a faculty member. How these experiences are implemented is very different in the two universities. There are, however, some common lessons that have been learned by these two universities. Two major foci of this paper will be the lessons learned and recommendations for other universities trying to implement similar practical experiences for students.

Bringing Groupwork into an Applied Statistics Course

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Most of today's statistics instructors were taught by the lecture method. Today most of these instructors continue to use the lecture method even though it has been shown that more active forms of teaching improve the learning in a class. One way to promote active learning is to use groups or teams. In this paper the author reports on the variety of the ways that he has brought groupwork into his classes. At first he only formally required groups of students to work on written projects. Then he encouraged informal groups of students to work on homework assignments. Recently he has successfully expanded his use of groups to include oral presentations of group projects, in-class group exercises, group class participation, and group quizzes. He also reports on the results of a recent experiment in which he assigned groups of students to work on homework assignments. In conclusion, he discusses the advantages and disadvantages of using groups in an applied statistics course.

Introductory Statistics as a Single Project

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The course *Investigational Statistics* was designed to accomplish three goals. The first is to motivate lower division students who have had no previous exposure to statistical inference to take further courses in both mathematics and statistics. The second is to give those mathematics majors who have previously taken the theoretical probability and statistics sequence a realistic environment for applying their knowledge in the hope of encouraging them to consider statistics as a career. And the third is to provide those students whose academic interests lie in the natural or social sciences an introduction to statistical reasoning which will demonstrate its value as an important tool in scientific research, and will give them a foundation for using this tool in their future careers.

The class is broken into teams of three or four students per team. Each team spends the semester working on a single data set, and is required to provide both a written and oral report of the statistical analysis of the data as the term project. This paper will discuss the structure of the course, and the educational experience as perceived by the instructor and the students.

Reinforcing Statistical Concepts through Collaborative Research Projects for Undergraduates

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Collaborative research investigations provide a unique way to structure hands-on project based experiences for undergraduates. Using research tools, students learn to identify, analyze, and solve problems and to communicate conclusions and solutions. Through an Honors Apprenticeship Program at Moorhead State University, highly qualified students may elect to pursue research with faculty mentors. In addition, University, national, and corporate research grants awarded to faculty are often used to support undergraduate research. We have found that collaborative scientific investigations provide an important source of individual student projects in statistics. Recent student projects have been completed in the areas of statistical education, biology, laboratory medicine, hematology, and rheumatology. Through these projects students have developed new statistical techniques or gained additional experience in the areas of regression, time series analysis, non-parametric statistics, mixture distributions, analysis of variance, log-linear models, and survival analysis.

Student evaluations of their research experiences have been universally positive citing the excitement and challenge of working toward a common goal in cooperation with other students and scientists. Demonstrating the success of this project based approach, students have published research papers, made presentations at regional and national meetings, won University academic awards, been accepted to graduate programs in statistics, and obtained research positions in statistics. We conclude that collaborative scientific projects provide exce llent tools for teaching research methods and reinforcing statistical concepts.

Teaching Consulting: One Experience

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The consulting course at the University of Manitoba has evolved over about 10 years. Normally more than one person teaches it, thus giving a variety of viewpoints. Major components of the course include:

- discussion of a text by Boen and Zahn: dry land training.
- an experience in giving a short presentation and being filmed.
- analysis of a dataset from the viewpoint of making a presentation of the results to your boss who is a non-statistician.
- students presenting and discussing articles from the literature.
- live consulting leading up to an oral and written report.

Class Demonstrations for Improved Learning and Comprehension in Teaching Probability and Statistics

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As in the case of teaching courses in the physical sciences, class demonstrations can play a fundamental role for increased comprehension of difficult concepts in statistical sciences. Using simple devices in the classroom for illustrations of uncertain phenomenon has shown to be an effective teaching strategy in statistics and probability courses at the introductory level. The use of computers in generating data as well as collection of data by students is commonly practiced by statistics teachers. For teaching design of experiments in industry, a model of catapult has been used extensively and results in better understanding of factorial experiments. It is believed that the use of classroom demonstration for teaching intrductory courses in probability and statistics is not very common. The results of a study reported in a Ph.D. dissertation by Robert Situmeang submitted to The Ohio State University will be discussed. Recommendations for their use will be made for teachers in the statistical sciences.

You Can Get There from Here: An Analysis of Student Projects in a Community College Statistics Class

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It is a challenge to teach statistics to students in a community college in the US. They are a diverse group, coming from different age brackets, socio-economic backgrounds and so forth. One way to get students involved in the course is for them to do a research project on a topic of their choice. They will gather and collect data, analyze it and draw appropriate conclusions in this endeavor. This becomes an integral part of the class as they apply what they have learned throughout the semester. In addition, the relevance of statistics will hopefully become more apparent.

This presentation will focus on the lessons drawn from several years of doing this in an introductory statistics class and on future prospects for students doing this kind of hands-on work.

Activity-Based Statistics: Engaging Students in the Learning Process

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Their fast-paced world of action movies, rapid-fire TV commercials and video games does not prepare today's students to sit and absorb a lecture, especially on a supposedly dull subject like statistics. To capture the interest of these students, teaching must move a way from lecture-and-listen to innovative activities that engage students in the learning process. The Activity-Based Statistics Project is developing a set of such activities to cover the statistical concepts that are essential to any introductory course. The classroom-tested activities consider topics such as:

- experiencing and describing variation in data
- understanding randomness in processes
- seeing the importance of inserting randomness into data collection
- conducting and comparing sample surveys, experiments and observational studies
- developing good questions for surveys
- solving problems by use of quality improvement techniques
- modeling physical processes

Some of the activities make use of archived data, some require students to produce data, and some use no data. Many of the activities can be used as demonstrations in large lectures, as small group assignments in a laboratory setting, or as take home assignments for individuals or groups. Use of a computer is encouraged, but not required for most activities. As a resource for instructors, references for further investigations and ideas on assessment will be provided. The activities are presented with a certain amount of flexibility so that instructors can adapt them to their own settings.

This presentation will review and discuss some of the arguments in favor of making the classroom a more active learning environment, and then demonstrate the process with a few of the activities from the ABS Project.

Inexpensive Devices for Encouraging Statistical Explorations

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Much attention has been given in recent years to ways in which a computer can be used to help illustrate statistical concepts. In this paper, we take a much lower-tech approach to consider how some ordinary objects might also provide useful means for allowing students to generate data and explore statistical techniques. For example, what can we do with a coin - besides flip it? How can we fix a die so that our students won't notice a difference - but statistics will? How can we keep students busy for an hour with a single blank sheet of paper?

Teaching Statistics with the Use of Projects: Experiences in Malawi

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Traditional methods of teaching statistics involve stating (and in some cases proving) theorems, describing statistical methods, and working through "textbook examples". These examples are often simplified and do not reflect real world problems. Students recognize these as contrived. To give the students a better appreciation for the value of statistics, one can assign them to work on a project. The project can include specifying the question to be answered, designing the study, dealing with problems of data collection, and data checking, as well as analysis. The type of project assigned depends on the level of the student and the size of the class. We have used projects with classes smaller than 20 and larger than 100. We will describe several of the projects that students have used. Some of the projects require the use of surveys taken in different areas of the country. An important consideration here is the translation of the questions into the local language. To assess the student response to the use of projects, we have collected data through a brief questionnaire. We will summarize the student responses. We believe that the use of projects enhances student learning and student appreciation for the value of statistics.

Learning Statistics Through Self-Discovery

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Many statistics educators believe that instructors can better serve their students by lecturing less and providing more opportunities for students' hands-on involvement with data. In this presentation I describe a project which takes this approach to the extreme of abandoning lectures completely. Students spend class time working on activities carefully designed to enable them to discover statistical concepts, explore statistical principles, and apply statistical techniques for themselves. These activities ask students to analyze and to explore genuine data, some of which come from available sources as well as some collected by the students themselves. Some of the activities ask students to use a computer or a hand-held graphics calculator. Students are encouraged to interact with their peers, with student teaching assistants, and with the instructor as they work through these activities.

I will provide examples of the types of activities used and of curricular materials that support this self-discovery approach. As an example, consider the correlation coefficient as a measure of the linear association between two variables. Students do not need to hear lectures about the properties of this measure; they can discover those properties for themselves through suitably chosen examples and activities. They need not be warned that association does not imply causation; ask them to investigate the association between the life expectancy and the number of people per television set in a variety of countries, and they can tell you that association and causation are separate ideas. The goals of these activities are to create a more enjoyable and productive learning environment as well as to deepen students' understanding of fundamental statistical ideas.

Importance of Research Projects in Teaching Statistics

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This paper affirms that data analysis becomes meaningful to students only when the data are not just numbers from a book but have a history and context. In particular, it describes the experience of teaching statistics through real life data and classroom projects to school students and educators through programs sponsored by the United States National Science Foundation's Directorate for Education and Human Resources. The paper also recommends a number of project topics to teachers who wish to incorporate such discovery-based projects in their classes.

THE USE OF MULTIVARIATE METHODS TO ANALYZE STUDENTS' STOCHASTIC CONCEPTIONS

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SUMMARY

The theoretical basis of this paper is the modeling of students' conceptions about a specific topic as a qualitative and systemic construct. Following therefrom, a discussion about the role of multivariate analysis for studying the structure of these conceptions and for building explanatory models relating this structure to task, cognitive and instructional variables. An empirical study of students' intuitive conceptions referring to statistical association is used as an example.

INTRODUCTION

In mathematics, a concept is given by its attributes and by the relationships which exist between them: the definition of a concept (whether it be given by abstraction, complete induction, etc..) accurately describes its characteristic features. However, the present tendency in cognitive psychology considers that there are no necessary and satisfactory attributes which might fully determine the internal structure of concepts. From a psychological and didactic viewpoint, Vergnaud (1982) proposes a definition of concept in which he includes not just the invariant properties which give the concept meaning, but also the situations and significants associated with it. Therefore it is necessary to consider concepts, and generally speaking, mathematical objects as composite and complex cultural entities.

Consequently, a subject's conceptions about a given object, at a given moment, must also be modelled as an organized and complex whole, emerging from the systems of practices, as carried out by a person faced with problematic situations (Godino and Batanero, 1993). This systemic complexity makes it necessary to develop a new theoretical framework for educational and psychological measurement, which will overcome the limitations of the classical psychometric approach. Thus, the evaluation must take note of the multiple

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manifestations of subjective knowledge, that is to say, of the different components of personal meanings of objects and their interrelationships.

In the sections below, we analyze this problem in further detail, especially the role which is to be played by the multivariate techniques of data analysis in determining the relational structure between the different aspects of the students' knowledge. We shall use Estepa's research work as an example (Doctoral thesis supervised by C. Batanero at the Didactics of Mathematics Department at Granada University, 1993), referring to the notion of statistical association.

DESCRIPTION OF THE EXPERIMENTAL STUDY

One of the interesting points in Estepa's research work (1993) was how to determine students' conceptions about statistical association, prior to teaching on the subject. In order to determine them, the answers to a questionnaire involving 10 questions from a sample of 213 students were used. In each one of them, the student had to express his opinion about the existence or otherwise of association between two statistical variables, supporting his answer. The following were used as empirical indicators of the conceptions: the judgments about association expressed, the strategies used in solving the problems, the interpretation given to the tables and graphs and the prior theories expressed about the association on the variables in the problem. As an example, in figure 1, we show one of the items on the questionnaire, corresponding to a judgment about association in a contingency table.

Item 1: In a medical centre 250 people have been observed in order to determine whether the habit of smoking has some relationship with a bronchial disease. The following results have been obtained

	Bronchial disease	No bronchial disease	Total
Smoke	90	60	150
Don't smoke	60	40	100
Total	150	100	250

Using the information contained in this table, would you think that for this sample of people bronchial disease depends on taking the drug? Explain your answer.

Figure 1.

The variables considered in the questionnaire were as follows:

V1; Type of item: Contingency tables (2x2, 2x3 and 3x3), scatter plots or comparison of one numerical variable in two different samples.

V2: Sign of the association: Direct, inverse and independent association were used in 2x2 tables and scatter plots.

V3: Relationship between context and prior belief: The association suggested by the context of the problem and the empirical association presented in the table, which may (theory agreeing with data) or may not coincide (theory contradicting data).

V4: Strength of association.

THE STRUCTURE OF KNOWLEDGE AND THE PROBLEM WITH ITS EVALUATION

As we pointed out in Godino and Batanero (1993), we conceptualize a subject's knowledge about a mathematical object as a complex system. The study of this system's structure, that is to say, of the relationships of implication between the different variables which influence the answers given by the subjects in an evaluation situation must be tackled from a structuralist methodology. There must be included amongst these variables not only those deriving from the tasks proposed, but also the variables of the subject and of the context or didactic situation.

Furthermore, subjective knowledge has the nature of an **unobsevable construct**, so several different empirical indicators have to be used to determine it, that is to say, a problem of **measurement** arises (Dane, 1990). These indicators are the answers (strategies, arguments, mistakes and solutions) to the tasks in which this knowledge is brought into play.

The items of the evaluation instruments form a sample of the universe of possible **characteristic problematic situations** of the corresponding mathematical object. In the case of statistical association, it is possible to imagine many different problems, when changing the task variables systematically in those we have described.

As a result of these epistemological and cognitive assumptions, in the analysis and interpretation of the evaluation results, carried out for research purposes, it is necessary to bear in mind the following characteristics of the system of empirical indicators of the students' mathematical knowledge:

(1) Multidimensionality: we cannot assume a priori, and generally speaking, the existence of a quantifiable latent trait which would indicate the degrees of acquisition thereof; on the contrary, the knowledge would be made up

of multiple aspects, for the construction of which we would have to carry out different "acts of understanding" (Sierpinska, 1990). Metaphorically speaking, knowledge is more like a tree than a ladder or an upward slope.

(2) Qualitative characteristic: which is manifested in every one of these components; thus, for a concept or given property we cannot simplify the possible manifestations that the students make about it by stating that they "know it" or they do not "know it"; it is worthwhile differentiating between the different types of mistakes and strategies, which, generally speaking, cannot be put in order on a numerical scale.

(3) Importance of the interactions: since knowledge is modelized as a system, this is not determined by listing its components. Its structure is an essential aspect, because it reveals to us possible variables on which to act if we wish to obtain the progression of the said knowledge.

TECHNIQUES FOR THE ANALYSIS AND INTERPRETATION OF DATA.

Adopting this approach in the analysis of conceptions poses the problem of the simultaneous study of a large number of variables. This study is made possible at the present time by the multivariate analysis of data, which, according to Gras (1992), constitutes an epistemological breaking with classical statistics. Its objective is that of being used as an exploratory instrument in the study of the systems of complex interrelationships between variables and in determining the structure of such systems.

To sum up, once we have selected a representative sample of characteristics set problems of the conceptual objects which interests us, we would analyze the students' answers together with the variables included in the problems. The group of answers from the subjects to the items are taken as coordinates of two point systems in a double empirical multidimensional vectorial space (space of items/dual space of subjects). The geometrical metaphor used to modelize the data set has great potential, since it allows us, by means of the definition of a distance between points (subjects or variables), to define a topology to these spaces, to which it is possible to apply topological, algebraic and geometrical techniques.

Cluster analysis

A first group of classification techniques (Celeux and colls, 1989) allow individuals and variables to be grouped together using very distinct kinds of algorithms (cluster analysis of subjects or variables; hierarchical or non-hierarchical; ascendent or descendent). The proximity between items shall show

the similarity of answers with regards to these items from the subjects, or what is really the same thing, the presence of similarities in components of knowledge (analogous interpretation reveals proximity between subjects). In Estepa's research work (1993), the hierarchical cluster analysis of the answers (split into correct and incorrect answers) to the different items which indicated the presence of differentiated factors in the abilities needed to solve the problems proposed. These groups were later checked and interpreted with the aid of factorial analysis, in which 5 basic factors or necessary abilities were identified for solving the association judgments:

1. Study of the association between variables as a variation of the relative conditional frequencies of one variable according to the other one. This capacity may be used for the study of any problem of association and it is essential in the study of contingency tables, in which the variables are qualitative.

2. Study of the association between variables as a variation of the numerical value of one of the variables according to the other one. This may be used to solve problems of association when one of the variables, at least, is quantitative.

3. Interpretation of the sign of the association. Some students do not consider the case of negative association.

4. Differentiation between correlation and causality.

5. Differentiation of the study of association as a comparison of one variable in different independent samples or as a comparison of two variables in the same sample (related samples).

Factorial techniques.

On the other hand, factorial techniques such as factorial analysis, multidimensional scaling, single and multiple correspondences analysis, (Escofier and Pages, 1988) use the properties of the Euclidean vectorial spaces in order to determine the possibility of reducing the size of the data and to make their graphic representation easier, which would allow an overall synthesis to be achieved. The fact that this complex system may or may not be structured in a few basic dimensions, and that the characteristics of the structure may vary due to the action of the subject's or instruction variables may all be explored with the aid of these techniques. Particularly in the factorial analysis of correspondences (Greenacre, 1984), it is possible to work with qualitative variables and their properties of distributional equivalence and dual representation make it a particularly valuable instrument.

The representation -as supplementary subjects- of the task variables in

space (individuals x tasks) will allow us to formulate and verify theories regarding the variables and their values which are related to a similar answer to these groups of related items. This possibility is considered as a new approach for regression and it allows us not only to see any variable of interest in perspective, but also to position "ideal profiles" proposed by the theory, the privileged position of which, on the projection plane is, always considered as a "proof" (Escofier and Pages, 1988). The study of the main factors relating to these task variables will allow us to identify relationships of dependency -interaction between these variables and to classify the task variables into groups of decreasing order of effects on the variability of the answers.

In the research into statistical association, the analysis of correspondences of the strategies used in the association judgments revealed two factors which jointly explained 82.6% of the inertia. The first factor was identified as the dimensionality of the table and showed that when increasing the number of rows and columns in the table, the students generally used more elaborate strategies. This also occurred in the case of perfect independence. Therefore, whereas with a partially correct intuitive strategy many students were capable of providing a correct association judgment in 2x2 tables, in which there was a noticeable dependency, in order to appreciate independence, even in 2x2 tables or the dependency in a larger sized table, the partially correct strategies proved to be insufficient.

The second factor showed the weight of the prior theories over the association expected in the context of the problem over the student's strategies. When these expectations did not coincide with the empirical association of the data in the problem, there was a tendency to replace correct or partially correct strategies by incorrect strategies, as a means of supporting their theories, even in spite of the evidence against them, clearly demonstrating the mechanism of the "illusory correlation" (Chapman and Chapman, 1969).

Implicative analysis:

Finally, we quote the implicative analysis technique, recently defined by R. Gras and his collaborators (Gras, 1992). Starting from the notion of quasi-implication, measured by an intensity, and that of the implication graph, this method allows us to show, within a family of variables, the partial order (prior order) from which it is structured. Whilst the techniques of cluster and correspondence analysis are based on notions of similarity and distance, which are symmetrical, the implication between variables is an asymmetrical relationship. Larher (1991) extends the algorithm to determining the implication

between classes of variables, on the basis of a sufficient implicative cohesion of the classes examined and of a maximal implicative relationship between their respective elements. Finally, the group of classes is organized by means of an arborescent structure, which reminds us of the hierarchical classification, though the nexus between two verteces in the tree is, in this case, oriented.

In his doctoral thesis, Larher (1991) demonstrates different applications of the method for the analysis of the data in a questionnaire, referring to the procedures used by the students in situations demonstrating geometry. In our opinion, a first application of the implicative analysis, demonstrated in Larher's work, to the study of the relationships between success/failure in the items in a test, may extend, with an obvious advantage, the classic studies of scalability in questionnaires, using Guttman's scalogram, since this presupposes a linear arrangement of the items, which is difficult to find in most of the applications. On the other hand, the analysis of the students' procedures allows us to predict whether a given type of mistake implies more easily another given mistake, or, even success in another question, thereby allowing us to establish a partially ordered hierarchy in the procedures for problem solving.

CONCLUSIONS

The systemic perspective in didactic studies, together with the latest technologies for analyzing available data, imply not just a change in the methods of data collection and transformation, but also a change in the very problems of research itself. They also imply significant changes in the paradigm of the evaluation of mathematical knowledge carried out for didactic research purposes.

In this paper, we have demonstrated the possibility of some techniques of data analysis for the study of the relational structure of the group of answers from the subjects according to the task, cognitive and instructional variables. Since the structure of this group of answers is an empirical indicator of the structure of the knowledge of a given group of students, the analysis carried out allows us to progressively work out a theory about relationships with weak causal order between the variables which define the aforesaid conceptual structure.

This structure would have an "ideal" character, in the sense that it would be the pattern or standard which underlies all of the observations. Since correspondence analysis allows us to deal, simultaneously, with both the categories of the variables either as statistical or collective subjects, and the individual subjects, it is also possible to see the variability of particular cases.

From different viewpoints, hierarchical classification techniques, factorial correspondence analysis and implicative analysis complement the qualitative

study of the structure of the students' answers. We should really include the remaining multivariate techniques, though, due to the space for this paper, we cannot go into any further detail.

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Probabilistic thinking, statistical reasoning and the search for causes: Do we need a probabilistic revolution after we have taught data analysis?

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My interest is in the relation between probability and statistics (data analysis) with regard to teaching and learning. Ideas for teaching (exploratory) data analysis with no preparation in probability emphasize, among other things, finding relations in sets of variables, identifying relevant variables, interpreting data with regard to sources of variation, possible explaining factors and causes. Probability is often introduced as an antithesis to deterministic situations. Some empirical research even blames children for looking for causes where there is "really" randomness. There is other research taking positions against stochastics. For instance, Davis and Hersh, in "Descartes' dream", criticize that statisticians often merely describe variability instead of looking for causes.

This controversy about the possibility of hidden variables and the orientation of scientific research has been taken up in current scientific thinking in the debate on non-linear systems with chaos, where things appear random that are "in fact" deterministic. Probability and deterministic models seem to be complementary approaches. In the history of probability and statistics, conceptions have been developed that make probability models compatible with reasoning in terms of causes or influencing variables, that is reasoning in terms of constant and variable causes, of random and assignable causes. Causality enters at another level, in that a change of distribution may indicate a change in (constant) causes, that is some kind of statistical determinism. In the methodological development of statistics, some of these conceptions have been transformed into techniques and concepts like ANOVA, bivariate probability distributions and correlation. There is some evidence that some of these conceptions tacitly underly the practice of data analysis although it seems to be probability-free.

With regard to introducing students into ideas of probability and data analysis, the question arises as to whether and how these two domains can and should be related in their reasoning. What are possible problems at the interface between probability and data analysis? Is it possible to think in terms of a continous development of ideas, or should we take into account the necessity of "revolutions", of obstacles to be overcome by learning?

Conceptions belonging to the history of probability and statistics will be linked to contemporary empirical research and curriculum conceptions in order to contribute towards clarifying these issues.

COGNITIVE MODELS AND PROBLEM SPACES IN "PURELY RANDOM" SITUATIONS

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ABSTRACT. As part of a study on the natural interpretations of probability, experiments about elementary "purely random" situations (with dice or poker chips) were carried out using students of various backgrounds in the theory of probability. A prior study on cognitive models which analysed the individual data of more than 600 subjects had shown that the most frequent model used is based on the following incorrect argument: the results to compare are equiprobable because it's a matter of chance; thus, random events are thought to be equiprobable "by nature". In the present paper, the following two hypotheses are tested: 1) Despite their incorrect model, subjects are able to find the correct response. 2) They are more likely to do so when the "chance" aspect of the situation has been masked. An experiment testing 87 students showed, as expected, that there is a way to induce the utilization of an appropriate cognitive model. However the transfer of this model to a classical random situation is not as frequent as one might expect.

INTRODUCTION

Consider the following problem. Two dice are simultaneously thrown, and the following two results are obtained: R1 "a 5 and a 6 are obtained" and R2 "a 6 is obtained twice". The question asked is, "Do you think the chance of obtaining each of these results is equal? Or is there more chance of obtaining one of them. and if so, which, R1 or R2? Or is it impossible for you to give an answer, and if so, why?". Now Consider another problem.

There are three poker chips in a jar, two red and one white, and two chips are drawn together. Asking the same question as before, compare result R1 "a red chip and a white chip are obtained" and result R2 "two red chips are obtained". Subjects were asked to give "spontaneous answers" by choosing one of the four possibilities proposed . This set-up was used because our main purpose was to provide evidence of intuitions or "natural interpretations" in the sense used by Feyerabend (1975). In the two previous examples, R1 is twice as probable as R2, and so the correct response is "there is more chance of obtaining R1". It is interesting to systematically study the responses given to this type of problem, which will hereafter be called the "standard problem", because it is an example of a large class of problems that bring into play the notion of exchangeability, now recognized in the theory of probability as more fundamental than the notion of independence (see de Finetti,1974).

Our motivation for conducting research in this area is twofold. There is a cognitive motivation -the formalization of various descriptive models of cognitive functioning in situations of uncertainty- and there is also a pedagogical motivation -the derivation, from experimental findings, of potential implications for the teaching of probability and statistics (for an illustration of such an approach, see Lecoutre and Lecoutre (1979) and Rouanet et al. (1987, 1990, 1993); the latter three books are recommended for the teaching of statistics in French universities, especially to students in psychology).

In our experimental study, using either chips or dice to test more than 1000 students of various backgrounds in probability theory, we observed a bias that we have called *equiprobability bias*. We suggest that this bias be added to the list of biases observed in various situations of uncertainty, especially those described by Tversky and Kahneman: representativeness bias, availability bias, anchoring bias, and so on (see Nisbett and Ross, 1981, or Kahneman, Slovic and Tversky, 1982). A systematic study of the available cognitive models (for a detailed description of these models, see Lecoutre and Durand, 1988) shows that the combinatorial ones (involving the explicit enumeration of all possible cases) or the logical ones (involving hypothetico-deductive reasoning) which lead to the correct response are very rarely utilized spontaneously (only about 5 to 10 percent of the subjects). The equiprobability bias is highly resistant to variations in the classification factors of the subjects or in the experimental context, and our findings are quite consistent with the idea recently brought up by Fischbein (1987), who claims that intuitions (correct

as well as incorrect) are often very robust, "being deeply rooted in the person's basic mental organization". See especially Lecoutre (1984, 1985), and Lecoutre, Durand and Cordier (1990).

Nevertheless, it seems reasonable to assume that combinatorial or logical models are available to most subjects, but are not spontaneously associated with situations in which "chance" is a factor which somehow inhibits by the equiprobability bias. In the present paper, the following two hypotheses are discussed. (1) Despite their incorrect model, subjects are able to find the correct response when the situation is conducive to the activation of the appropriate cognitive models. (2) In particular, in the situation of interest here, it is hypothesized that subjects are more likely to respond correctly when the "chance" aspect of the problem is masked.

Accordingly, we set up new situations which were isomorphous to the preceding ones, but in which the "chance" aspect was masked by formulating the problem in practical terms and bringing the subject's attention to a geometric figure. This was aimed at introducing a new problem space, in the sense defined by Newell and Simon (1972), which might promote the activation of combinatorial or logical models. In the main experiment, called the "House" experiment, three cards were used instead of the three chips in the previous problem. A triangle was drawn on two of the cards (for the two red chips), and a square, on the third (for the white chip). The subjects were shown that it was possible to construct either a house or a rhombus. For a detailed description of this experiment, and a thorough discussion of all the findings reported in this paper, see Lecoutre (1992).

"HOUSE" EXPERIMENT

In this "House" experiment, subjects were asked three successive questions. (1) The first dealt with a problem in which the "chance" aspect of the situation was masked by explicitely showing the subjects that a geometric figure (a "house" or a "rhombus") could be constructed from the cards drawn. According to our hypothesis, this should cause them to "forget" the random nature of the situation. (2) The second dealt with the "classical" standard problem, and (3) the third, concerned a comparison of the two problems.

Eighty-seven students, about 15 to 17 years old without any background in the theory of probability, answered the questionnaire in notebooks distributed for that purpose during a mathematics class.

Results

For *questions 1 and 2*, three main points should be noted. (1) For *question 1* (the "house" question), the proportion of equiprobability responses decreased substantially, to the benefit of the correct response, which was given in 75 percent of the cases. A noninformative Bayesian analysis (see Bernard, 1991) showed that we obtain a guarantee of 0.95 that the parent frequency φ of equiprobability responses was lower than 0.31 ($Pr(\varphi<0.31)=0.95$). So, masking the "chance" aspect of the problem, thus modifying the space in which the solution is searched (Richard, 1984), had a strong positive effect. (2) For *question 2* (the "classical" problem), the proportion of correct responses was not as high as for question 1, although it was noticeably higher than in all of our previous experiments. We obtained the Bayesian guarantee of 0.95 that the parent frequency φ of correct answers was greater than 0.36 ($P(\varphi>0.36)=0.95$) when all previously observed correct responses frequencies were approximatively 0.30. We can also see that the proportion of equiprobability responses was higher than for the first question, but not as high as in our previous experiments. (3) The distribution of the *pairs of responses* to questions 1 and 2 shows that 58 subjects gave the same answer to both questions. Out of the 65 subjects who responded correctly to question 1, 38 of them (60 percent) again responded correctly to question 2, whereas almost all other subjects gave the equiprobability response. So, the correct response was transferred to the subsequent standard problem in only 60 percent of the cases. All subjects (except two) who gave the incorrect equiprobability response to the first question repeated this response for the second question.

For *question 3*, our attention is mainly attracted by the high proportion of subjects (24 percent) who thought the two situations were different. Considering the sequence of three responses, the following remarks may be made. For all subjects except one who gave the same response to questions 1 and 2, the two situations were alike. For the subjects who gave two different responses to questions 1 and 2, 60 percent thought that the two situations were different. The arguments brought up in this case will be analyzed in paragraph 2 of the next section ("Some models"). For the other subjects, the two situations

were alike. These subjects either perceived an incoherence in their responses and modified one of them (this was especially the case for 3 subjects who answered +R1/=: they thought they had made a mistake on question 1 and that the two results were equiprobable after all), or did not perceive an incoherence and confirmed their responses without giving any further justification.

Some models

The above analysis of the sequences of responses and justifications points to several possible cognitive models, including the following five most important ones.

1) *"Correct model"*. For both questions, subjects utilize the same logical or combinatorial model and think that the two situations are alike. This model, which of course leads to correct responses, was used by 24 percent of the subjects. Comparing with the proportion obtained in our previous experiments (about 6 to 7 percent), this proportion is high.

2) *"Construction vs chance model"*. Here, subjects say that the two situations are different; the first one appeals to "reasoning", to "logic", or to the "construction of a figure or an object", and so on (these are examples of the justifications given), whereas the second is a problem of "pure chance", "probability", or "randomness", and so on. This model was used by all subjects who answered +R1/=, that is 23 percent of the subjects. Here, it clearly appears that these subjects spontaneously defined a different problem space in each of the situations.

3) *"Conditional model"*. For both questions, the subjects utilize an interesting representation of the following type: Knowing that in the pair of drawn elements, one of the two identical ones will inevitably be obtained , then one element of each kind remains, and so there is an even chance for the second element drawn. Consequently, they conclude there is equiprobability of the two results. This model was utilized by 16 percent of the subjects who gave two equiprobability responses.

4) *"Chance model"*. This model leads to equiprobability responses with the following argument: it is equiprobable "because it is by chance". This model was used by 5 percent of the subjects. Compared with the proportion obtained in all our previous experiments (about 50 percent, see Lecoutre and Durand, 1988), this proportion is quite small.

5) *"Numbers model"*. Subjects answer that in both situations, there is more chance of obtaining a pair with two identical elements (+R2 response) because there is a greater

number of them: there are more triangles than rectangles, so there is more chance of drawing two triangles. This model, which is based on the number of elements, is valid when only one element is drawn (it is the only model spontaneously utilized by subjects in this case, see Lecoutre, 1984), but generalization to the case of two elements is erroneous. Two percent of the subjects applied this model.

These five models account for the answers of 70 percent of the subjects. For the other subjects, it is impossible to define any characteristic model because their answers were vague, and no justifications were given.

These findings are consistent with other experiments in which only the material differed. (See Lecoutre and Cordier, 1990).

CONCLUSION

Two main results will be examined.

(1) Our findings show that it is possible, using experimental tricks and especially here by masking the "chance" aspect of the situation, to induce the utilization of appropriate cognitive models. Thus, we can see that correct models are often available, but are not spontaneously associated with the situations at hand. Such a result should be compared to the one found by Escarabajal and Richard (1986) for arithmetic problem solving tasks, where subjects who did not spontaneously develop correct reasoning could still do so when prompted. More generally, when a bias is observed in spontaneously devised models, correct models may in most cases be available, but experimental tricks are required to activate them. We have just seen an illustration of such an approach. This finding appears to have significant implications for teaching in general, and in particular, for the teaching of certain mathematical concepts. It indeed suggests the value, if not the necessity, of attempting to act upon the cognitive models used by subjects, by determining the conditions under which the appropriate models are activated (provided, however, given the current state of research, that the second finding reported above be taken into account).

(2) It also appears that the transfer of a relevant model to the subsequent "standard problem" is not as frequent as one might expect. Transfer of the correct response only occurred in about 60 percent of the cases. For more than 20 percent of the subjects the two situations were quite different. Thus, one of the questions on this matter is whether the number of transfers can be increased, for example, by insisting even more in the similarity

of the two situations, or whether the perception of a clear-cut difference between the two situations will always exist in some subjects? Furthermore, a final question can be raised: When experimental tricks are used to trigger the activation of an appropriate model, and transfer to the standard problem occurs, is such an acquisition stable? New experiments designed to answer these questions are in progress at the present time.

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Readiness of Teachers in Northern Ireland to teach Data Handling

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Data handling has recently been introduced in the United Kingdom as a major component of the mainstream school mathematics curriculum. A survey of teachers in Northern Ireland showed that they are generally not well prepared to teach the new material, particularly probability.

Background: Teaching Data Handling in the United Kingdom

Northern Ireland has, in most respects, the same educational system as the rest of the United Kingdom, although there are some important differences, such as a much greater proportion of grammar schools in Northern Ireland (i.e. highly selective secondary level schools with an academic character).

In the early 1980s, the Cockcroft Report on the teaching of mathematics in schools (Department of Education and Science, 1982) commanded a high degree of consensus. On the teaching of statistics, it stated clearly that:

> Statistics is essentially a practical subject and its study should be based on the collection of data, wherever possible by pupils themselves. It should consider the kinds of data which it is appropriate to collect, the reasons for collecting the data and the problems of doing so, the ways in which the data may legitimately be manipulated and the kinds of inference which may be drawn.
>
> . . . When statistics is taught within secondary mathematics courses too much emphasis is very often placed on the application of statistical techniques, rather than on discussion of the results of ordering and examining the data and on the inferences which should be drawn in the light of the context in which the data have been collected. The work can therefore become dry and technique-oriented and fail to show the power and nature of statistics.

Probably the most important development in the wake of the Cockcroft Report was diversification of classroom activities to include investigations within mathematics and applications of mathematics, including statistical investigations (Graham, 1989).

In 1987, the British Government decided to introduce a National Curriculum (the corresponding Curriculum in Northern Ireland is essentially the same). In all subjects, a specification of attainments defining 10 levels was drawn up. Mathematics has been divided into four main strands, namely number and measure, algebra, shape and space, and data handling. The prominence given to data handling, from the earliest years in school, represented a major departure; previously, statistics and probability had been mainly taught in schools only at the most advanced levels, usually in a narrowly technical way (as reflected in the second paragraph of the quotation above).

Although the place given to data handling in the National Curriculum may be welcomed, there are many aspects of its specification in the curriculum that may be criticized (cf Hawkins, 1991), in particular:

1. The lack of connexion between probability and statistics.

2. The limited variety of practical activities; after Level 5, these are almost entirely limited to questionnaires.

3. A limited and unimaginative repertoire of representations -- omitting stem-and-leaf diagrams, for example.

4. Exemplification of the comment of Ahlgren and Garfield (1991, p. 121) that "most curriculum in statistics is a potpourri of theoretical, frequentist and subjectivist ideas, not carefully articulated but presented haphazardly".

5. Lack of any guidance to the teacher on how concepts of probability can be built up.

Howson (1991, p. 22) commented that "the development of worthwhile and successful probability courses for all will prove a major challenge in the next decade". On the principle that "a national curriculum should be drawn from successfully piloted content and approaches rather than be part pipe dream" (p. 23) he suggested, in particular, that "the optimistic and untested assumptions concerning the teaching of probability [can be questioned]" (p. 32).

Survey of Teachers in Northern Ireland

In 1992, we undertook a project with the following aims:

1. To survey Northern Ireland teachers' views about the new emphasis on teaching data handling (Greer & Ritson, 1993b).

2. To review the literature (Greer & Ritson, 1993a).

3. To assemble a selection of exemplary materials.

We decided to conduct the survey through interviews rather than by postal questionnaire. The interviews balanced questions with specific responses (Table 1), open-ended questions, and general raising of issues of importance to the teachers. Co-operation was excellent, and many of those interviewed were very happy to have the opportunity to air anxieties. Visits were made by Rene to 16 primary and 24 secondary schools (of which 6 were grammar schools), selected with due attention to important factors such as location and size. Those interviewed were principals and teachers, mathematics co-ordinators in primary schools, and heads of mathematics in secondary schools. The most salient aspects revealed by the interviews may be summarized as follows.

Level of importance attached to data handling within the curriculum

Responses to the questions labelled 3 and 4 in Table 1 show that of the four strands in the curriculum, handling data (along with algebra) is considered least important, especially by the primary teachers.

Concerns about the introduction of probability

Within data handling, probability is considered much less important than collecting and representing data (question 4), again particularly by the primary teachers, and also by the primary principals (1). (See also 6 and 7). Many teachers, both primary and secondary, expressed the opinion that probability is introduced too early in the National Curriculum.

Lack of confidence in the use of computers

While the importance of computers was acknowledged, there was a widespread reaction that teachers need more time and help to develop confidence and expertise in their use. This, together with many practical and financial constraints, probably accounts for the relatively low usage of computer applications such as databases and spreadsheets revealed in question 5.

Lack of previous and current training

Judging by this sample, primary teachers are ill-prepared to teach data handling (questions 9-11), and even the secondary sample gives rise for concern (questions 8-10, 12) -- bearing in mind, for example, that positive responses to question 10 in many cases will mean having read a book on the topic. The clearest pattern of all was the view that insufficient provision is being made for in-service training (question 2); the responses from primary co-ordinators and secondary heads of mathematics (not shown) were similar.

Other comments from open-ended questions

As a touchstone question, primary teachers were asked: "How do you develop the idea of the measure of probability being represented on a 0 to 1 scale?". This is placed at Level 4 which is expected to be reached by the average child at the end of primary school. Only 3 out of the 16 teachers interviewed had attempted to teach this. One teacher said: "I know nothing about probability and what I have seen in books about it looks very difficult. I don't know how I can teach that to my children".

For a similar purpose, secondary teachers were asked: "How do you introduce the use of scatter graphs and the idea of correlation?" This is placed at Level 6 and is therefore expected to be reached by the average 14-year-old. Only half of the teachers interviewed said they got as far as this and many felt it should be left until later.

When asked what help was needed, frequent responses were: raw data of local relevance suitable for use in schools, suggested activities for teaching probability, more computer packages for statistics and probability, time to learn how to use computers and more hands-on experience, a series of short courses on teaching probability, and more information on forms of assessment.

Assessment

Assessment in mathematics in the UK has undergone several major changes of direction during the last ten years (Brown, 1993). Following the Cockcroft Report (1982), broader modes of summative assessment were introduced, including extended coursework marked by teachers, and many innovative approaches and materials were developed. After rapid fluctuations in

policy following the introduction of the National Curriculum "the UK now seems to be heading back to our previous position where the curriculum becomes subservient to the requirements of regular routine written examinations, which the Cockcroft Committee identified as a major cause of low standards of motivation and achievement" (p. 82). One recent manifestation of trying to assess practical investigational skills within this system was a question set in 1993 in a written exam which included:

> Think about a survey you have done.
> What did you hope to find out in your survey?
> Write down one of your results.

The idea of assessing survey work in this way is bizarre. A student could get full marks without ever having done a survey. Imagine how teachers might prepare pupils for such questions if they continue to be used.

Two examples of questions from Northern Ireland illustrate how bad assessment of data handling can be. The first, of which only a part is given, is from a 1992 A Level paper (the highest level of school examination):

> The number of hours of sunshine per day in Fuengirola in June (of any year) may be described by a continuous random variable, X_1 whose distribution is given by the probability density function
>
> $$f(x) = 1/4 \quad 8 \leq x \leq 12$$

Is comment necessary?

The second is from a paper for pupils aged about 14. In this question, the pupil is told that 180 people were asked to name their favourite snack. A table of frequencies is then give for 4 types of snack. Are you surprised to learn that all the frequencies are multiples of 5? The pupils are then asked to construct a pie chart using a circle divided round the circumference in 10° units. This shows the pernicious influence of the curriculum. A sensible way of constructing pie charts is to convert frequencies to percentages. However, "express one number as a percentage of another" is at level 7 whereas "construct a pie chart" is at level 6 -- hence this emasculated approach which requires artificially "nice" data and conveys the message that the pupil is never expected to construct a pie chart with real data as part of an authentic activity.

Final comment

The inclusion of data handling as a major component of the National Curriculum was a progressive step. However, it will come to naught if insufficient steps are taken to provide the necessary support. Above all, as Howson (1991, p. 26) said "a curriculum cannot be considered in isolation from the teaching force which must implement it". There is no sign of an appropriate commitment from our present political masters, whose view of mathematics barely extends beyond learning tables and being good at sums.

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Table 1. Selected results from the survey (numbered for reference purposes, not as in original). Totals are smaller than the number of schools visited for various reasons.

PRINCIPALS	Primary				Secondary			
(SA = strongly agree A = agree D = disagree SD = strongly disagree)	SA	A	D	SD	SA	A	D	SD
(1) It is very important that a child's mathematical education should include substantial emphasis on:								
• the role of statistics in society	0	12	2	0	4	7	1	0
• applications of mathematics involving probability	1	7	5	1	3	8	1	0
(2) There is sufficient advice and support available for teachers about teaching:								
• statistics	0	1	9	3	0	1	6	2
• probability	0	1	5	7	0	1	6	2

TEACHERS	Primary			Secondary		
(3) Within the mathematics curriculum could you indicate how you rate the relative importance of the four components? (RU = relatively unimportant I = important VI = vitally important	RU	I	VI	RU	I	VI
Number and measure	0	0	16	0	1	22
Algebra	1	13	2	4	13	6
Shape and space	1	7	8	0	9	14
Handling data	2	12	2	0	13	10
(4) Could you give similar ratings for the three aspects of handling data?						
Collecting data	0	11	5	1	13	9
Representing data	0	12	4	0	7	16
Probability	11	5	0	5	15	3

(5) How often do you use the following?

(M = once a month or more T = once a term Y = once a year N = never)

	M	T	Y	N	M	T	Y	N
• personal data	10	5	0	0	5	11	6	1
• collecting data through observation	7	6	2	0	0	6	13	4
• published data	2	7	3	3	4	12	6	1
• computer database	3	10	0	2	3	6	5	9
• spreadsheet	0	3	0	12	1	5	7	10
• probability experiments	0	5	6	4	2	8	10	3
• computer bar charts etc	6	6	0	3	0	6	6	11
• pencil and paper charts	11	4	0	0	11	10	2	0

	SA	A	D	SD	SA	A	D	SD
(6) It is essential that children should collect and represent data	9	6	1	0	13	9	1	0
(7) It is essential that:								
• the foundations of probability are laid in the primary school	0	7	8	1				
• an understanding of probability is established in the secondary school					9	12	2	0

	Yes	No	Yes	No
(8) Were you trained to teach mathematics?			19	4
(9) Were you taught about probability in your initial training?	1	15	11	12
(10) Have you learned about teaching probability since then?	6	10	20	3
(11) Do you think you understand the mathematics which will be built on the probability that you have to teach?	2	14		
(12) Do you feel that you know the future applications of the data handling skills that you are helping the pupils to develop?			17	6

WHY ASK WHY?

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1. Background

Research to investigate students' facility with proportions has been undertaken by the author and Fay Sharples of the University of Waikato, New Zealand between 1989 and 1992. In the initial study (1989 and 1990) 64 students at the University of Waikato and 57 at Brunel University in the UK took part. A further study took place in 1992 when 127 students at Waikato and 29 at Thames Polytechnic (now the University of Greenwich) took part.

In both studies students were given a short set of self-completion questions. They were instructed to "Give the answers which you <u>think</u> and <u>feel</u> are correct" and to write DK if they felt they did not know the answer. All questions were followed with "Why do you say this?" and nearly all were open-ended. The 1992 questionnaire was a modified version of that used initially. Most of the students who took part were first year undergraduates.

Apart from 26 Brunel students who were registered for mathematical degrees, all were taking statistics as a service course and many of them were weak in mathematics.

The spread of responses in the initial study was broadly the same in both institutions and for students with different levels of mathematics. There was a tendency for students to think events were equally likely whatever the situation and wrong answers also occurred because of errors in arithmetic and an apparent lack of understanding of semi-technical terms. Some details are given in Jolliffe and Sharples (1993). Our first impression of the 1992 study was that there were more wrong and strange answers than in the previous study, and possibly higher proportions of no responses and "Don't knows" in some questions. Some results are reported in Jolliffe (1993).

This paper concentrates on the "Why?" parts of some of the simpler questions and discusses the usefulness of asking students to give a brief reason as to why they had chosen the answer they gave. Responses given by the UK students are used to illustrate points.

2. "Why?" helps our understanding of errors

In studies probing into the understanding of concepts and techniques it is common to ask respondents why they have given answers (for example Konold et al 1991).

This helps the researcher sort out reasons for misconceptions and wrong answers which can then be used to inform teaching. We had some idea of the wrong answers which might be given to the questions we posed and thought we knew what explanations students would give for these. For example, in part (a) of the question in Display 1 we had expected explanations consistent with the interpretation of "at least 8" as "larger than 8". In the question shown in Display 2 we felt that some students would choose the third answer and justify this by some such statement as "It has 3 odd numbers and 3 even numbers" given by one student. The wording of this question was "The <u>product</u> of the two numbers is" in the first study. As some students appeared not to know what was meant by product this was changed for the second study.

However, part of the purpose and excitement of doing studies of this nature is that unexpected responses sometimes occur. The explanation of the response can then be a clue as to why it is wrong. For example the answer 0·35 to part (a) of the question in Display 3 appears rather mysterious, but on reading the explanation "Pin can land up or down. Prob $= \frac{28}{40*2} = 0{\cdot}35$" it is possible to see the student's error. It is perhaps not surprising that this student answered 50 to part (b) of the question, giving the explanation "As 50% chance

either up or down", a pair of responses we had anticipated. Sometimes the explanation suggests that the wording of the question was not as clear as intended - a message to all those who set questions for research or assessment purposes (see Hawkins et al 1992).

3. "Why?" helps coding

The answer to "Why?" is sometimes an aid to coding. For example, a response "2 to 3" looks like an odds suggesting that the chance of an event is 2/5, but given the explanation "2 to 3 = 2/3" it is clear that the student thought the chance was 2/3. A few students explained their incorrect answer of 8/10 to part (b) of the question in Display 1 by saying there were 8 out of 10 chances of getting a number less than 7, and a few explained this answer by indicating that they had added the probabilities of 1/10 for a 5 and 7/10 for a number less than 7. Without these responses to "Why?" it would not have been possible to distinguish between the error of interpreting less than 7 as less than or equal to 7 and the error of including 5 twice. As another example, an answer of 2/10 to part (a) of the question in Display 1 was explained by the statement "As 1 ball is labelled 5 and 1 ball is labelled 8, therefore 1+1=2 therefore 2 out of 10 balls is likely to be chosen" indicating that greater than 8 had been interpreted as exactly 8 which is not a common error. Another student explained the answer

of 2/10 by the statement "Between 5 and 7. There is no balls labelled except the ball of No. 6. The ball has to be less than 7 therefore there are only two balls i.e. 5 and 6".

Ideally there would be only one way of getting any answer in which case it would be unnecessary to ask for a justification. In practice this is difficult to achieve. There will often be answers the researcher did not anticipate - and obtained in a way not anticipated. Arithmetical errors compound the problem.

4. Difficulties in answering "Why?"

The distinction between an explanation of an answer and details of arithmetic is sometimes very slight. In part (b) of the question shown in display 3 one student justified the correct answer 70 by "100/40 * 28 = 70", another by "The same % of points up as before", and a third by "28/40 = 0·7 * 100 = 70. Find proportion of times point upwards and multiply by times thrown." It seems to me that all three were giving the correct (even if badly expressed) and really the same reason here. One student gave as explanation "40 + 40 + 20 = 100" on one line and underneath "28 + 28 + 14 = 70" which gives a good insight into this student's method.

It can, of course, sometimes be difficult to give an explanation of a fairly obvious answer. For example,

in part (a) of the question shown in Display 3 what explanation can one give for an answer of 7/10 or 0·7 other than "28 times out of 40 the point lands upwards" or "28/40 = 7/10" or "It's 28/40 cancelled down"? Possibly students giving the correct answer wondered what we were trying to find out when we asked "Why do you say this?" and perhaps accounts for those who left this blank or answered "DK". On a question like this it is, of course, the explanations for wrong answers which are more interesting as already indicated.

Sometimes the explanation is little more than an alternative statement of an answer as 1/2 explained as "1 in 2 chance" or 2/3 as "two in three" or an answer 1/5 to a question about drawing balls from a bag explained by "Because the chance that the drawn ball is five is one in five". A few students have the tendency to give as explanation such words as "Probability", "Percentage" or "Chance happening" or even "Because it is so". One student who answered "Random" to a question about the probability of a child being a boy wrote as the reason for saying this "Not predictable".

Some students clearly have difficulty in expressing themselves (apart from any puzzlement they might have as to how to explain an obvious answer or how to do a more difficult question). For example one student explained the answer 70 to part (b) of the question in Display 3 by

saying "Because it should follow the same pattern as above". Another who answered 70/100 said this was "Because the base is heavier". One who answered 50% (sic) wrote "The ratio above is over 50% but if you increase the number of options it usually evens out". One who correctly answered even on the original version of the question shown in Display 2 stated "Even numbers multiply to give even numbers and odd numbers also multiply to give even numbers".

5. Conclusion

From the examples given it should be clear that asking "Why do you say this? at times throws real light on the response to the numerical part of the question helping us see the student's understanding and reasoning, perhaps enabling us to interpret and code a response correctly. It is particularly helpful in the case of incorrect responses and in the more complex questions which there has been no space to discuss here. The benefits of these responses far outweigh the lack of usefulness of those which add nothing to the answer given either because they are an alternative statement of it or because we cannot understand a poorly expressed explanation.

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Display 1

A ball is to be drawn by a blind-folded person from a bag containing ten balls. The balls are identical except for their labels which are

9, 3, 6, 2, 7, 5, 0, 4, 8 and 1.

(a) What is the chance that the ball chosen is labelled 5 or with a number which is at least 8?

(b) "What is the chance that the ball chosen is labelled 5 or with a number less than seven?"

Display 2

Two ordinary 6-sided dice are rolled. If the two numbers are multiplied together the answer is

more likely to be odd than even
more likely to be even than odd
as likely to be even as odd

Display 3

A drawing pin is tossed 40 times and lands "point up" 28 times.

(a) What proportion are "point up" landings?

(b) If the drawing pin is now tossed 100 times what is your estimate of the number of times it will land "point up"?"

Understanding the role of computer based technology in developing fundamental concepts of statistical inference

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Abstract

Traditional courses in statistics generally approach inference from a theoretical probability based perspective. Since the mathematical backgrounds of students is often not strong, many courses use computer based simulations to empirically justify ideas which are too complex or too abstract for most students. However, eventually, students must move from the empirical to the theoretical understanding of the concept if they are to apply these ideas to traditional inference methodologies. This paper questions the effectiveness of some of these strategies, and discusses how computer based technologies may be used effectively to bring together these theoretical and empirical perspectives.

Introduction

Amongst mathematics educators the use of technology in the mathematics classroom is a source of much concern. The situation is somewhat different in statistics. Here technology is well accepted because of the computationally intensive nature of the subject. However, the role of technology in statistics education is evolving, with an increasing number of educators beginning to view the technology as more than a computational tool. This is particularly true in teaching the ideas of statistical inference, because the computer has an obvious role in the empirical development of many of the key ideas. For example, by carrying out repeated sampling and summarising the results as a sampling distribution. A number of instructional sequences have been developed built around these capabilities. Unfortunately these approaches, although widely promoted and now commonplace activities in introductory statistics courses, have sometimes been less successful than statistics educators might have hoped for. As noted by Hawkins (1990):

> ICOTS 2 delegates were treated to "101 ways of prettying up the Central Limit Theorem on screen", but if the students are not helped to see the purpose of the CLT, and if the

> software does not take them beyond what is still, for them, an abstract representation, then the software fails. (p 28)

In this paper we will look at why early attempts at computer based explanations might not have been as successful as they might be, and suggest reasons why more recent approaches appear more likely to succeed.

Effects *with* and *of* technology

A framework for thinking about the role of technology in teaching and learning, which the author believes is relevant to the current issue, has been suggested by Salomon, Perkins, & Globerson (1991).. They suggest that when considering how technology affects student performance we "must distinguish between two very different ways in which intelligent[1] technologies might have an effect" (Salomon, et al., 1991, pp3). One concerns the changes in performance that might occur when the student is working with technology. These are termed effects *with* the technology. The other way concerns effects that might occur as a result of a student participating in an activity that makes use of the technology but that also remain when the student is involved in activities that do *not* involve the technology. These are termed effects *of* the technology. For example, when working with a computer a student may become skilled in calculating plotting a bivariate data set and calculating the corresponding correlation. This would constitute an effect *with* the technology. We might also find that, as a results of their experience of plotting a bivariate data set and calculating the corresponding correlation students come to understand more about the relationship between the correlation and the plot. They may for instance learn to recognise when the calculation of the correlation is inappropriate. When a student shows evidence of this understanding when dealing with correlation away from the computer then this constitutes an effect *of* the technology.

Understanding a complex statistical concept – the sampling distribution

[1] Salomon et al define an intelligent technology as one which "undertakes significant cognitive processing on behalf of the user" ((Salomon, et al., 1991, p2).

Many concepts in quantitative disciplines such as mathematics and statistics are multifaceted and cannot be described using a single representation. For example, consider the notion of "a statistical distribution". To communicate the idea of a distribution educators use sets of data values, frequency tables, various plots and summary statistics, all essential to illustrate the many facets of a distribution.

A particularly important idea in the development of the theory of statistical inference is the idea of a sampling distribution – the recognition that the estimates of a population parameter will vary and that this variation will conform to a predictable pattern. Yet, for all its importance, experience and research have shown that the idea is generally poorly understood (Moore, 1992; Rubin, Bruce, & Tenney, 1990 for example). One reason for this might be the way in which the idea has been traditionally introduced in statistics courses using a deductive approach based on probability theory (Johnson & Bhattacharyya, 1987; Mendenhall, Wackerly, & Scheaffer, 1990 for example). Such explanations are usually expressed in a highly mathematical language which tends to make the argument inaccessible to all but the mathematically able, now a very small minority of the students taking introductory courses in inferential statistics. But, perhaps more importantly, it is a theoretical development which is difficult to relate to the physical process of drawing a sample from a population. Statistics educators have come to recognise that there are deficiencies with a purely theory based explanation and now often accompany or replace this with an empirical argument. The alternative interpretation uses the long run relative frequency approach, where the sampling distribution is viewed as the result of taking repeated samples of a fixed size from a population and calculating the value of the sample statistic for each (Devore & Peck, 1986; Ott & Mendenhall, 1990 for example) The empirical approach has the advantages of being more readily related to the actual physical process of sampling and requires minimal use of formal mathematical language..

Using the computer in the teaching of sampling distribution

What are the ways in which the computer is used to complement the teaching of (empirical) sampling distribution? Consider the following:

Paper based images: A computer is used to generate images (usually histograms) of empirical sampling distributions. These are generally prepared by an instructor and communicated to the student in the form of printed output (notes, overhead images etc.). Because the instructor has the flexibility to generate many such images without much effort, several can be used in order to illustrate the shape, centre and spread of the resultant distribution, and how each of these are affected by sample size.

Computer based images: The continued development of statistical software has resulted in a proliferation of computer based images. For the purpose of this exercise they will be considered within two general categories.

Static computer images: The usual sort of image produced by statistical software is a static display, generally a single representation although more may be present. Students are given access to the computer and software which enables them to produce these for themselves. An example of the type of software commonly used for such activities is Minitab. The resulting images produced on the computer screen are essentially the same as those which could be produced on paper, if time permitted.

Dynamic computer images: Computer technology is now such that screen displays may be dynamic. An example of this is the spin plot, originally used as a statistical tool, but increasingly appreciated for its educational potential. An elaboration of the dynamic capability of the computer is the facility to automatically link multiple images, thereby increasing the educational potential of the display. Various representations are shown simultaneously on the computer screen, linked in such a way that variations are immediately reflected in all images. An example of computer software which supports the teaching of sampling distribution through dynamic, linked images is Sampling Laboratory ((Rubin, 1990).

Comparative educational gains through computerisation

What then has the introduction of the computer contributed to the development of the idea of a sampling distribution? The sampling distribution is a complex idea whose understanding cannot be dissociated from an understanding of the sampling process by which it is formed (Jones & Lipson, 1993). The sampling process is dynamic and involves the linking of several elements: a parent population, the samples drawn from the population, the values of the test statistic extracted from each of the samples, and the sampling distribution they give rise to. In a purely paper based explanation, the written word is used to describe the process outlined above and graphics are used to illustrate the end product of the process, the empirical distribution of the sample statistic. The bringing together of the sampling process and the resulting sampling distribution requires a high degree of mental processing which seems to be difficult for many students.

Certainly, the computer gives the student an active role to play in generating the samples, extracting the values of the test statistic and forming the sampling distribution. Using it also gives them the opportunity to experiment with parameter values of their own to see how the form of the sampling distribution changes in response. *But what has been done by the computer could have been achieved, in theory at least, with pen and paper.* The product (the empirical sampling distribution) is certainly there, but the process involved in generating the sampling distribution is at best implicit. Students are still required to make for themselves the connections needed to gain insight into the sampling distribution. As a result, it would appear that this computer based strategy has done little to reduce the mental processing that is required by a purely written explanation. As well, the complexity of the code used to create the displays may be confusing and offputting to students, and may even be seen as an end in itself.

In contrast the computer based strategy illustrated by the computer package Sampling Laboratory creates a working model of the sampling process which has as its product a histogram displaying the resulting sampling distribution

(similar to that produced by Minitab), but also displays the process by which the sampling distribution is obtained. The object of Sampling Laboratory is to illustrate both the sample to sample variability as well as the formation of a sampling distribution with a (predictable) pattern. The computer generated images used in Sampling Laboratory are dynamic and linked so that they can illustrate the product (the sampling distribution), the process (sampling from a known population) and the relationship between the two. In this way the computer based images have the potential to considerably reduce the cognitive load involved in understanding text based explanations of the idea of a sampling distribution and aid learning. However, this has yet to be empirically tested.

Discussion

The analysis so far has been concerned with a particular instructional problem, the understanding of the idea of an empirical sampling distribution and specific technology, Minitab and Sampling Laboratory. However, as indicated by Kaput (1992), if we are to make progress in understanding the way in which technology can be integrated into the educative process and not just replicate what we have done in the past, we need to be able to step back from specific content areas and technologies and look at the general principles involved. Two of Kaput's key principles emerge from this analysis. Firstly, with computers we are now in the position to create new notations (ways of recording and /or displaying information) (Kaput, 1992 p523) that are more capable of conveying a complex idea than the traditional paper based notations used currently. This has been clearly illustrated in Sampling Laboratory. While packages such as Minitab could actually generate similar graphical images to those used by Sampling Laboratory, even if the individual images produced could be arranged appropriately and displayed simultaneously, the end result would be no different than printing out the same images on a sheet of paper. To use Kaput's terminology, the notations used by Minitab, like those of most other statistical packages, have not been designed to do any more than replicate paper based notations which in turn have been designed to convey information in an inert medium. Whilst there may be an educational payoff of using the computer in

this instance, by enabling the student to be more actively involved in the learning process, in effect the images produced convey no additional information to the student.

The second general point made by Kaput and others (Lesh, Post, & Behr, 1987 for example) is the need to recognise that many concepts in quantitative disciplines like mathematics and statistics are multi-faceted and cannot be fully described by a single representation. Furthermore, it has been suggested (Janvier, 1987, for example) that a sign of real understanding is the ability to move between the various representations of a complex concept. In a paper-based explanation (even when carried out on the screen of a computer) any linkages between representations must be formed mentally. The dynamic nature of computer generated graphics offers the facility for both the representations and the linkages between them be explicitly displayed. Kaput suggests that such electronic linkages between the representations have the potential to facilitate learning and understanding of complex concepts of the type that arise in mathematics and statistics by significantly reducing the cognitive load on the student.

Conclusion

This paper has presented a theoretical perspective on teaching and learning statistical inference with computer technology. Research is currently being undertaken to test these ideas, and some of the results of this research will be available for discussion in the near future.

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INSTRUMENTS TO ASSESS STATISTICAL CONCEPTS IN THE SCHOOL CURRICULUM

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This paper will document four instruments devised to assess student understanding of statistical concepts. Two are intended for large scale administration and two are for individual interviews.

The movement to include chance and data as part of the mathematics curriculum in schools has been gaining pace in many countries since the publication of curriculum statements including the topics (e.g., Australian Education Council (AEC), 1991; National Council of Teachers of Mathematics, 1989). The preparation of the curriculum documents and subsequent decisions made by education authorities have taken place, however, virtually without the benefit of research about students' abilities to cope with the topics at the levels suggested. The instruments discussed here were developed as part of a large project funded from 1993 to 1995 to (i) follow the implementation of the chance and data curriculum in Australia, (ii) suggest appropriate concepts for students of various ages, and (iii) develop assessment procedures appropriate for the content in the curriculum. It is to be hoped that by the end of the decade a model of student understanding will emerge which will assist educators and curriculum designers with the revision of current statements and guidelines.

The initial stages of the project focused on devising and trialing items to be used over the life of the project with students in Grades 3, 6 and 9. With the three main purposes of the project, as mentioned above, in mind, it was necessary also to cater for five practical considerations. (i) Items should reflect the current national guidelines. (ii) They should take into account the existing research from other countries. (iii) Items should allow for different levels and modes of cognitive functioning. (iv) They should be motivating to elicit optimal responses. (v) Items should be practical to administer and interpret.

The theoretical model used as a framework for developing and evaluating instruments was the SOLO model based on the taxonomy developed by Biggs and

Collis (1982) and later extended by them (Biggs & Collis, 1991; Collis & Biggs, 1991). This neo-Piagetian model incorporates a multimodal functioning component, acknowledging the continued development of earlier modes of functioning in association with later modes. Of interest here are the ikonic and concrete symbolic modes, these being associated with intuitive functioning and the symbolic learning which takes place in school, and which is usually based on concrete materials. Results demonstrating multimodal functioning in the acquisition of understanding of fractions (Watson, Campbell & Collis, 1993) lead to the belief that such functioning may also occur for concepts in statistics and probability. Within modes it has been possible for other areas of mathematics to identify learning cycles in a hierarchy described as unistructural, multistructural and relational. In the concrete symbolic mode, two such cycles have been identified when studying fractions (Watson, Collis & Campbell, in press) and the measurement of volume (Campbell, Watson & Collis, 1992), and it is hypothesized that two similar cycles will also exist in the learning of chance and data concepts.

It became apparent very early that one instrument could not meet all of the assessment objectives of the project. Hence four instruments evolved over time, each devised for a specific purpose. These are documented below. Copies of the final versions may be obtained from the author.

Paper-and-pencil questionnaire

A 20-item short-answer/multiple-choice paper-and-pencil questionnaire was devised based on items from previous research studies elsewhere in the world. The first ten items were used with all grade levels, while the second ten were used only with Grades 6 and 9. Table 1 contains brief annotations of the part of the curriculum covered by each item, a specific reference to the Australian *National Statement* (AEC, 1991), and the reference to the source of the item. In many cases the items were adapted for use in this study. This questionnaire was designed for large scale use in whole-class situations in a period of 40-50 minutes. The items provide an overall picture of basic understanding and possible misconceptions. While some items ask for explanation, a simple coding system has ensured that minimal data analysis yields considerable information. Three items are shown in Figure 1.

Table 1. Paper-and-pencil Questionnaire References

Item	Curriculum reference	Source
1-3	Chance language (A1)	Adapted from Fischbein & Gazit (1984), p.4, Q.A1-3.
4	Chance language (A1)	Original, modelled on National Statement, p.166.
5	Likelihood of everyday experiences (B1) [Left side of bed]	Adapted from Fischbein & Gazit (1984), p.4, Q.B2. [see Figure 1]
6	Order events (A3), interpret predictions (B3) [Lucky numbers]	Adapted from Fischbein & Gazit (1984), p.4, Q.B3. [see Figure 1]
7	Order events (A3) [Numbers on dice]	Original, modelled on Varga (1983), p.76; Green (1983).
8	Describe outcomes (A2, A3) [Names from a hat]	Adapted from Green (1982), in Borovcnik & Bentz (1991), p.81.
9	Describe, order outcomes (A3, B2) [Proportions in boxes]	Adapted from Konold & Garfield (1992), Q.7. [see Figure 1]
10	Interpret information (A5, B5) [Interpret tables]	Original.
11	Likelihood of everyday experiences (B1, C1) [Interpreting risk]	Adapted from Konold & Garfield (1992), Q.2.
12	Measures of location (C7) [Average]	Adapted from Konold & Garfield (1992), Q.22.
13	Measures of location (C7) [Median]	Adapted from Konold & Garfield (1992), Q.1.
14	Describe, order everyday experiences (B1, B2) [Conditional number estimates]	Original, modelled on Pollatsek et al. (1987), p.260, Q.5.
15	Language/ likelihood of everyday experiences (B1, C1) [Conjunction probabilities]	Original, modelled on Tversky & Kahneman (1983), p.309.
16	Describe, order events (B1, B2, C2) [Conditional probabilities]	Pollatsek et al. (1987), p.260, Q.3
17	Analyse events, estimate populations (C2, D7) [Sample/resample; proportion]	Adapted from Fischbein & Gazit (1984), p.4, Q.A7.
18	Analyse everyday events (B1, B2) [Conjunction number estimates]	Adapted from Tversky & Kahneman (1983), p.309.
19	Evaluate, interpret information from daily life (C5, C9) [Sample size]	Adapted from Konold & Garfield (1992), Q.11.
20	Evaluate, interpret information from daily life (C5, C9) [Regression to mean]	Adapted from Nisbett, Krantz, Jepson & Kunda (1983), p.354.

Every morning Jaines gets out of bed on the left side. He says that this increases his chances of getting good marks. What do you think? [Adapted from Fischbein & Gazit, 1984]

One day Claire won Tattslotto with the numbers 1; 7; 13; 21; 22; 36. So she said she would always play the same group of numbers because they were lucky. What do you think about this? [Adapted from Fischbein & Gazit, 1984]

Box A and Box B are filled with red and blue marbles as follows:

Box A	Box B
6 red 4 blue	60 red 40 blue

Each box is shaken. You want to get a blue marble, but you are only allowed to pick out one marble without looking. Which box should you choose?

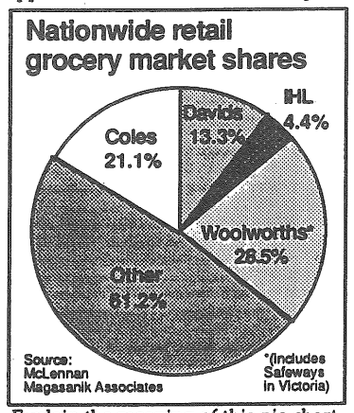
❑ Box A ❑ Box B ❑ It doesn't matter

[Adapted from Konold & Garfield, 1992]

Figure 1

Media survey

The items for the media survey used probabilistic and statistical concepts in social contexts, and addressed the concern for the application of school-based concepts outside the classroom. All items were taken verbatim from newspaper articles and asked for interpretations of situations which people meet in society every day. Of the 10 items, six were administered to Grade 6 students and all 10 to Grade 9. Table 2 contains brief annotations of the part of the curriculum covered by each item, a specific reference to the Australian *National Statement* (AEC, 1991), and the topic of the item. One item is shown in Figure 2.



Explain the meaning of this pie chart. Is there anything unusual about it?
Figure 2

Table 2. Media Item References

Item	Curriculum reference	Topic
1	Use chance language (B1, C1)	Order terms in headlines by likelihood
2	Understand chance in common usage (B1)	Interpret triathlete's chances of winning
3	Understand conditional language (B1)	Give conditions (smoking) & outcomes (wrinkling)
4	Understand social uses of chance processes (C1)	Explain odds for a football match
5	Evaluate/ interpret information in charts (C5)	See Figure 2
6	Interpret data using measures of location (C5, C7, C8)	Explain median house price, average wage earner
7	Appraise data collection & presentation (C5, D4)	Interpret (graph) claims of association of car usage & heart deaths
8	Evaluate arguments based on sample data (C10)	Question claim based on sample of students with guns in Chicago
9	Recognize the importance of random sampling (C9, D4)	Judge claims from phone-in sample on decriminalising marijuana
10	Appraise data collection & presentation (D4)	Summarize articles on enjoying long life

Interviews with concrete materials

A third instrument included four interview protocols which were based on the manipulation of concrete materials in conjunction with logical reasoning: creation of a pictograph to represent information, interpretation of a large adjustable bar chart, determination of the fairness of dice, and representation of associations presented on data cards. Three of the protocols were based on suggestions of Pereira-Mendoza (1992; personal communication, 15 April, 1993). The first three

items were used at all grade levels with the fourth used only at Grades 6 and 9. The major drawback with the items using dice and data cards was the time required in an interview setting. While retaining the dice item, the one using data cards was dropped for the purposes of individual interviews in the main study. It will be adapted later for use in other classroom assessment contexts.

Of interest in these interviews is the level of response associated with the ikonic mode, as well as the concrete symbolic mode, and the interaction of the two. In the trials of all four interviews there was evidence of multimodal functioning. This varied according to the context of the question and is one of the promising avenues of further research resulting from the pilot work.

Problem-solving interviews

The fourth instrument included six interview protocols modelled on the *Collis-Romberg Problem Solving Profiles* (1992), each consisting of four sub-parts designed to reflect the hierarchy of the SOLO Taxonomy (Biggs & Collis, 1982; Collis & Biggs, 1991). The six items assessed concepts in the following areas: sample spaces, comparison of two groups, average, sampling, randomization, and conditional probability. Initial parts were designed to test if the students were able to engage in the concept, with subsequent parts of increasing difficulty. The initial parts of each protocol were used with all students and questioning ceased when students could no longer comprehend the question. The sources for parts of the interviews are given in Table 3, along with the references to coverage of the Australian curriculum. The interview instruments were designed for use in one 40-minute session with individual students.

As an example of the starting point for interviews, the protocol on average asks if the child has heard of the term "average", and if so what it means. This is followed by a printed discussion of average television viewing time, which the child is asked to interpret. Most Grade 3 children cannot progress past this point. The next part asks for the method of finding the average, and this is followed by a question which supplies the mean and two data values before asking for possible values for the other data. These parts are successfully answered by some Grade 6 and 9 students. The final part deals with weighted averages and is difficult for most Grade 9 students. It is not expected that many students will successfully

answer the final part of most interview protocols, as they are designed to require a formal (or near-formal) level of cognitive processing.

Trials and implementation

The trialing of the instruments took place in local schools of similar socio-economic status to the schools to be used in the main study. The sample sizes for the short-answer questionnaire were n = 26 for Grade 3, n = 26 for Grade 6, and n = 32 for Grade 9. For the media survey, sample sizes were n = 41 for Grade 6 and n = 56 for Grade 9. For the interviews, 18 students were selected, six at each grade level. All interviews were video taped and later transcribed for detailed analysis. Results of the pilot work are given in Watson, Collis and Moritz (1993), Watson and Collis (1994) and other reports under preparation.

Table 3. Problem-solving Interview Item References

Item	Curriculum reference	Source
1. Sample spaces	1. Describe possible outcomes (A1, A2) 2, 3. Deduce order of probability of possible outcomes (B2, C2) 4. Construct sample space/ apply binomial distribution (C2, D2)	1, 2, 3. Fischbein, Nello, & Marino (1991), p.526, Q.A1; p.536, Q.A4; p.532, Q.A3. 4. Konold & Garfield (1992), Q.14.
2. Comparison of two groups	1. Represent & interpret information (A5, B5) 2, 3, 4. Summarise & interpret data using visual representations & measures of location (A5, B5, C7)	1. Gal, Rothschild & Wagner (1990), Q.1. 2. Adapted from Gal et al. (1990), Q.4. 3,4. Gal et al. (1990), Q.5,7.
3. Average	1, 2, 3, 4. Summarise & interpret data using measures of location (C7)	1, 2. Gal (Personal communication, 16/3/1993), STARC - Toys, p.11, L1, L2. 3. Original 4. Adapted from Pollatsek, Lima & Well (1981).
4. Sampling	1. Understand what samples are (B6) 2. Select appropriate samples (B6) 3. Recognise the importance of sample size (C9, C5) 4. Examine probabilistic misconceptions (D2)	1, 2. Gal (Personal communication, 16/3/1993), STARC - Toys, p.9, k1, k2. (b) Original 3. Adapted from Garfield & delMas, 1991, p.347, Q.3. 4. Adapted from Tversky & Kahneman (1971).
5. Randomization	1. Appreciate random element of some events (B1) 2. Study social use of chance process: lottery (C2) 3. Recognise that samples may be unrepresentative (C9) 4. Recognise the importance of random sampling (B6, C9)	1. Adapted from Gal (Personal communication, 16/3/1993), STARC - Toys, p.10, k4. 2. Adapted from Fischbein & Gazit (1984), p.4, Q.B4. 3. Adapted from Garfield & delMas (1991), p.347, Q.1, 2. 4. Adapted from Konold & Garfield (1992), Q.6.
6 Conditional probability	1. Understand conditional language (B1, B2, C2) 2. Understand conditional language & read table data (A5, B5, C2) 3,4. Calculating conditional probabilities (C2, D1 (extended))	1. Pollatsek, Well, Konold, Hardiman & Cobb (1987), p.260, Q.3. 2. Original. 3. Falk (1983), p.319. 4. Tversky & Kahneman (1980).

Following the pilot stage of the project, the paper-and-pencil questionnaire and an adapted media survey were administered to over 300 students in each of Grades 3, 6 and 9 in Tasmanian schools in Term 3, 1993. These students will be retested in Term 3, 1995. The local retention rates in Tasmanian schools make it reasonable to assume that retesting will involve a high percentage of the original sample. Additional Grade 3 students will also be tested in 1995. It is intended that some of the schools involved in the 1993 sample will avail themselves of opportunities offered for professional development in Chance and Data. The data may then provide the opportunity to gauge the success of curriculum implementation in the state.

Following the large-scale administration of the questionnaires, approximately 20 students from each grade level were selected for extended interviews based on the protocols using concrete materials and the hierarchical problem-solving format. The results of these interviews will be combined with those from the paper-and-pencil questionnaires to provide a basis for the analyses of levels of cognitive functioning and of multimodal functioning. This will lead to suggestions for teachers and curriculum planners in relation to the levels at which concepts should be introduced and possible teaching methods.

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Introducing Box and Whisker Plots

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Box and whisker plots were introduced to a group of eight students for enrichment and follow-up sessions as part of a project looking at the ideas that 11 and 12-year-old children have about central tendency and dispersion. This paper reports some of the tentative findings about the teaching and learning of box and whisker plots to middle-school children.

A SYNTHESIS OF THE RESEARCH LITERATURE ON THE LEARNING AND TEACHING OF DATA ANALYSIS CONCEPTS AND SKILLS

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Over the last few years, several reviews of the literature on the learning and teaching of probability have appeared. There has not been, to the best of this author's knowledge, any comprehensive review of the literature on the learning and teaching of data analysis concepts and skills. The purpose of this paper is to provide such a review. This paper will not simply review the literature, but will provide a synthesis of the literature on the learning and teaching in the areas of descriptive statistics, exploratory data analysis, graphics (both creating and interpreting), inferential statistics, sampling/polling, survey/questionnaire design, design of experiments, modeling (including regression) and uses of calculators, computers and computer packages. The focus will be on research relating to secondary schools (approximately ages 12 to 18) and post-secondary institutions (up through doctoral level studies). The paper will conclude with a section on implications for teachers.

The Success of Graphic Models to Visualize Conditional Probabilities

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We worked out special training programs for conditional probabilities and compared their success. The programs were based on graphic models to visualize conditional probabilities: the tree diagram, the inverted tree diagram and the unit square; a program with purely numeric representation was added. Theoretical considerations from the viewpoint of cognitive psychology lead to the following hypotheses:

- Graphic visualization makes the understanding of conditional probabilities easier.
- The unit square is superior to the other two graphic models as it not only supports the access to the event space but also visualizes geometrically the size of probabilities.

To test the hypotheses we carried out two experiments.

Experiment 1 compared the *short-term* success of different training programs (directly after the training) using a pretest-posttest design. The results could just slightly confirm our hypotheses. However training significantly improved the ability to deal with conditional tasks regardless of the training method.

Experiment 2 compared the *long-term* success of the different training programs (half a year after the training). Both hypotheses could be confirmed with significant results.

The findings strongly support our suggestion to visualize conditional probabilities with graphic models. Although the relevant relations seem to be accessible by the numeric form as well (experiment 1), they can be stored and retrieved more easily with graphic support (experiment 2). Obviously graphical representations induce a more sustainable knowledge on conditional probabilities. The question for the appropriate model can also be answered: theoretically and in practice - at least long-term - the unit square has proven to be superior. These results are in sharp contrast to didactic reality where textbooks in probability theory use, if at all, the tree diagram.

Assessment Issues in the Teaching of Statistics

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Recent research in New Zealand at the senior secondary school and early tertiary level suggests that the type of assessment used in statistics courses has a marked effect on performance. The research strongly suggests that, in particular, female students perform better in the investigative, open-ended project work used in internal assessment than they do in timed examinations. Within examinations certain students perform better on questions set in a relevant social context than they do in questions with a more theoretical context. The layout of a question was seen to have an effect in some cases. This research has implications for teaching as it indicates that certain contexts make statistics more or less accessible to particular groups of students.

Further research comparing the ongoing participation in statistics courses for students under different assessment regimes is desirable in order to establish if some of these regimes are discouraging participation in statistics for certain groups of students.

Children's Intuitive Understanding of Variance

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The idea of confidence limits plays an important role in integrating the topics of probability and statistics. It is often poorly understood by beginners and frequently omitted from elementary courses.

This paper presents the results of clinical interviews with 32 children in Years 4, 6, 8 and 10. The children were presented with an asymmetrical two-outcome random generator and asked a sequence of questions designed to establish what they saw as "unsurprising" results from groups of 9 trials and 50 trials.

The paper argues that these children do have a naïve understanding that results obtained from a group of trials will vary from group to group but that their understanding has a number of inconsistencies. With an asymmetrical two-outcome random generator surprising results for the more likely outcome are not always consistent with surprising results for the less likely outcome. Surprising results for the smaller group of trials are not always consistent with the larger group.

The paper concludes with some suggestions about how these findings might be used to design appropriate forms of classroom activities which might help to eliminate these inconsistencies.

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Children's Understanding of Random Generators

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This paper discusses the premise that young children do not perceive relationships between the behaviour of different, but related random generators.

Data has been collected from primary school aged children from 7-12 years from a range of city, country, independent and public primary schools in South Australia who were questioned about their perceptions of the behaviour of dice, coins, raffle tickets and a range of different and unusual random generators in identical situations, for example, playing a game of Snakes and Ladders.

The findings indicate that children predict different results depending on, for example, whether tickets rather than dice are used in a game. The belief appears to be based on the observation of the physical differences between dice and raffle ticklets. The responses indicate that children's thinking extends beyond the availability and representativeness heuristics. It is important that this thinking is investigated in more detail.

The study is designed to add to the store of knowledge of children's thinking in probabilistic situations by providing an interrelationship between current theoretical perspectives of learning and the actual practices of children in the classroom. The results have provided a basis for in-service material for practicing and pre-service teachers in South Australia which will be made available at the conference.

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Challenging and Building on Students' Intuitions about Probability: Can We Improve Undergraduate Learning?

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In this paper we will describe part of an ongoing study into the teaching and learning in a large introductory stochastics course at the University of Auckland, New Zealand. Traditionally, students have experienced difficulties making the transition from descriptive or exploratory methods to inferential methods. One hypothesis is that this is due in part to lingering misconceptions about chance and probability. In this study we investigate the learning and understanding of probability concepts of a small group of students enrolled in the 1994 course. Taking an interactive approach to our instruction, we engage these students in a series of activities designed to challenge and build on their beliefs and intuitions about chance. We discuss the results of this intervention, and its implications for the teaching of introductory stochastics courses.

Students' understanding of computer-based simulations of random behaviour.

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Abstract

This paper is motivated by a concern about the increasingly important role being given to computer-based simulations of random behaviour in the teaching and learning of probability and statistics.Many curriculum developments in this area make the implicit assumption that students accept the computer algorithm for generating random outcomes as an appropriate representation of random behaviour,and that computer based simulations can be treated as exhibiting random behaviour. This paper will outline some reasons for questioning this assumption,and will indicate a need to investigate how students' mental models of random behaviour differ from their understanding of the computer representation of randomness.

Software as a statistical teaching and consulting tool

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Researchers in Ecology accumulate more and more numerical observations. They meet with difficulties during the (late) data analysis stage. However, they often have to manage by themselves due to the serious imbalance between a constant methodological demand and a weak supply from sparse statisticians. The first step in consulting is the adaptation of the research questions to the statistician's language. In return, the statistician gives theoretical and practical (calculus, graphics) tools. The development of personal computers now permits to meet demands in term of software production.

We propose that statistical software, especially the multivariate linear analysis software ADE[1] (Environmental Data Analysis), can be used as a statistical teaching and consulting tool. Our experience in teaching a graduate course "analysis and modeling of biological systems" in University of Lyon (France) will be described. Students attending the course both acquire their own data and look for statistical training and consulting. Our software can be used even for aspiring consultants to understand proper methods and to get a thorough knowledge of biological subjects. The concepts of statistics (mean, standard deviation, correlation...) are linked to real life ones (space, time, species behavior...).

ADE software includes two original pedagogical tools among others: a biological data-base and bibliographic references.
The incorporation of biological data sets makes biologists sensitive to statistics because of similarities with their own work. The topics included in the course are governed by the requirements of the subjects to which they are oriented. We emphasize data sets matching methods to study species-environment relationships, spatial variability to investigate species competition and time series analysis to observe, for instance, community evolution.
Two kinds of bibliography are combined in this software. One is a statistical one to enlarge users' theoretical abilities. The other is an experimental one so as to cover a wide field of applications.

Running the ADE software depends on a basic understanding of its theoretical principles. These principles are taught during the related course. The underlying mathematics are algebra. A geometrical view of the statistical concepts is proposed. For example, a variance is seen as the length of the corresponding n-dimensional vector.
The program structure is based on the duality diagram[2]. The first step consists of choosing a free triplet (X,Q,D), i.e., a transformed (by centering, projection, etc) data set (X), a weighting of statistical units (D) and a metric for the variables (Q). The second step unifies well-known methods (Principal Components Analysis (PCA),

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1 ADE :Chessel, D. et Dolédec, S. (1993) ADE Version 3.6 : Hypercard© Stacks and Programme library for the Analysis of Environmental Data. Ecologie des eaux douces et des grands fleuves - URA CNRS 1451, Université Claude Bernard, 69622 Villeurbanne, France.

2 Escoufier, Y. (1987) The duality diagram : a means for better practical applications. In *Developments in numerical ecology*. P. Legendre et L. Legendre (eds). NATO Advanced Study Institute Series G (Ecological Sciences). Springer-Verlag : Berlin, 139-156.

Correspondence Analysis, Discriminant Analysis, PCA with respect to instrumental variables, etc) by eigenvector analysis of one of the two symmetric operators X'DXQ or XQX'D. This formalization allows us to consider process PCA and spatial PCA in ADE programs.

Graphics in ADE software are based upon three fundamental laws: scientific graphics, biological meaning and Euclidean representation to establish standardized (canonical) practices.

The ADE software is an organized package of elementary modules of numerical calculation and graphics. Programmers are also teachers and apply statistics in the field of ecology. They develop methods in the scope of biology purposes. The elaboration of new statistical techniques leads to new modules. The updating of documentation consists in a thematic card index analyzing particular practical cases. This dictionary is a digest, a memory of the consulting history of these researchers. The advantage of being an open software package may be in the future limited because of its growing complexity. It is essential to define a new methodology organization. A development towards artificial intelligence to represent knowledge using structured objects aims to rearrange this scientific means wealth and to help to problems solving in ecological data analyses.

Formation par la consultation statistique dans les Instituts d'Agro-Foresterie au Maroc

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R E S U M E

Toute étude statistique peut être décomposée en deux phases au moins: le rassemblement ou la collecte des données statistiques, et leur analyse ou leur interprétation. Le rassemblement des données, notamment en Biologie, peut être réalisé soit par la simple observation des phénomènes auxquels on s'intéresse, soit par l'expérimentation. Quand à l'analyse statistique, elle peut elle-même être décomposée en deux étapes l'une déductive ou descriptive, l'autre inductive.

Pour l'analyse statistique, le Biologiste peut avoir recours à un Biométricien pour l'aidé à mieux organisé l'observation et l'expérimentation d'une part, et à traiter les données d'autre part. Ce recours et qualifier de consultation statistique.

La consultation statistique est donc l'unité élémentaire du dialogue entre un biométricien et un biologiste. Ils y échangent un savoir faire ou un pouvoir faire contre un accès aux données réelles.

Vue sa formation "polyvalente" le biométricien a pour objectif primaire l'articulation de la biologie, de la mathématique et de la logique de l'expérimentation et par conséquent sa situation est réellement fondamentalement pluridisciplinaire.

En tant que Biométricien, Enseignant-Chercheur dans une Ecole d'Ingénieurs en Foresterie et se basant sur ma courte expérience dans le domaine, je subdivise les consultations en trois catégories:

- Consultation pour la planification d'expérience
- Consultation purement statistique;
- Consultation relative à l'utilisation de logiciels statistiques

Dans ce qui suit le point sera mis sur les consultations statistiques pour lesquelles on va détailler les points suivants:

. Les différents type de consultations statistiques;
. La qualité des consultants;
. Quelle formation cela donne aux consultants et aux consultés;
. La suite réservée aux méthodes objet de la consultation.

Enfin, on terminera par une conclusion qui portera l'accon sur les action à mener pour rendre les consultations beaucoup plus efficaces et plus profitables aux consultants et aux consultés.

Consulting experience as the culmination of an undergraduate statistics major

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Traditional undergraduate statistics courses teach a succession of statistical techniques, usually as isolated units - a semester on regression, a semester on experimental design, etc. Students emerge with a lot of compartmentalised knowledge, but very rarely possess skills in knowing which procedure to use in a given practical situation.

Employers of our graduates want communication skills and the ability to focus on the essence of a problem and apply the right methods. Caulcutt (1987) has recommended that the training of statisticians should include *"contact with practical problems..."* and *"practice in the art of communication"*.

Some graduate courses (van Belle,1982) have incorporated training in statistical consulting, but it is rare in undergraduate courses.

In the final semester of a 3 year statistics major, I wanted a unit which would give an overview of all the techniques studied, and would give students experience in dealing with real statistical problems.

At the same time, as a teacher of service courses to first year students in areas such as biology, psychology and physical education, I had numerous requests from students doing third year projects who had forgotten all they were taught in first year but now realised the need for some statistics.

In semester 2 of 1993 I introduced a scheme designed to solve both of these problems. Each of my statistics majors was allocated four "clients" : students doing third year projects in a variety of courses. The "consultant" statistician gave advice ranging from initial experimental design and or survey design, through data entry, choice of the most appropriate statistical package to use, analysis and interpretation of results.

Many of the projects were fairly simple surveys requiring only crosstabulations and graphical display of results, but others went as far as manova or factor analysis.

This paper will give details of how the scheme was organised and assessed, and give examples of some of the positive feedback obtained.

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ENHANCING ELEMENTARY EDUCATION THROUGH QUANTITATIVE LITERACY

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ABSTRACT

It is widely recognised that programs which enhance quantitative skills must be in the mainstream of mathematics education, beginning at the elementary level. These skills are essential if schools are to produce intelligent consumers, effective workers and involved citizens. Programs providing these skills can no longer be considered as enrichment; they must be available to all students. Yet, the typical elementary teacher of today was not exposed to modern quantitative techniques as part of their education, and these teachers have few opportunities to improve their skills in this area. For these reasons, the American Statistical Association and the National Council of Teachers of Mathematics have joined with the school districts of Baltimore County and Baltimore City to produce a teacher-enhancement program called **Quantitative Literacy in the Elementary Mathematics Curriculum** (abbreviated EQL). Funding is provided by the National Science Foundation. The two main arms of the project are the development of materials to help teachers learn a hands-on, discovery-based approach to modern data analysis, statistics and probability, and the production of a series of one-week workshops for teachers to participate first hand in practising this approach to teaching mathematics. School-based administrators are brought to the workshop, or to a follow-up session, so that they can learn enough about the project to be supportive of the teacher in the local school setting. Examples of the kinds of activities being developed will be included in this report.

BACKGROUND AND NEED

A basic understanding of the collection and use of data for making decisions must be a mainstream goal of mathematics education, beginning at the elementary school level. The National Council of Supervisors of Mathematics listed knowledge of statistics as one of the necessary fundamental skills that each student must possess if he or she is to function intelligently as consumer, worker and citizen. This point of view is embraced by the National Council of Teachers of Mathematics (NCTM) and the Mathematical Sciences Education Board (MSEB). Curricular reform in mathematics is taking place at a rapid rate at the middle and high school levels; curricular reform at the elementary school level is in its infancy, but reform must begin at this level if significant long-range change is to be made. Throughout the K-12 mathematics curriculum, a key component of reform is what the American Statistical Association (ASA) programmes have termed quantitative literacy - statistics from a data collection, data exploration and graphical point of view and probability form an empirical relative frequency and simulation orientation. The specific subject of this report is a joint ASA - NCTM project in **Elementary Quantitative Literacy** (EQL) that seeks to develop materials and provide workshops for in-service elementary teachers to upgrade their skills in this area so that they can be leaders of the reform effort in mathematics education at the elementary level.

That much help is needed to change the knowledge base, focus and orientation of the vast majority of elementary teachers is made clear in numerous studies and reports. The MSEB report **Everybody Counts**, comments as follows:

The preparation of mathematics teachers is a crucial factor in revitalising curricular practices. Too often, elementary teachers take only one course in mathematics, approaching it with trepidation and leaving it with relief. Such experiences leave many elementary teachers totally unprepared to inspire children with the confidence in their own mathematical abilities.

Those who would teach mathematics need to learn contemporary mathematics appropriate to the grades they will teach, in a style consistent with the way in which they are expected to teach. It is time we identify a cadre of teachers with special interest in mathematics and science who will be well prepared to teach young children both mathematics and science in an integrated, discovery-based environment.

The NCTM's **Curriculum and Evaluation Standards for School Mathematics** presents a strong justification for teaching quantitative literacy in the elementary grades.

Collecting, organising, describing, and interpreting data, as well as making decisions and predictions on the basis of that information, are skills that are increasingly important in a society based on technology and communication. These processes are particularly appropriate for younger children because they can be used to solve problems that are inherently interesting, represent significant applications of mathematics to practical questions and offer rich opportunities for mathematical inquiry.

Thus, the need for educational opportunities, for both teachers and students, and the critical importance of the subject matter are both addressed in the EQL program, which does attempt to improve the mathematical abilities of the teachers, integrate mathematics with other disciplines, use a discovery-based approach, deal with questions and applications of inherent interest to the students, and offer rich opportunities for mathematical inquiry. Even though the subject matter of quantitative literacy is inherently inter-disciplinary, being part of science, social science and life skills, it is appropriate that this corporate body of knowledge be part of the mathematics curriculum, with links to the other disciplines. Since the elementary teacher is generally responsible for many subject areas, he or she can make better use of the inter-disciplinary nature of statistics than can teachers at the higher levels.

GOALS AND 'ANTICIPATED OUTCOMES

The goals of the EQL project are to:

1. Develop and deliver an in-service workshop for elementary school teachers that will allow them to implement a quantitative literacy strand in their mathematics curriculum.

2. Develop and deliver an in-service workshop for elementary school-based administrators to inform them of the content and techniques of a quantitative literacy strand so as to ensure proper teacher support and implementation.

3. Plan and deliver a quantitative literacy resource package that will support teacher and administrator workshops in any elementary (K-6) school whose goal is to implement quantitative literacy in the curriculum.

This program will produce:

1. A complete scope and sequence plan and a set of modules for the quantitative literacy strand, including examples and activities that will allow teachers to incorporate the strand into each level of the elementary mathematics curriculum.

2. A model workshop for elementary teachers (and a companion workshop for administrators) including content, techniques and field-tested materials designed to ensure proper implementation of the program.

3. A workshop package that any school system can use as a staff development vehicle to effectively implement a quantitative literacy strand.

CONTENT OF MATERIALS

The central focus of the materials being developed is the series of activities used in the workshops to introduce and extend notions of quantitative literacy in a hands-on, learning-by-discovery environment. These activities are arranged in ten modules that parallel the development of mathematical topics throughout the elementary school curriculum. The titles of the modules are:

Classifying and Counting
Ordering and Counting
Counting to Measure
Refining Measurement
Anticipating Outcomes - Probability
Associating Classifications
Associating Measurement with Classification
Associating Measurements
Changes Across Time
Multivariable Data

Obviously, the arrangement of topics also parallels statistical developments from simple categorical responses through ordered categorical responses, measurement, association between variables, time-dependent data, and mutivariable data. It should be noted that the approach throughout is exploratory and empirical; no formal notions of statistical inference are introduced, although proper randomisation in designing surveys and experiments is discussed and illustrated.

The modules will be supported by Math Development Pages, which go into more detail on topics that might be new to the teacher (such as boxplots), and Classroom Connections, which show actual examples of how particular lessons have been adapted for and used in an elementary school classroom.

The best way to see the EQL approach is to study a few examples. Typical activities from the modules will be presented in the Session.

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Training Teachers to Teach Statistics in Australia

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Prior to 1990 the mathematics education community in Australia had in general shown little real interest in statistics being a part of the school mathematics curriculum. Mathematically able students were introduced to formal ideas of probability at Year 11 (at about age 16), and continued this in Year 12 if they chose to proceed in mathematics. The study of statistics was virtually non existent; except for the ubiquitous histogram, which seemed to be taught in the last week of every year from years 7 through till 10, with little purpose and even less enthusiasm from teachers and students alike. However, a major review of mathematics curricula in Australia, begun in the late 1980's and culminating in the publication of *A National Statement on Mathematics for Australian Schools* (Australian Education Council, 1990), recommended that somewhere around 20% of the mathematical content taught in Australian schools at all levels should be concerned with Chance and Data. The scope of the recommendations can be seen in Table 1 which has been compiled from information contained in the National Statement.

Whilst there is no compulsion for individual States to adopt the National guidelines, curriculum in Australia is determined at the state level, there now seems to be general agreement in Australia that substantial amounts of probability and statistics should be included in the mathematics curricula at all levels. However, this has created a problem for teachers, the vast majority of whom have had little, if any, training in statistics. Whilst some attempts may be made to rectify this problem at a pre–service level, the vast majority of teachers who would be expected to teach the new curriculum are presently teaching in the schools. Thus, it was recognised at a national level that there was a need for teacher retraining in statistics before the new curriculum guide lines could be properly implemented. This training has taken place at both the national and state level.

CHANCE and DATA

Band A (K–3)
A1 use, with clarity, everyday language associated with chance events
A2 describe possible outcomes for familiar random events and one-stage experiments
A3 place outcomes for familiar events and one-stage experiments in order from those least likely to happen to those most likely to happen
A4 frame questions about themselves, families and friends, and collect, sort and organise information in ways in order to answer these questions
A5 represent and interpret information to answer questions about themselves, friends and families

Band B (4–6)
B1 make statements about how likely are everyday experiences which involve some elements of chance and understand the terms 'chance' and 'probability' in common usage
B2 for random events, systematically list possible outcomes, deduce the order of probability of outcomes and test predictions experimentally
B3 make and interpret empirically based predictions about simple situations
B4 systematically collect, organise and record data to answer questions posed by themselves and others
B5 represent, interpret and report on data in order to answer questions posed by themselves and others
B6 understand what samples are, select appropriate samples from specified groups and draw informal inferences from data collected

Band C (7–10)
C1 understand and explain social uses of chance processes
C2 construct sample spaces to analyse and explain possible outcomes of simple experiments and calculate probabilities by analysis of equally likely events
C3 estimate probabilities using the long-run relative frequency (that is, empirical probabilities)
C4 model situations and devise and carry out simulations
C5 access, evaluate and interpret information presented in different forms from a variety of sources
C6 systematically collect, organise and record data for practical purposes
C7 summarise and interpret data using visual representations and measures of location and spread
C8 understand the impact of statistics on daily life
C9 understand what samples are and recognise the importance of random samples and sample size
C10 draw inferences and construct and evaluate arguments based on sample data

Band D (11–12)
D1 use experimental and theoretical approaches to investigate situations involving chance and to determine the likelihood of particular outcomes
D2 generate, use, interpret and investigate properties of probability models
D3 use simulations to model uncertain events
D4 plan, manage and appraise data collection and presentation
D5 undertake exploratory data analysis
D6 examine various sampling methods and the relationship between samples and populations
D7 determine and use estimates of population parameters and confidence intervals

Table 1: An outline of the relevant statements concerning topics in Chance and Data at the various year levels from the National Statement on Mathematics for Australian Schools.

At the National level, the initial response has been in the area of materials development. A major project was undertaken by the Curriculum Corporation (a federally funded centre involved in the development of materials across all age groups and subject areas) in 1991-92, which culminated in the two volume publication *Chance and Data Investigations* (Lovitt & Lowe, 1993), and supporting software which contains programs and data to support the books. These materials are designed for use by teachers with students from levels K–12 and consist of extended investigations which

target important ideas in probability and statistics. As stated in the rationale, these extended investigations promote the following instructional philosophy:

1 Learning through problem solving as a method of inquiry
2 A holistics approach
3 An emphasis on modelling, and simulation in particular
4 A high technological profile
5 Development of major content areas
6 Treating chance and data concurrently
7 Significant integration with other topics and social contexts

(*Chance and Data Investigations*, Volume 1, p VII)

Each investigations has been extensively trialed by practising teachers and includes information to the teacher on many levels:

- what the teachers should say and do in the conduct of the lesson
- expected responses from the students and sample data
- statistical theory underpinning the lesson sequence.

The breadth and spirit of the investigations is captured in their titles which can be found in Table 2.

1 Intuitive probability
Clothes line
Colour dice
Crazy animals
Likely choices
Peg spin
Early probability
2 Probability calculations
Sums and differences
Myths and misconceptions
Probability smorgasbord
3 Applications of chance
Horse races
Odds: fair and unfair
Swapping schools
Radioactivity
Medical testing
4 Modelling with simulations
Walk the plank
Beetle game
Birth month paradox
Winning streaks
Matching
Chocolate–chip cookies
5 Using personal data
People graphs
Performance data
Soup kitchen
Chairs and tables
Groups and sorting rules
Bikes, monkey bars and skeletons
Popcorn
6 Using second hand data
Video data
Population centre of Australia
Top of the class
Dying for a smoke
Sunsmart?
7 Using databases
Database debut
Pocket money
Weather patterns
Cemetery maths
8 Sampling and inference
What's in the bag?
Duelling dice
How long is a rod?
Colas

Table 2: Contents page of *Chance and Data Investigations, Vol. I(1-4)& Vol. II(5-8)*

While the production of the Chance and Data materials provides teachers with classroom resources, the need for in-service training of practising teachers has also been recognised. In response to this need an in-service training program, funded by the Department of Employment, Education and Training (DEET) and administered by the Australian Association of Mathematics Teachers was set in place. This program involved the development of eight special issues workshops one of which, the workshop *Maths Works: Chance and Data* (Watson, 1993a), was specifically concerned with Chance and Data. The workshop involves about 10 hours of teacher contact time and is supported by materials designed to:

- introduce Chance and Data to teachers,
- provide opportunities to appreciate the rationale for its inclusion in the mathematics curriculum,
- provide exemplary activities,
- introduce some resources in the area,
- motivate teachers to ask for further support.

(Watson, 1993b)

These materials have been successfully trialed but the professional development program which they support has yet to be widely implemented.

At the State level, responses to the problem have tended to be driven by local needs. For example, in Victoria, some of the curriculum changes recommended by the National Statement had been anticipated and an externally assessed Year 12 subject called Reasoning and Data, which involved extensive studies in the area of probability and statistics was introduced in 1989. Responding to this need the Statistics Education Unit at the University of Melbourne ran a series of half day and full day workshops for senior mathematics teachers, specifically to introduce them to more sophisticated statistical ideas needed to teach this subject. The emphasis in these workshops was on project work and problem solving activities. Over the years 1989–1992 the Statistics Education Unit ran workshops for over 600 secondary mathematics teachers in Victoria. The Unit also produced a publication for teachers, *Projects in Probability and Statistics* (Lipson, Sharpe, & Watson, 1990). Recognising that there was also a need to improve the statistics education of teachers beyond what they explicitly needed for the classroom, the Victorian Government made funds available through the Victorian Education Foundation (VEF) to establish a Graduate Diploma in Mathematics and Mathematics Education in 1992. This was offered by two provider institutions: on a weekly lecture basis by the University of Melbourne, and as a Distance Learning Course through Deakin University. Scholarships were offered to teachers undertaking the two core units of this course, Statistics for Teachers and Mathematical Modelling.

Statistics for Teachers was designed to be the equivalent of a second year university level course in statistics. About 200 teachers enrolled for the Statistics for Teachers subject in the period 1992/3.

While the Year 12 subject Reasoning and Data contained a substantial amount of probability and statistics, it was not considered to be one of the mainstream mathematics courses in Year 12 and often not taken by students aiming for University entrance in the sciences and technologies. However, recent political changes have led to a review of the Year 12 curriculum and methods of assessment and as a result there has been a rewriting of curricula. In the process, the study of probability and statistics has been written into all Year 11 & 12 mathematics subjects, so that it now makes up a substantive part of the curriculum, see Table 3.

Year	Subject	Contents	% of subject
11	General Mathematics	Descriptive Statistics Bivariate Data Sampling for Attributes	17%
11	Mathematical Methods 1 & 2	Introductory Probability Combinatorics Sampling without replacement Sampling with replacement	33%
12	Further Mathematics	CORE (taken by all students) Simulation Correlation and regression Time series OPTION Discrete random variables Sampling with replacement Control Charts	25% 25%
12	Mathematical Methods 3 & 4	CORE (taken by all students) Discrete random variables Binomial distribution Normal distribution Sampling and estimation	25%
12	Specialist Mathematics	OPTION Continuous random variables Sampling and estimation	25%

Table 3: Statistics content of Year 11 and 12 mathematics subjects in Victoria

As is evident from Table 3, extensive studies in statistics are necessary for all students of senior mathematics in Victoria, and this is likely to be the case throughout Australia in the near future.

Clearly there is a large and increasing need for teacher training in statistics in Australia. To date there has been three levels of response; curriculum materials, in-service workshops and formal training courses leading to further qualifications. All have their place and each has been successful in its own right. Teachers at all levels have taken up the challenge. There has already been a noticeable change in teacher knowledge and attitude to teaching statistics. A start has been made to addressing the problem but there is still much to be done.

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Students' Understanding of Statistical Concepts: Implications for Teacher Training

by

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Introduction

Many educational organizations have acknowledged the increasing importance of statistics in the curriculum. This is reflected, for example, in the Australian Education Council's *National Statement for Australian Schools* (1991), the National Council of Teachers of Mathematics *Curriculum and Evaluation Standards for School Mathematics* (1989) and in the current British National Curriculum where a significant component of the Mathematics Curriculum is directed towards "Data Handling". With this current "explosion" of the role of statistics in the school curriculum the question of appropriate teacher training takes on great significance.

Over the past few years the issues associated with training statistics teachers have been the subject of considerable discussion. Many of these issues were discussed in the 1988 ISI round table held in Budapest just prior to ICME VI (Hawkins, 1990), and some of them resurfaced at the 1992 round table (Pereira-Mendoza, 1993).

This paper will focus on one particular issue that is of central importance to the training of statistics teachers, namely, how do we incorporate current research regarding the development of statistical concepts and

misconceptions into a pre-service or in-service programme for teachers? It is a brief overview of some of the research findings and implications. As such, it is not meant to contain a definitive list of either conclusions from the research or implications. It contains exemplars that are designed to provide the reader with a perspective on this paper. The exemplars will be expanded and extended in the final paper.

Although the general focus of this paper applies equally to primary and secondary teachers, it is important to include one note regarding specific problems faced by primary teachers. First, although statistics teachers at school levels are generally not well trained in statistics, this is particularly true of primary teachers (Hawkins, 1993). Second, the primary teacher is usually a generalist. This situation is unlikely to change and, consequently, poses particular problems for the primary-teacher training in statistics education.

Research Literature

In order to discuss the implications of research for Pre-Service and In-Service training, it is essential to "review" the current state of knowledge regarding research on statistics (not probability, per se). The following are four "key" conclusions that have been discussed in the research literature. They do not constitute a definitive list but, for the purpose of this brief summary of this paper, provide exemplars of some of the underlying conceptual problems students have with graphing.

1. Students have many misconceptions conceptualizing "average". While students can compute the average, they have considerable difficulty understanding the concept as well as developing different conceptualizations. (Goodchild, 1988; Leon and Zawojewski, 1991; Russell and Mokros, 1991).

2. Students have difficulty "going beyond the direct reading of a graph" (Bestgen, 1980). This result has been consistently found by researchers (Padilla, McKenzie & Shaw Jr, 1986; Pereira-Mendoza and Mellor, 1991). Students have misconceptions regarding the role of pattern within graphical representations of data.

3. Students have misconceptions regarding the role of knowledge of (familiarity with) the topic when dealing with problems involving graphs. As with going beyond the data, the existence of these misconceptions has also been a consistent finding of the research (Curcio & Smith-Burke, 1982; Pereira-Mendoza & Mellor, 1991).

4. Students have misconceptions regarding the role of scale in interpreting a graph. Kerslake (1977) showed how students do not correctly use scale in interpreting a graph, and Huff (1954) showed how manipulating the scale of a graph could lead to misinterpreting the information.

These exemplars of the results from the research provide a basis to discuss the implications of research for training of statistics teachers. However, before discussing the implications it is necessary for the reader to understand the overall pedagogical framework within which this paper is written.

Pedagogical Framework

Constructivism, as a framework for instruction, is currently the basis for the pedagogy within many disciplines. For example, it formed one of the topic groups at Seventh International Congress on Mathematics Education

(Malone and Taylor). The author brings to the discussion a constructivist perspective. Consequently, in discussing the implications for the training of statistics teachers it is assumed that the goal is to produce a teacher who can teach statistics from a constructivist perspective. While there may be a debate regarding an operational definition of constructivism, it seems generally accepted that this is the perspective that one desires of a teacher.

Implications

How should what we know about students' conceptualization and misconceptions of statistical concepts impact on teacher training? It is this author's contention that it is one on the central supports for effective teacher training. A bridge between research and practice must be developed if an effective teacher-training programme is to be developed. Much of the education literature talks about developing comprehension rather than the rote development of algorithms. The statistical education of children is no exception. However, if teachers are to develop comprehension of statistical ideas in children (such as mean, pictographs, range and so on), it is essential that they understand both how statistical concepts are developed as well as how misconceptions are formed. In order for instruction to develop understanding and avoid children developing misconceptions, teachers must be aware of potential misconceptions. Without this understanding teachers will not be able to design and utilize activities in a manner such that misconceptions will be avoided. Parallel to the research conclusions, the following is not a definitive list, but provides exemplars of the implications and will be expanded upon in the presentation and final paper. These exemplars focus on implications that would, in many cases, involve a change in focus from current practice.

A. Teachers need to have experience interviewing children to determine the nature of their statistical concepts.

Although many teacher training programmes include work with children, in many cases this does not involve detailed case studies of concept development. While no pre-service programme can do this extensively, it should be a major focus for statistical education.

B. Statistical activities should be critically analyzed both in terms of their ability to develop concepts as well as their potential to lead to misconceptions.

There any many examples of statistical activities in the literature. Usually when activities are discussed, explored, and so on, the focus is on how they help develop a concept. However, activities often have an inherent danger of leading to incorrect generalizations or misconceptions. For example, students experience with patterns often leads to the assumption that patterns must exist.

C. Teachers should be "exposed" to the research on concept development in statistics.

Often in teacher training programmes, particularly with pre-service teachers, the research base is implicit in the programme, but not explicitly discussed. This suggests that it should be explicit.

Conclusion

This brief summary of the paper has illustrated some of the conclusions that can be drawn from the limited research in statistics education. It has tried to focus the reader on the implications of this research for teacher training. It is important to note that some of these implications would involve changing current practice. The final version of the paper will expand and further develop these ideas.

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Cross-University Collaboration in Teacher Training

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Abstract

This paper describes the collaboration between teacher trainers and their students in the areas of statistics and exercise physiology. It identifies the problem on which the students worked and the nature of the collaboration process. The benefits and drawbacks of this curriculum initiative are discussed.

Background

Teacher training in England is currently mainly undertaken within the University sector, although this seems likely to change in the near future. Sheffield Hallam University has a long history of teacher training provision dating back to the incorporation of several teacher-training colleges into the Polytechnic which was the forerunner of the University. Currently there is a large School of Education within the University which has an excellent reputation for both its in-service and pre-service provision. The

other Schools within the University input teaching of various specialisms onto these courses, but the staff concerned have few opportunities to integrate due to the multi-site nature of the Institution.

The pre-service training can take several forms. At present there are two major routes, the B.Ed and the PGCE. The B.Ed. (Bachelor of Education) is normally a four-year course leading to an honours degree whilst the P.G.C.E. is usually a one-year course for students who already have a degree in their subject specialism.

This paper relates to two groups of students studying for the B.Ed., one group specialising in Mathematics and the other in Physical Education. The mathematics students are a mixed class of third years on a 'normal' B.Ed. and second years on a 'fast track' two year B.Ed. for mature students with existing qualifications. The former group have covered some statistics in the each of the previous two years of the course whilst the latter group joined them for their statistics course in the last year only. So all the students have a good grounding in basic statistical techniques. The course is taught by a statistician with an education background based in the School of Computing and Management Sciences.

The Physical Education students are in their final year of the course. In order to underpin the pedagogical component they undertake a suite of courses in Movement Science. This discipline is increasingly important to their training, as many will be expected to teach A' level Physical Education or Sports Studies in their future careers.

Exercise physiology is is a popular but demanding option for these students who easily become overwhelmed by the complexities of fitness testing and the design of appropriate exercise programmes for children.

The Project

The project in question aims to bring together the students on the two courses to work together on one problem, with the Mathematics students acting as consultants to the Physical Education students. The project is based on the work of the The Sports Council's Allied Dunbar National Fitness Survey (NFS)(1991) in which the physical activity patterns and fitness levels of the English population were rigorously and uniquely assessed and published in order to establish a data base against which future trends might be measured. It is expected that National Bodies, such as The Sports Council and The Health Education Authority, will use these findings to develop policies and strategies.

The Physical Education students

For the Physical Education students the NFS provides a vehicle for investigation and discussion about the vailidity of the fitness tests which many schools have introduced into the PE curriculum.

The most controversial fitness test is the testing of cardiorespiratory fitness (sometimes referred to as aerobic capacity or Maximum Oxygen Consumption (Max VO_2)). Physical educationalists have received considerable criticism recently for not addressing the issue of inactivity in school children as a result of the move towards a leisure society. It is important then that the PE students understand what has been learned about the capacity for aerobic work and aeobic cardiorespiratory fitness.

The Mathematics students

The Mathematics students are studying Statistical Modelling as the culmination of their statistical studies. Working on the data provided by the Physical education students enables them to develop their skills in a real context and at the same time deal with the problems of communicating their findings to non-statisticians.

The Problem

The NFS data for Max VO_2 was based on various assumptions. Most relevant to this project was the assumption that submaximal exercise would predict what was happening at maximal exercise or exhaustion.

Walking on a treadmill was chosen as the most relevant activity for the survey, with respondents walking at increased speed or elevation. Energy expenditure was measured through the direct measurement of oxygen consumption and cardiovascular responses monitored by changes in heart rate. Thus the increase in heart rate occurring in response to increasing levels of VO_2 could be determined. For safety reasons the test was terminated at a work rate which produced a heart rate of 85% age predicted maximum (which was taken to be 220 minus age in years). Due to the lack of data beyond 85% maximum heart rate and the assumption that the formula *220 minus the age in years* gives a true maximum heart rate, the validity of the NFS protocol warrants investigation (Whaley, 1992). Such an investigation allows Physical Education students to question the validlity of fitness tests and hence their desirability - especially in schools where equipment and counselling are unavailable.

The Physical Education students are expected to compare their data from the NFS protocols with the maximal data which they have collected themselves as a part of their course. They do not possess the relevant skills, however, to perform regression analysis. Graphical methods resulted in such wide disparities that even the basic information became confusing to them. There has been some statistical analysis of the data (Nevill and Holder, 1992) but the report on this was much too technical in nature for these students to assimilate.

The Mathematics students model both the submaximal data and the maximal data in order to try to find a more accurate measure of Maximum VO_2 . They also use some additional data on

anthropometric measurements in order to try to refine these predictions.

The Rationale

For the Mathematics students this is a very valuable exercise because they have to work as 'real' statisticians tackling a very real and rather messy problem. They have to work with a very small data set which has been collected before they have any input. (Timetabling constraints mean that they cannot be involved in the data collection). The model itself is not obvious and so there is no clear 'correct' answer. In addition they have to work with the Physical education students, learning their 'language' and explaining their own work in simple non-technical terms. It is hoped that these students will benefit in a variety of ways and that they will pass on some of these benefits to the children they will go on to teach. They will have experience of what Statistics is really like and of its value in tackling a difficult problem.

There has been a great deal written about the value of using real data in the classroom so it seems logical to give prospective teachers experience of working with genuine real data on a real problem. The value of extending the use of real data to trainee teachers has been recognised (Phillips, 1990) but the idea of solving a genuinely new problem has not received as much attention. Previous attempts at using real data with this particular group have proved less than ideal because inevitably the problems were trivial and contrived.

There has been a very welcome move towards cooperation and collaboration across subject areas within schools (Holmes and Rouncefield 1990, Turner 1981) but there is little evidence that this is being practised within teacher training courses.It is hoped that these students, having had first-hand experience of collaboration with other subject specialisms, will be encouraged to develop such co-operation in the schools in which they will eventually teach.

For the Physical Education students there is the challenge of explaining a complex physiological process in simple language and of demonstrating the manner in which the data has been collected. The question and answer sessions provide an environment in which their preconceptions are challenged by their peers.

More generally this initiative is felt to be valuable fostering co-operation between different disciplines within the University. There is encouragement for collaboration and co-operation in the school sector but very little consideration of its benefits in the University sector. Links with other subject areas can provide very useful sets of real data even if no more tangible work ensues. For the staff involved there are benefits in terms of morale as a result of the cooperation with other staff who are rather isolated, as well as the more obvious academic benefits.

Considerations

It is not a trivial exercise to set up an exercise like this. It involves considerable preparatory discussion about the problem to be covered so as to ensure benefits to all concerned. Both staff need to be present at the sessions involving both groups of students so that the barriers between the disciplines are removed and the project is kept on track. There are also very real practical problems in bringing the two groups of students together, not the least of which is timetabling of students, staff and rooms! Finally there is the problem of time. So far this has been resolved by Physical Education students gathering data whilst the Mathematics students are learning techniques, but finding time to allow the Physical Education students time to assimilate the information provided by the statisticians still causes a problem.

Feedback

The informal feedback from the students is mixed but encouraging. The Mathematics students find the problem challenging and at times are rather discouraged, particularly as, in so much of their other mathematics they are assured of a correct answer. In attempting to solve this problem they quickly learn that nothing is quite as simple and straightforward as it seems and when they do come up with a solution they cannot be sure that they have found the absolute truth. (Practising statisticians will recognise these feelings no doubt !) However they respond to the challenge and soon become deeply involved in solving the problem as best they can. This involvement almost certainly comes from the fact that this is a real problem and other students are relying on them for assistance. It is too early to obtain any formal feedback from students this year but it is good to be told 'I think this is great, why haven't we done this before' and 'I find statistics fascinating'.

One, not insignificant, problem is the amount of time and effort which the Mathematics students put into the work. They take it very seriously and so spend a great deal of time on it. Over the last few years whilst this work has been developing the scope of the study has been repeatedly narrowed but there is still a concern that the effort put into it may have a detrimental effect on their other studies.

The motivation of the Physical Education students is enhanced by the need to collect data quickly and efficiently. They enjoy preparing the seminar for their peers and the demonstrating the protocols they employed, as well as being able to make use of the consultancy process provided by the Statisticians.

Conclusions

This is felt to be valuable development in the teaching of prospective teachers of both Mathematics and Physical

Education. There are drawbacks, particularly the high degree of commitment required of the staff involved, but these are far outweighed by the advantages in terms of curriculum enhancement. It is almost certain that similar co-operation could be of benefit in other subject areas but the major stumbling block is the lack of contact between University disciplines. The breaking down of these barriers is as important in Universities as it is in schools.

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A Step in the Right Direction

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The existing system of statistical education in Pakistan is predominantly textbook-oriented, and there is little room for experimentation, innovation and research. At the FA/FSc and BA/BSc levels, the pattern and style of the examination questions promote rote-learning of textbook-material and, in the presence of such an examination system, college-teachers of Statistics do not experience the *need* for a constant improvement in their understanding of statistical concepts as well as their method of teaching.[1]

In view of the great need for improving the quality of statistical education in Pakistan, a teacher-training programme has recently been launched by the Department of Statistics at Kinnaird College for Women, Lahore. The Statistics Teachers' Educational Program (STEP) consists of day-long meetings of statistics teachers to be held twice a year, and aims at better understanding of statistical concepts, improvement of teaching techniques, and enhancement of professional esteem. Five such meetings have been organised between September 1992 and November 1993, and three of these have focused on the types of practicals that should be carried out in order to fulfil the requirements of the new FA/FSc Statistics syllabus prescribed by the Government of Pakistan.

Whereas STEP 1 was a relatively modest beginning, STEPS 2,3,4 and 5 have attracted teachers not only from various colleges of Lahore but also from other cities! Feedback from participants indicates that they have found discussion and group-work *particularly* useful, and that such programs should be continued in the future.

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Teaching Statistics to Adults: Covering a Range of Needs

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Our recently completed study of a naturally occurring student population (*Adult Learners on Campus,* Falmer Press, 1993) examined similarities and differences among both Young Adult and Adult learners across undergraduate, graduate, and professional (i.e. law and medicine) programs. Results of both a stratified random sampling of students and in-depth interviews using the survey's results as stimuli for discussion produced findings bearing on teaching statistics. First, undergraduates are insecure about their succeeding in their programmes of study, and second, these students look to teachers to model ways members of the teacher's profession approach and solve problems. This implies faculty not responding to students' needs or not showing the role of statistics in solving problems in the students' areas of study keeps students from seeing how statistics contributes to the students' educational goals. Such students will not incorporate statistical logic and methods into their repertoires of skill and knowledge. In contrast, graduate students have lost these insecurities and are committed to learning the teachers' approaches to problem solving. They look to teachers to show them practical application in their areas of specialisation. Faculty failing to cast statistical teaching in practical terms will lose these students; those showing how statistics relates to solving problems of importance to these students will profit the students immensely. Professional students fall between graduates and undergraduates; for example, medical students in the basic sciences look like undergraduates while those in clinical studies behave like graduate students. Young Adult students lack the richness of experiences of Adult learners and so need to be shown how the statistics they're learning applies in the professional areas they're studying. Adult learners, in contrast, will immediately compare what they're learning to their past experiences and evaluate the new learnings accordingly. These students will also value highly information showing the new learnings' range of applicability. Examples of teaching methods appropriate to both age groups and the different programme types will be presented.

PRACTICAL DATA HANDLING

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The importance of statistics in the primary and secondary curriculum was highlighted in 1989 by the publication of the national curriculum for mathematics. This document was the first to be published and initially defined 14 compulsory classifications of mathematics to be studied by all pupils, aged between 5 and 16 years, in state schools throughout England & Wales. Subsequent amendments to this document have resulted in the refinement of the content into 5 programmes of study of which 25% is classified as 'Handling Data'.

This increased emphasis on statistics as a recognised skill to be continuously developed during the full period of pupils' schooling highlighted the need for support for both practicing and student teachers alike.

The Centre for Statistical Education (England) responded to the concerns expressed by teachers with regard to their unfamiliarity with the content of the curriculum and their lack of experience/confidence in teaching this " new subject " by funding the project *Data Handling in the National Curriculum for Mathematics in England & Wales.* As project officer responsible for this initiative I was charged with investigating examples of good practice developed internationally over the past twenty years and providing appropriate support materials.

The results of this research have recently been published as two teachers books which provide ideas for over 300 activities addressing the 'Handling Data' section of the mathematics curriculum. Each activity description includes ideas on how pupils' understanding may be developed, links to other curriculum areas, purpose, alternative ideas and resource requirements. Reference is also made to the inter-relationships between the statistical ideas being developed. The philosophy underpinning both books is to encourage teachers to teach statistics through practical, purposive, realistic, investigative and enjoyable activities.

This paper will draw on examples from both these books and extend these ideas to consider the skills teachers will require if they hope to develop a statistical awareness in pupils. Consideration will be given to interpreting results and attempting to draw conclusions when the purpose of an investigation may be hidden due to the techniques involved and/or the numerical nature of the data.

A NATURAL PROGRESSION OR A QUANTUM LEAP?

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In England and Wales the number of pupils aged 16+ opting for mathematics based subjects at advanced level has declined constantly over the past five years.

The format of assessment at sixteen changed in 1986 to the General Certificate of Secondary Education, the structure of which is significantly different from the previous General Certificate of Education and the Certificate of Secondary Education. The General Certificate of Secondary Education incorporates a differentiated curricula which imposes limitations on the range of grades available. A major implication of this is that pupils may be denied the opportunity to study at the advanced level because of a decision which may have been made by the teacher as early as year 9 (pupils aged 13 to 14 years).

At the same time, the staged introduction of the National Curriculum for Mathematics (England and Wales) has also had a major impact on the content of what is taught in schools. In 1994 the first cohort of pupils aged 16 years will be assessed on the content of this 'new' curriculum by the terminal (end of compulsory schooling) GCSE in mathematics.

Statistics, or Handling Data as it is called, constitutes approximately 25% of this curriculum and therefore now forms a major part of all GCSE assessments in mathematics.

This paper will consider pupils' pre 16 mathematical experience and discuss why those experiences may not provide individuals with the skills they need to progress to advanced study. Pupil success will be considered with respect to both ability and gender.

If this trend is to be stemmed (or even reversed) teachers must address these issues and attempt, as far as is possible within the constraints imposed upon them by the examination structures and the topic areas, to help pupils make the quantum leap.

Teacher education - developing student activities aimed at stimulating statistical thinking

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Abstract: In Canada, there is a belated move to introduce statistical concepts into the mathematics curriculum of the early grades. Unfortunately teachers at these grade levels rarely have any experience with statistics. This results in boring classes involving repeated manual classification of data and routine computation of indicators.

In this presentation we shall recommend criteria for the selection of introductory statistical activities, we shall provide examples of such activities and we shall discuss teacher training aimed at providing environments which support the development of statistical thinking.

In brief we shall discuss activities that explore the variability of data, and that emphasize exploration. These activities will use manipulatives, such as dice and spinners, will use computers running spreadsheets, and will support both individual and cooperative learning. The author has developed a game [1]) which typifies the kinds of activities which, he believes, should be used to stimulate statistical thinking in the mathematics classroom.

[1]) Muller Eric, "Developing Statistical Thinking: An Activity", Ontario Mathematics Gazette, 26, (1987) 19-22

Teacher Preparation in Statistics at the Secondary School Level: Need, Innovation and Challenges

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Keywords: Teaching, Statistics, Teacher Preparation, Secondary School Education.

This paper presents the details of a United States National Science Foundation (NSF) sponsored Teacher Enhancement Program (TEP) in Statistics as implemented in the western region of Puerto Rico, a U.S. territory in the Caribbean. The project is important for three reasons. First, it provides pedagogical methods whose innovation is founded on an alternative vision; that is, that statistics must be taught through real life applications and student projects. Second, it emphasizes the need for mathematics teachers to change their approach to the field such that they treat and teach statistics as an applied science, as opposed to traditional courses in algebra and geometry. One specialty of the TEP is its comprehensiveness: its focus on classical statistics, modern teaching methods, the role of statistics in research, critical thinking, as well as the use of computer packages, lectures by practitioners and hands-on data analysis. The paper discusses the evaluation of the project, which took place over an extensive period of three years, based on questionnaires distributed to teachers and system administrators, teacher visits and workshops. It closes with suggestions to those who wish to emulate or help administer this project, particularly in a highly centralized, hierarchical educational system similar to Puerto Rico's.

Teaching Strategies in Probability and Statistics for Middle and Secondary School Teachers with Inadequate Background

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In the United States, it is not uncommon for teachers in their mid-thirties or older never to have taken a course in probability or statistics. Recent recommendations of the National Council of Teachers of Mathematics to incorporate topics from probability and statistics into the curriculum at every grade level K-12 have caused anxiety and concern among many teachers. Pressure has been brought to bear on some teachers to introduce topics from probability and statistics, and often this pressure has not been accompanied by concomitant opportunities for retraining. Although many workshops of short duration have been offered in various parts of the country in recent years, most teachers have not participated due to reasons which include fear and intimidation created by such compact offerings. New math text books for middle and high schools include topics from probability and statistics. Thus, teachers are expected to introduce them to their classes.

As a result, many teachers are looking for convenient sources of basic information which they can learn without pressure at a pace which allows time for absorption of concepts. Evening classes of 12 - 16 weeks' duration designed especially for school teachers with inadequate background, and taught in colleges and universities, may well serve the needs of such teachers.

The teaching of such courses can be very interesting and challenging. Assignment of topics of progressive difficulty for student presentation and the reaction of their classmates can help identify difficulties students have understanding the material. In this presentation, strategies will be discussed which, in a simplified and meaningful way, allow students exposure to a wide variety of topics in probability and statistics.

The Importance of Cultural Orientation in Teacher Training in Statistics

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Teaching Statistics to students from different cultural backgrounds can be very exciting and challenging if examples and problems are drawn from the students' own environments. Although teacher-training programmes do cover areas such as education and society, curriculum studies, teaching methods, etc., and are culturally biased with respect to the countries in which the programmes are offered, not enough stress is laid on how different things are in other societies/cultures. This paper will stress the need and importance of cultural orientation in Teacher Training in Statistics, high-lighting the need to be trained to be adaptable/responsive to the educational needs of a society that is different.

CONVINCING VERSUS PROVING: THE CENTRAL LIMIT THEOREM

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The pre-university training programme of future teachers includes only a short introductory course on probability and/or statistics at most. This usually does not cover a well-demonstrated treatment of the central limit theorem. Shortage of time is only one reason for this. As a rule, instructors leave out the mathematical proof and, as a consequence, the precise formulation of the theorem because of its complexity. We suggest a statistical method which helps students to convince themselves that the central limit theorem really works.

We start with reasoning that we need a kind of standardisation in order to be able to compare different random variables. This theoretical argument leads to considering the standardised version of variables. Now we need a variety of random variables, which can be easily sampled, inspected, and processed by the students both during the instruction period and during their future classroom work. Such a variety can be obtained from written texts by different mappings of the alphabet to the reals. Instead of written texts, any long enough computer file could be used.

The process of convincing utilises personal computers, but, at some extra work, one can follow it manually. The essence of the process is as follows. Students are asked to invent their own mappings in a dialogue with a PC, where there is a mild constraint on the mappings. Then a program forms blocks of the given text, assigns values according to the mapping chosen, computes the standardised sums, while everything is shown on the screen at a speed which is adjusted to the viewer's wish. Histograms for grouped data are evolving in front of the students. The procedure is repeated for increased block-length, allowing the students to form opinion on the speed of convergence, too.

Details, like comments on the variation used for standardisation, or on the constraint applied to the mappings, will be given. We will also comment on our experience with students on a project-type working up the program. Generalisations to other usage are straightforward. With a minimum of change, the law of large numbers, convergence to the (discrete) uniform distribution can be demonstrated.

Introducing the logic of statistical inference through computer intensive methods

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Introduction

Many of us are faced with the problem of teaching introductory inferential statistics to students who lack the necessary mathematical background to understand the distribution theory that underlies the statistical techniques they have to learn. Because of this, introductory statistics courses designed for such students tend to take a 'recipe book' approach in which learning to perform statistical tests such as the *t*-test become the prime focus of the course. The introduction of relatively easy to use statistical software has been seen by many as a way of making these courses less recipe like. Certainly, the introduction of statistical packages into these courses has led to a welcome reduction in the amount of time that students have to spend on computational activities. It has also enabled teachers to use simulation activities as a means of helping students understand theoretical concepts such as the central limit theorem. However, there is little evidence (Rubin et al 1988, Hawkins 1990 for example) to suggest that the introduction of these computer based simulation activities has done much to help such students improve their understanding of the distribution theory that underlies the classical approach to statistical inference. If this is the case, then it may be that we should be putting the computer to better use.

Computer intensive methods

An alternative path to inference, which does not rely on the properties of theoretically derived probability distributions, is provided by the developing area of computer intensive methods. These methods are called computer intensive because they involve the computation of the statistic of interest for many data sets. According to Diaconis and Efron

> The payoff for such intensive computation is freedom from two limiting statistical factors that have dominated statistical theory since its beginnings: the assumption that the data conform to a bell-shaped curve and the need to focus on statistical measures whose theoretical properties can be analysed mathematically. (Diaconis & Efron, 1983, p96)

For the practising statistician there are often definite advantages of using a computer intensive method rather than a classical method when restrictive assumptions about the nature of the data do not hold or traditionally used test statistics are not appropriate.

From the curriculum point of view, Speed (1984, p192) has suggested that computer-intensive methods should have a place in the university statistics curriculum because 'they can exemplify good statistical thinking in a far better way than many of the more elaborate procedures we currently teach, and I believe they can provide a better basis for good statistical practice after a student graduates'. However, from the purely pedagogic point of view there may also be great advantage in introducing inferential statistics from a computer intensive perspective.

Why might this be so? Firstly, using a computer intensive method means that the entire inference problem is dealt with from an empirical and concrete perspective. No understanding of abstract theoretical distribution theory is required. Secondly, unlike the formal process we use to conduct a distribution based statistical test, the logic that underlies the statistical testing process is always at the forefront when using computer intensive methods. We will illustrate this with two examples of the type commonly met in introductory statistics courses.

Some illustrative examples

Is Australia Post's claim valid?

Australia Post claims that it delivers at least 96% of standard letters on time. A local newspaper challenged the claim because they found that only 52 or 88% of 59 standard letters they posted arrived at their destination on time. Does the newspaper's finding of only 88% of standard letters arriving on time invalidate Australia Post's claim? We will assume here that valid sampling procedures have been followed in gathering the data.

Classical method of solution

From the question the students must recognise that they are required to perform a hypothesis test for a population proportion p with a one-sided alternative thus:

H_0: $p = 0.96$
H_1: $p < 0.96$

For large n (sample size), a sample proportion $\hat{p}$ can be considered to be approximately normally distributed. The test statistic is

$$z = \frac{\hat{p} - p}{\sqrt{\frac{p(1-p)}{n}}} = \frac{.88-.96}{\sqrt{\frac{.96(1-.96)}{59}}} = -3.14$$

From normal tables it can then be shown that P(Z<–3.14) = 0.0008; that is, there is only .08% chance of getting a Z value less than –3.14 if the null hypothesis is true.

Thus we conclude that the 88% delivery rate constitutes evidence against Australia Post's claim that 96% of standard letters arrive on time.

Computer intensive method

In the computer intensive solution, we simulate the situation by setting up a population in which there are two outcomes, 'success' (letter delivered) and 'failure' (letter not delivered) and which the proportion of successes is 0.96. We then take a random sample of 59 elements from the population and record the proportion of successes (letters delivered on time) in the sample. This process is repeated a large number of times to give an empirical distribution of the proportion of letters delivered. From this distribution an estimate is then obtained of the likelihood of obtaining a sample of 59 letters with an 88% delivery rate when the population delivery rate is 96%. If this probability is low we would count this as evidence against Australia Post's claim.

A special purpose sampling package Sampling Laboratory (SLAB) for the Macintosh (Rubin, 1990, unpublished), was use to perform the simulation. Two hundred samples were drawn and the results are displayed in figure 1. From the sampling distribution we can see that samples with delivery rates of 88% or less are extremely rare when the population delivery rate is 96%, and this is confirmed by a box plot analysis produced by SLAB (not shown) which tells us that they make up less than 0.5% of the distribution. We would thus conclude that a delivery rate of 88% in a sample of 59 letters would count as evidence against Australia Post's claim.

Both the classical method and the computer intensive method lead us to identical decisions. However, the classical method relies on the user being able to approximate the underlying binomial distribution with a normal distribution. According to Ott & Mendenhall (1990, p 348), the normal approximation to the binomial should be viewed with scepticism if np or $n(1-p)$ is 2 or less. For the population parameters involved, n =59 and p = .96, the approximation would appear to be reasonable but on the borderline as $n(1-p) = 2.4$. If Australia Post had claimed a 97% delivery rate, then p would be .97, and $n(1-p) = 1.8 < 2$. In this situation, we would have to have severe reservations about the use of the normal approximation to help us solve the problem. We could, of course, revert back to the binomial distribution and work out the probabilities from there, but this is an immense computational task. Thus while the classical method is relatively straight forward, it rests on a number of assumptions that in practice will be violated. The user must first be aware of this and secondly know how to get around the problem. The user of the computer intensive method is not faced with such problems and has only the statistics of the problem to consider, not the mathematics.

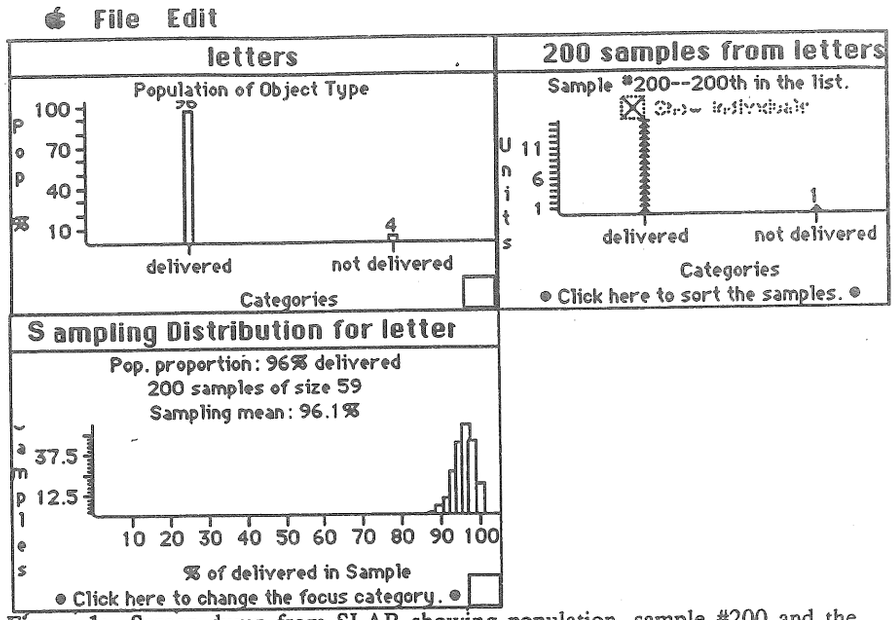


Figure 1: Screen dump from SLAB showing population, sample #200 and the sampling distribution.

Does the new drug work?

Consider the following example which is used to illustrate the independent samples t-test for the difference of two population means when the assumption of equal population variances is not appropriate.

> An experiment was conducted to compare the mean number of tape worms in the stomach of sheep that had been treated for worms against the mean number of those that were untreated. Thirteen worm infected sheep were randomly divided into two groups; seven were injected with the drug and the remaining six left untreated. After a 6 month period, worm counts were recorded for all thirteen sheep. These data are shown here.
>
> | | | | | | | | |
> |---|---|---|---|---|---|---|---|
> | Treated with drug | 5 | 13 | 18 | 6 | 4 | 2 | 15 |
> | Untreated | 40 | 54 | 26 | 63 | 21 | 37 | |
>
> Test the research hypothesis H_1: $\mu_1 - \mu_2 < 0$ under the assumption that the two population variances are different. Use $\alpha = 0.05$.
> (Ott & Mendenhall, 1990, p316)

Classical method of solution

From the question the students must recognise that they are required to perform a hypothesis test for the equality of means with a one sided alternative thus:

$$H_0: \quad \mu_1 - \mu_2 = 0$$
$$H_1: \quad \mu_1 - \mu_2 < 0$$

If we assume that the two samples are taken independently from two normally distributed populations with means μ_1 and μ_2 respectively, and the respective standard deviations are unknown, then a hypothesis test for comparing the means can be carried out by consideration of the test statistic

$$t = \frac{\overline{x_1} - \overline{x_2}}{\sqrt{s_1^2 / n_1 + s_2^2 / n_2}}$$

which has a distribution which can be approximated by a t–distribution with degrees of freedom given by

$$df = \frac{\left(s_1^2 / n_1 + s_2^2 / n_2\right)^2}{\frac{\left(s_1^2 / n_1\right)^2}{n_1 - 1} + \frac{\left(s_2^2 / n_2\right)^2}{n_2 - 1}}$$

where n_1 and n_2 are the sizes of the samples, $\overline{x_1}$ and $\overline{x_2}$ the means of the samples, and s_1^2 and s_2^2 the sample variances. Substituting in these formulae gives value of the test statistic which is then compared with a value from the tables.

While the text book goes on to calculate the value of the test statistic and degrees of freedom by hand, we will assume that the student has access to a package such as Minitab and proceeds as follows:

```
MTB > twosample t 'drug' 'no-drug';
SUBC> alternative -1.

TWOSAMPLE T FOR drug VS no-drug
           N      MEAN      STDEV   SE MEAN
drug       7      9.00       6.22       2.4
no-drug    6      40.2       16.1       6.6

TTEST MU drug = MU no-drug (VS LT): T= -4.47  P=0.0021  DF=  6
```

Of course the student must now relate the computer output to the original question, which would be on the basis of the P–value to reject the null hypothesis and conclude that the mean number of tape worms in the treated sheep was less than the mean number of tape worms in the untreated sheep and hence presumably conclude that the drug was effective in reducing worm numbers.

Computer intensive method

The mean number of worms in the 7 treated sheep is 9.0 while the mean number of worms in the 6 untreated sheep is 40.2. The difference in means is thus –31.2. This difference may be due to the fact that the drug does indeed reduce worm numbers, or it might simply be a product of the chance allocation of the 13 sheep to the two treatment groups. We can test this 'null' hypothesis by assuming that the drug had no effect on

worm numbers. If this is true then, the observed difference in the means would not be particularly unusual when compared to the many differences in means that could arise when the sheep are randomly allocated into one of two groups, one of size 7, nominally termed the 'drug group' and the other of size 6 termed the 'no-drug group'. Using a computer, this random allocation can performed many times with the difference in the means being computed and recorded each time. As a result an empirical distribution for the difference in means is generated. The probability that there is a real difference in the mean may then be estimated by determining the proportion of the randomisation samples that give a difference as far below zero as the actual difference observed. Further details regarding this procedure can be found in Noreen (1989).

There are many computer packages readily available which will enable the problem to be solved in the manner described. The empirical distribution of the difference in group means for the example under consideration shown below was generated by Models 'n' Data (Stirling, 1991), a Macintosh based computer package designed for teaching and learning statistics which offers the facility of using various computer intensive methods.

```
Stems:10's    Leaves:1's

+
3
2 58
2 01123
1 55666777788899
1 00000000001222223333444
0 55555666677777888999999
0 00000111222222233333444444
-0 44444443333332222222211111100000
-0 99988888877776666666666555555
-1 43222221111111111100
-1 888766666555
-2 443321110
-2 7
-3
-
```

Figure 2: Stem-and-leaf plot of difference in sample means obtained from 200 random allocations of the 13 sheep into two groups of size 7 and 6 respectively.

In this example, an empirical distribution of 200 observations was generated, and displayed as a stem-and-leaf plot, see figure 2. From the plot it may be seen that in 200 random allocations not one led to a difference in means as extreme as that observed, -31.2 making it highly unlikely that the observed difference in mean worm numbers is purely a product of the chance allocation of the 13 sheep into the two groups (our estimated P-value would be less than 1/200) or 0.005). Thus we would conclude that the drug has been effective in reducing worm numbers.

Comparison of Classical and Computer Intensive Methods

The essential components of a hypothesis test have been well described by Noreen:

> Three ingredients are usually required for a hypothesis test: a hypothesis, a test statistic, and some means of generating the probability distribution of the test statistic under the assumption that the hypothesis is true. (Noreen, 1989, p2)

It is in this process of defining a test statistic and determining its distribution where the essential difference between the classical and computer intensive methods lies. The test statistic and its distribution are often complex, and their origins obscure to students of classical statistical methodologies. The essential purpose of the process, to determine the likelihood of such a set of outcomes under certain assumptions becomes easily lost. In classical hypothesis testing the fundamental logic of the hypothesis test becomes entangled with the theory underlying the sampling distribution of the test statistic. Using a computer intensive method an intuitively obvious test statistic is selected for which an empirical distribution is generated. The students remain linked to the overriding purpose of the exercise – the inference. Using the technology in this way amounts to forming a partnership between the student and the computer in which the computer takes on the lower level tasks of performing the numerous calculations whilst the student undertakes the higher order tasks of actually applying the logic of inference to the particular situation. In fact, the student must keep in mind the overall purpose of the exercise in order to carry it out successfully. Whilst the student of classical inference needs to recognise certain situations and make the appropriate assumptions, the students of computer intensive methods has been equipped with valuable problem solving skills which may have application in circumstances far removed from the one at hand.

Conclusion

There is no question that computer intensive methods have become essential elements in the toolbox of the practising statistician. On this basis alone, one could argue that computer intensive methods have an important place in the undergraduate statistics curriculum, and they are now being taught in many courses. Thus computer intensive methods have already achieved a level of acceptance based on their *statistical* value. In this context, computer intensive methods are generally seen as an extension to traditional material taught to students who already have undertaken several courses in statistics.

The contention of this paper is that there is also a significant *pedagogic* value in using computer intensive methods to introduce students to statistical inference. The reasons

are twofold. Firstly, there appear to be clear benefits from a utilitarian point of view: computer intensive methods are a valuable statistical problem solving tool that are easy to use and have wide applicability. The second reason is concerned with the learning task. Teaching introductory inference through computer intensive methods reduces the cognitive load on students as the need to keep in mind and apply the appropriate distribution theory is removed. Because of this, the student has only to concentrate on learning the purpose and logic of the inference, which has the potential to lead to greater understanding. It also possible that this understanding could support the learning of classical hypothesis testing, although one might ask why, in this computer age, this would be necessary.

Thus it seems that there is a logical basis for contending that computer intensive methods will enable beginning students of statistics, especially those without strong mathematical backgrounds, to appreciate the important principles of statistical inference. However, at this stage little research exists to support this contention, although what does exist seems encouraging (Simon, Atkinson & Shevokas, 1976 for example). There is clearly a need for further research as we seek to clarify how new and rapidly advancing technologies can best be used to improve the quality of statistical education in the future.

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The role of computer simulation in teaching of statistics

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Understanding statistical concepts and methods is not always easy. Teachers of statistics are using many tools and approaches to make students understand statistics. Simulations, and among them computer simulations, play very important role in showing probabilistic foundations of statistics.

Statistical methods are sometimes easier to understand if they are illustrated with clear, well defined example. Computer simulations enable us to analyze data with known, predefined statistical properties and distribution. Such illustrations, repeated (without the data collecting effort) as many times we wish, can serve as preparation for students/users to be able to see the structure of analyzed processes in real situations.

It is very important to develop a sort of statistical intuition in students. Computer simulations can help students to gain some experience with data under various assumptions, which is very important for statistical reasoning.

To understand some statistical concepts (such as confidence intervals, standard error, hypothesis testing and some other) graphically supported computer simulations can be utilized. They must show not only the final analytical results but also intermediate, backstage results on which the illustrated concept rely. Carefully prepared simulations can be impresive enough to be remmembered even after the learning phase.

Simulations to illustrate Results in Theoretical Statistics

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Summary

This paper describes a computer based teaching unit intended for complementing the theoretical statistics course for third year students in Economics. One of the roles of the computer in this new unit (developed with students who had already acquired a good skill in programming and handling of graphical displays) has been to provide illustrations of results in probability and statistics. The present paper focuses on simulation examples chosen to illustrate asymptotic behaviour of certain statistics (sample average, order statistics, median...) including cases in which problems arise from failure of the usual convergence assumptions (with the particular example of the generalization of the central limit theorem in the case of a Pareto law when either the expectation or the variance is infinite, as occurs in various applications in Economics and Insurance). Other applications show the usual normal asymptotic behaviour of maximum likelihood estimators with counterexamples where the asymptotic distribution is not Gaussian.

Main References

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The use of Spreadsheets for Teaching Statistics at Degree Level

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Over the past decade, software has found its way into the curriculum for a number of educational purposes. Of all the categories of software applications used in the teaching of statistics, one of the more educationally dynamic is the use of integrated spreadsheet packages. Spreadsheets are not only influencing how the subject is taught but also what material is being used. These spreadsheet packages can be used in many aspects of statistics for example modelling of decision trees, forecasting and goodness-of-fit. Data sets of company and government sponsored data can be downloaded from on line sources and used for statistical analysis, such as tracing cohorts, utilising time series and cross sectional data.

Statistical analysis is only as good as the data on which it is based and therefore the quality of the data is a principle problem. Errors from downloading data must be addressed since this will have significant impact on the calculations obtained. Spreadsheets have the effect of removing the burden of time consuming number crunching but there is a real danger of reducing statistics to a black-box approach. One of the great strengths of statistics teaching is its relevance to the real world of the students and teaching using real examples should be encouraged. The approach using spreadsheets is to be illustrated on data from real cases.

The aim of this paper is threefold namely to identify and describe with various examples how spreadsheets can be used within the statistics curriculum for students of various disciplines; to elucidate some of the problems that could arise and to outline approaches that could be implemented within higher educational establishments.

Breathing life into theoretical statistics using Minitab simulations.

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Introductory statistics courses today often involves teaching *service courses* to a broad range of students from varying backgrounds. The current availability of statistical packages for personal computers and the ever increasing facilities of the humble hand-held calculator, provide an excellent opportunity to introduce simulation activities to students who tend not to have strong mathematical backgrounds.

Computer simulations play an important role in our modern *high-tech* society. Their usefulness is readily seen in such areas as medicine, engineering, architectural design, economics, disaster management, and so the list goes on. Simulations can easily be designed to enhance students' understanding of otherwise abstract concepts, and can have the added advantage of providing students with a more interactive learning environment.

Concepts of *unbiasedness* and *efficiency* of estimators are often omitted from service courses in statistics because they are too theoretical. Even in mathematically based courses students frequently fail to understand them. This paper presents a number of simple practical exercises using Minitab simulations which can greatly enhance the teaching of these theoretical concepts.

The Minitab simulations will show that both the sample mean and the sample median are *unbiased* estimators of the population mean of a normal distribution. This leads directly to the concept of *efficiency*. A quick visual check of the simulation output shows that the sample means tend not to vary as much as the sample medians. Further exploration of these concepts will be shown using sample variances where the use of $n-1$ (rather than n) in the denominator will be treated. This simulation shows that as sample size increases the degree of biasedness in the estimates decreases, and the efficiency increases.

Using DERIVE in a Course on Stochastic Processes

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Many degree programmes in Statistics and Operational Research will feature one or more modules in stochastic processes. Many undergraduates experience difficulty with such courses because of the mathematical and technical skills demanded. However they find the topics very interesting and without doubt the applications of these ideas to develop models for epidemics, queues, population growth and reliability, for example, are very important.
The analysis requires proficiency in the technical skills for manipulating generating functions, matrices, limits and sets of equations. If students can use a computer algebra package such as DERIVE to handle these problems they are able to devote more time to the concepts involved, to the structure and assumptions underlying the modelling process and of course to interpreting the results from the analysis into conclusions concerning the systems being modelled.
Particular areas where a computer algebra package can play a role include the manipulation of generating functions, summation of series, convergence of powers of a stochastic matrix, limits of indeterminate forms, and extinction probabilities for population models. As well as giving students the confidence that algebraic and calculus manipulations are not going to restrict their progress the graphical facilities which go with DERIVE make the results from the models more dynamic and relevant.

Computer Algebra Systems in Statistics*

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Abstract

The development of statistical software packages such as SPSS and BMDP have dramatically altered the practice of statistics during the past two decades. Such systems tend to have powerful numeric and graphic features but they lack symbolic computing capabilities. By contrast, computer algebra systems such as *Maple* and *Mathematica* provide a rich environment for mathematical manipulations but they lack features that are essential for statistical analysis and statistics instruction. This paper describes an effort to supplement *Maple* in order to make it more suitable for statistics instruction—not statistical analysis.

1 Introduction

During the past three years, Professor Elliot Tanis (a speaker in this section) and I have developed 100 or so *Maple* procedures and special "laboratory" exercises in an advanced two-semester probability and statistics sequence taught from [1]. The central objective of the exercises, to be published soon (see [3]), is to improve students' understanding of certain key ideas of the course by looking at empirical evidence for these ideas. Most of the algorithms for the procedures of this supplement can be found in [2] and fall roughly into the following categories.

1. Generators of random samples from commonly used discrete and continuous distributions (e.g, binomial, normal).

2. Generation of observations from sampling distributions (e.g, generation of means of random samples from a uniform distribution).

3. Plotting routines (e.g., histograms, empirical p.d.f. plots, empirical distribution plots, ogives, plots of certain confidence intervals).

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4. Density and distribution functions for a variety of discrete and continuous distributions.

5. Routines for the computation of percentiles for some distributions.

6. A few routines for the study of multivariate distributions (e.g., computation of marginal relative frequencies, linear regressions, scatter plots).

The examples of the following sections will show the use of some, actually relatively few, of the *Maple* procedures in our package.

2 Simple Simulations

With our statistics supplement, flips of coins, rolls of dice, poker hands, etc. can be easily simulated. In the following, `A` is a list consisting of 10 rolls of a six-sided die. `B` represents 500 rolls of a 12-sided die and `F` gives the frequencies of $1, 2, \ldots, 12$ in `B`. The list `PokerHands` has 10 entries each of which is a list of 5 entries representing a poker hand. `Flip1, Flip2, Flip3`, by generating random samples of size 600 from the discrete uniform distribution with values 0 and 1, simulate flips of a coin. `NumberHeads` gives the number of heads in each of the 600 3-coin flips and `FreqHeads` gives the frequencies of 0, 1, 2, and 3 heads in these 3-coin flips.

```
> A:=Die(6,10);
```

$$A := [4,\ 3,\ 4,\ 6,\ 5,\ 3,\ 6,\ 3,\ 2,\ 2]$$

```
> B:=Die(12,500):   F:=Freq(B,1,12);
```

$$F := [36,\ 41,\ 37,\ 51,\ 52,\ 42,\ 38,\ 35,\ 37,\ 49,\ 38,\ 44]$$

```
> with(combinat,randcomb):
> PokerHands:=[seq(randcomb(Cards,5), i=1..10)];
```

$$PokerHands := [\,[D1,\ DQ,\ H3,\ HQ,\ S3],\ [C9,\ D1,\ D2,\ D4,\ S3],$$
$$[D1,\ D2,\ D10,\ H8,\ S8],\ [C8,\ D3,\ H2,\ H10,\ HK],\ [C4,\ C10,\ D7,\ H8,\ HQ],$$
$$[C1,\ C3,\ H8,\ S8,\ S10],\ [H1,\ H2,\ H4,\ H9,\ S5],\ [D8,\ H4,\ S5,\ S6,\ SQ],$$
$$[C8,\ CJ,\ D5,\ D10,\ H3],\ [C4,\ C8,\ D6,\ DK,\ HK]]$$

```
> Flip1:=DiscUniformS(0..1,600);
```

$$Flip1 := [1,\ 0,\ 1,\ 1,\ 0,\ 1,\ 1,\ 1,\ 0,\ 0,\ 1,\ 0,\ 0,\ 1,\ 1,\ \ldots$$

```
> Flip2:=DiscUniformS(0..1,600):   Flip3:=DiscUniformS(0..1,600):
> NumberHeads:=[seq(Flip1[i]+Flip2[i]+Flip3[i], i=1..600)];
```


$$NumberHeads := [3,\ 1,\ 2,\ 2,\ 2,\ 1,\ 2,\ 3,\ 1,\ 1,\ 3,\ 0,\ 1,\ 3,\ 2,\ \ldots$$

```
> FreqHeads:=Freq(NumberHeads, 0, 3);
```

$$FreqHeads := [73,\ 211,\ 233,\ 83]$$

3 Theoretical Versus Empirical Distributions

One of the simplest ways that students can develop their intuition is to compare empirically produced results, such as from the roll of a die, with theoretically prescribed patterns. This is illustrated below for the Binomial distribution, $B(n,p)$, with $n = 7$, and $p = 0.6$. `A:=BinomialS(7, 0.6, 200);` generates a sample of size 200 from $B(7,0.6)$, `H:=HIST(A,0,7,8):` produces the data structure for a histogram (for values from 0 to 7 on 8 intervals) of this sample and `pdf:=BinomialPDF(7,0.6,x)` makes the p.d.f. of $B(7,0.6)$ available for subsequent computations. The probability histogram for $B(7,0.6)$ is obtained through `ProbHist(pdf, 0, 7)` and then plotted together with the histogram of the sample. The empirical distribution of `A`, designated by `ED`, and the distribution of $B(7,0.6)$, designated by `DD` are also compared. The two graphs are shown following the *Maple* interaction.

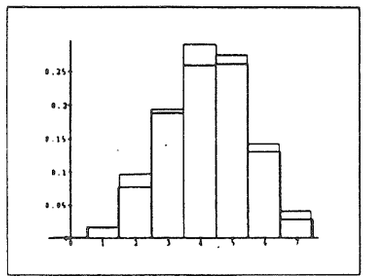
```
> A:=BinomialS(7, 0.6, 200);
```

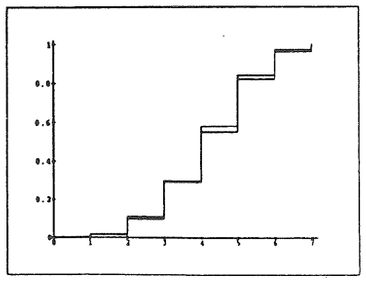
$$A := [5,\ 3,\ 5,\ 5,\ 5,\ 4,\ 1,\ 2,\ 5,\ 3,\ 5,\ 3,\ 7,\ 4,\ 5,\ 4,\ 3,\ 5,\ \ldots$$

```
> H:=HIST(A,0,7,8):   pdf:=BinomialPDF(7, 0.6, x);
```

$$pdf := \binom{7}{x} 0.6^x 0.4^{7-x}$$

```
> P:=ProbHist(pdf, 0,7):   plot({H,P});
> ED:=EmpDist(A):   DD:=DiscDist(pdf,0,7):   plot({ED,DD});
```





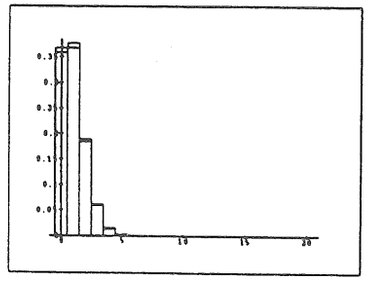
4 Approximation of One Distribution by Another

With the supplement that we have, students can investigate the manner in which one distribution can be used as an approximation of another and make judgements on the quality of such approximations. The binomial distribution, $B(n,p)$, for example, can be approximated by the Poisson distribution, $P(\lambda)$, with $\lambda = np$. But, how good is the approximation? How does the quality of the approximation vary with the parameters, n and p? In a typical interaction (shown below) a student can set $n = 20$ and $p = 0.05$ and compare the probability histograms of $B(20, 0.05)$ and $P(20 \times 0.05)$.

```
> n:=20:   p:=0.05:   Bp:=BinomialPDF(n,p,x);   Pp:=PoissonPDF(n*p,x);
```

$$Bp := \binom{20}{x} 0.05^x 0.95^{20-x} \qquad Pp := \frac{1.0^x e^{-1.0}}{x!}$$

```
> Bh:=ProbHist(Bp,0,n):   Ph:=ProbHist(Pp,0,n):   plot({Bh,Ph});
```

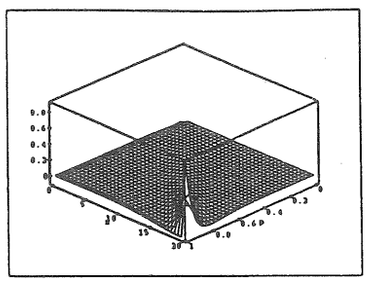


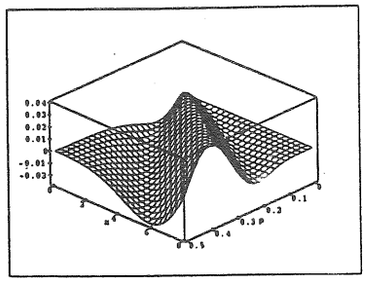
Symbolic and graphic approaches are more likely to be productive. A student, perhaps with some encouragement and a reminder that $n!$ is defined for non-integral n through the continuous gamma function, can now engage in the following type of exploration. The difference of the $B(20,p)$ and $P(20p)$ density functions (defined by `D` below), can be obtained through the `BinomialPDF` and `PoissonPDF` procedures. It should be clear from the graph of `D` that the approximation is poor for p near 1 and x near 20. However, when p is restricted to $0 \le p \le 0.5$, as in the second graph, the approximation error seems to be bounded by 0.04.

```
> D:=BinomialPDF(20,p,x)-PoissonPDF(20*p,x);
```

$$D := \binom{20}{x} p^x (1-p)^{20-x} - \frac{(20p)^x e^{-20p}}{x!}$$

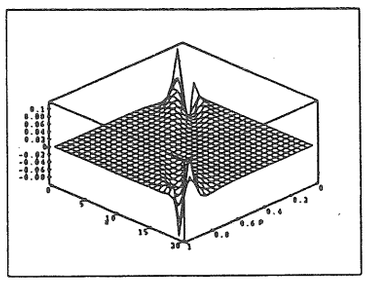
```
> plot3d(D, p=0..1, x=0..20, grid=[35,35], axes=BOXED);
> plot3d(D, p=0..0.5, x=0..8, axes=BOXED);
```

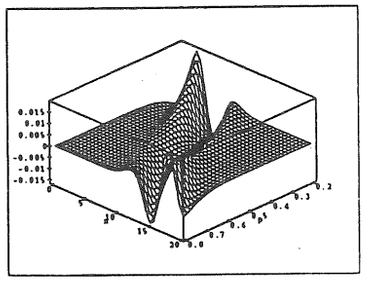





To study the normal approximation to the binomial, the normal p.d.f. with mean $\mu = 20p$ and variance $\sigma^2 = 20p(1-p)$ is used. The first graph shows that this approximation not good if p is near 0 or near 1. If values of p close to 0 and 1 are excluded, as in the second graph, the upper bound of $|D|$ seems to be about 0.015.

```
> D:=BinomialPDF(20,p,x)-NormalPDF(20*p,20*p*(1-p),x):
> plot3d(D, p=0.01..0.99, x=0..20, axes=BOXED);
> plot3d(D, p=0.2..0.8, x=0..20, grid=[35,35], axes=BOXED);
```





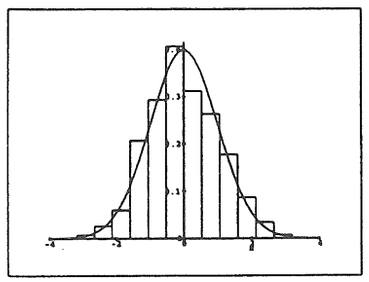
5 Relationships Between Random Variables

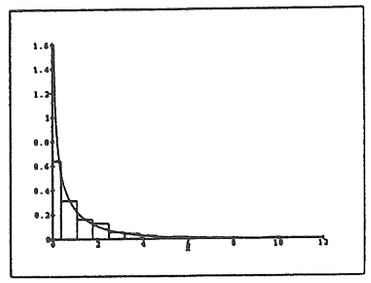
With some encouragement, students can discover a variety of relationships between specified random variables. For example, the distribution of $Y = Z^2$, where Z is the standard normal random variable can be considered empirically before it is proved that Y has a chi squared distribution with one degree of freedom, $\chi^2(1)$. In the following, `Z1` represents a random sample of size 500 from $N(0,1)$ and `Z1h` represents

a histogram of Z1 with 16 intervals. Plotting this histogram with the $N(0,1)$ density function verifies the student's expectation of close agreement between the two. Next, Y, a list of 500 squared values of Z1 is generated. A histogram of Y with the $\chi^2(1)$ density function provides evidence that Y may have $\chi^2(1)$ distribution.

```
> Z1:=NormalS(0,1,500):   Z1h:=HIST(Z1, -4, 4, 16):
> N01:=NormalPDF(0,1,x):   plot({N01, Z1h}, x=-4..4);
> Y:=[seq(Z1[i]*Z1[i], i=1..500)]:   Yh:=HIST(Y, 0, 12, 18):
> CH1:=ChisqPDF(1,x);   plot({CH1, Yh}, x=0..12);
```

$$\frac{\sqrt{2}e^{-\frac{x}{2}}}{2\sqrt{\pi}\sqrt{x}}$$



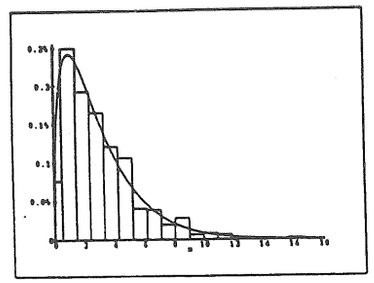


To investigate the behavior of the sum of squares of standard normal random variables, Z2 and Z3, two additional random samples from $N(0,1)$, each of size 500, are generated. Next, Y is reset to the sum of squares of the respective observations from Z1, Z2 and Z3. Plotting the histogram of Y with the density of $\chi^2(3)$ indicates that Y may have $\chi^2(3)$ distribution.

```
> Z2:=NormalS(0,1,500):
> Z3:=NormalS(0,1,500):
> Y:=[seq(Z1[i]^2+Z2[i]^2+Z3[i]^2, i=1..500)]:
> Yh:=HIST(Y,0,18, 20):
> CH3:=ChisqPDF(3,x);
```

$$\frac{\sqrt{2}\sqrt{x}e^{-\frac{x}{2}}}{2\sqrt{\pi}}$$

```
> plot({CH3,Yh}, x=0..18);
```

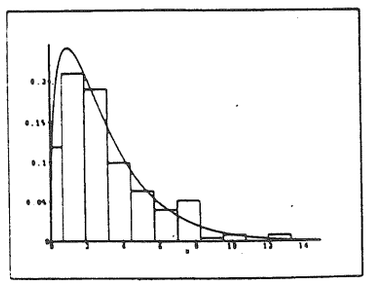



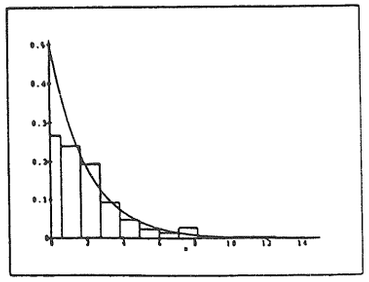
For a random sample, $X_1, X_2, \ldots, X_n$, from an arbitrary normal distribution, $N(\mu, \sigma^2)$, it is important to know the distributions of

$$S = \sum_{i=1}^{n}(X_i - \mu)^2/\sigma^2 \quad \text{and} \quad T = \sum_{i=1}^{n}(X_i - \bar{X})^2/\sigma^2$$

Again, empirical evidence for the relevant results can obtained through the use of random samples from $N(\mu, \sigma^2)$—$N(37, 16)$ in the illustration below—leading to random samples of S and T and evidence for $\chi^2(3)$ and $\chi^2(2)$ distributions for S and T, respectively.

```
> Z:=[seq(NormalS(37,16,3), i=1..200)]:
> S:=[seq(sum( (Z[i][j]-37)^2/16, j=1..3), i=1..200)]:
> T:=[seq(sum( (Z[i][j]-average(A[i]))^2/16, j=1..3), i=1..200)]:
> Sh:=HIST(S,0,14,12):   Th:=HIST(T,0,12,12):
> CH2:=ChisqPDF(2,x):   CH3:=ChisqPDF(3,x):
> plot({Sh,CH3}, x=0..15);   plot({Th,CH2}, x=0..15);
```

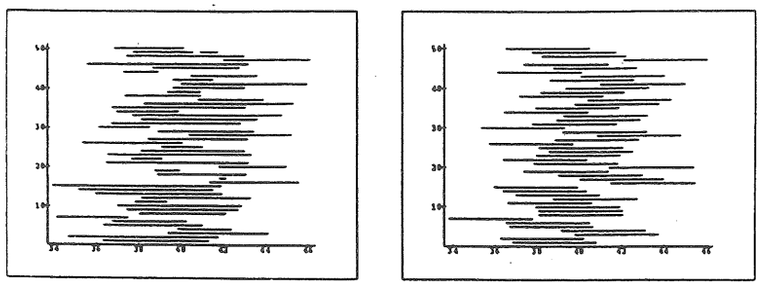




6 Confidence Intervals

Students' understanding of confidence intervals will improve if they can look at many confidence intervals in a fixed situation. For example, for a given α, students can consider confidence intervals of the mean μ, based on random samples of size n from $N(\mu, \sigma^2)$. Different random samples will lead to different $(1-\alpha)\%$ confidence intervals, some of which may not contain μ. What proportion of the intervals will contain μ? How will knowledge of σ^2 affect the confidence intervals? In the following `SetOfSamples` is a list of 50 samples, each of size 5, from $N(40, 12)$. The procedure `ConfIntMean(LL,CL)`, when invoked with two arguments, produces a graph of confidence intervals with confidence level `CL` for each of the samples in the list of lists, `LL`, assuming no knowledge of σ^2. When invoked with three arguments, it produces a similar graph, this time assuming that the third argument is σ^2.

```
> SetOfSamples:=[seq(NormalS(40,12,5), i=1..50)]:
> ConfIntMean(SetOfSamples, 80);   ConfIntMean(SetOfSamples, 80, 12);
```



References

1. Hogg R.V. and Tanis E.A. (1993). *Probability and Statistical Inference*, Fourth Edition, Macmillen Publishing Company, New York.

2. Karian, Z. A. and Dudewicz, E. J. (1991). *Modern Statistical, Systems, and GPSS Simulation*, Computer Science Press, New York.

3. Karian, Z. A. and Tanis, E. A. (to appear). *Probability and Statistics Explorations with Maple*, Macmillan Publishing Company, New York.

Maple and the Computer Provide Synergism for Learning Probability and Statistics

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There are many statistical packages that provide powerful methods for analyzing data both numerically and graphically. *Maple V* provides additional opportunities for using the computer. *Maple V* is a computer algebra system that has symbolic computing capabilities. Thus, it provides the basic tools for enhancing student learning in a probability and statistics course. In biology, synergism occurs when two (or more) substances or organisms achieve an effect of which each is individually incapable. We believe that *Maple V* has similar potential for student understanding and learning.

A laboratory for a mathematical statistics and probability course has been developed that uses *Maple V* as a basic ingredient. The central objectives of the laboratory exercises are to improve students' understanding of basic concepts and to encourage students to experiment. They do this in part by comparing empirical evidence with theoretical concepts. They also capitalize on the symbolic computing and graphing capabilities of *Maple V*.

The role of *Maple V* (and computer algebra systems, in general) will be discussed using several examples. The presentation will point out both positive enhancements of a probability and statistics course as well as potential pitfalls and challenges.

Teaching multivariate data analysis using SYNTAX software

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The SYN-TAX 5.0 package is designed to perform various procedures of multivariate analysis, and is equally useful for education and research. A unique user-friendly interactive environment with graphic and text menus, parameter windows and on-line help are provided to facilitate communication between the user and the computer. The pictorial menus are arranged in a hierarchical manner, to help the the instructor in explaining main possibilities of data analysis. Access to DOS and Utilities during paramcter input allows creation and modification of files at practically any point during parameter input. Sample data files are used to illustrate the multitude of pathways one can select when faced with a multivariate problem in various fields of science.

The procedures that can be demonstrated include:

Classification: hierarchical clustering (22 different divisive and agglomerative strategies, 40 distance and dissimilarity functions, coefficients for mixed data, generalized distances); non-hierarchical classification (k-means clustering, quick clustering of very large data sets, global optimization, multiple partitioning); minimum spanning trees; rearrangement of data matrices via block clustering; fuzzy clustering.

Ordination and related methods: principal components analysis, correspondence analysis; metric and nonmetric multidimensional scaling; seriation (optimization of diagonal structure in data and distance matrices); canonical correlation analysis; canonical variates (discriminant) analysis; eigenanalysis.

Evaluation of classifications and ordinations: comparison of dendrograms, partitons, fuzzy partitions or ordinations; hierarchical consensus of partitions; fuzzy consensus methods, Procrustes analysis for consensus ordinations; Monte Carlo simulation of distributions for dendrogram, partition and ordination dissimilarities to allow significance testing; multiple comparisons; importance of variables in clustering; probability ellipses to enhance ordination interpretability.

Character ranking: ordering of variables according to their contribution do data structures in terms of correlation, covariance and information theory measures.

Analysis of multispecies point patterns: computer simulated sampling from digitized patterns; pattern detection in species assemblages.

Graphics: dendrograms, ordination scattergrams (simple scattergrams, biplots, canonical variates analysis plots indicating group memberships, superimposed minimum spanning trees, probability ellipses and partitions, etc.), rotating plots (a great method to create the illusion of three dimensions); minimum spanning tree topologies, point patterns, histograms and graphs.

Utilities: data standardization and transformation; data entry and editing; conversion of data formats; flexible shortest path adjustment of ecological distance matrices, file viewing and browser routines.

System requirements: IBM-pc or compatibles with DOS 3.0 and higher (icons provided for WINDOWS support); CGA, Hercules, EGA or VGA monitor for graphics; hard disk; mathematical co-processor not required but used if present; min 520 K free RAM; EMS is recommended for accelerating the user interface. Mouse for editor, list viewer and file browser.

Experience with Authoring Problem-based Teaching and Learning Materials for Computer Based Learning.

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on behalf of the STEPS Consortium*

ABSTRACT

The U.K. STEPS (STatistical Education through Problem Solving) Consortium comprises seven universities who, in 1992, gained 3 years of funding from the Teaching and Learning Technology Programme to research, design, implement, validate and disseminate foundation level computer based learning materials for statistics authored in IBM PC, Macintosh and X-windows environments.

When statistics is taught as a support subject within another discipline, it is common to find that students lack motivation and that considerable effort is required to integrate course material with the rest of the curriculum. Also, there is usually a wide spread in the level of numerical skill within classes. One effective strategy to improve motivation is to introduce real problems within the students' own discipline. Attention is being devoted to four important application areas, namely Biology, Business, Geography and Psychology. Standard, commercially available authoring packages (ToolBook, Hypercard, Metacard) are being used in IBM PC, Macintosh and X-windows environments. Authoring tools enable teaching materials to be produced that allow students to take an investigative approach to learning. When statistical issues arise, graphical and other illustative material are used to explain ideas in a non-mathematical way.

Using this kind of approach to teaching and learning raises a wide variety of issues, some of which may be controversial. The intended use of the material is not to replace lectures but to provide a supportive environment within which students can explore practical issues and begin to appreciate the role of statistical tools within their own discipline. The material may best be used within a laboratory, tutorial and seminar setting.

We report the first two years' progress of the consortium and the EDA module will be used to show our approach to developing computer based learning material.

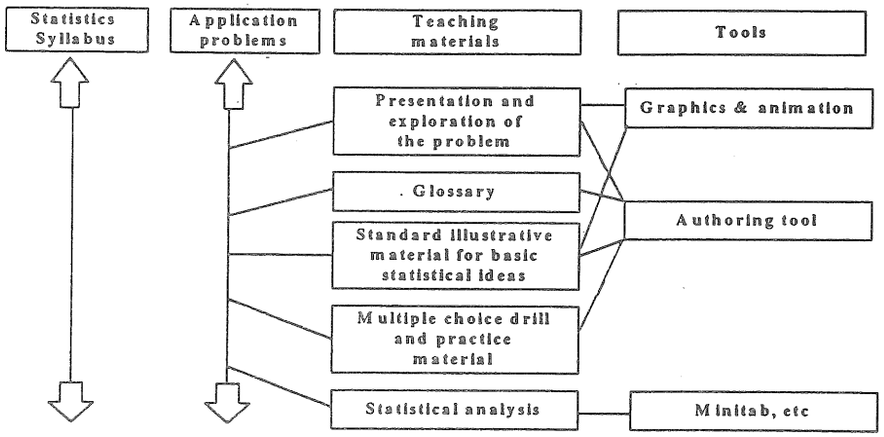
*We are representing members of the consortium from the following universities:
Glasgow, Lancaster, Leeds, Manchester, Reading, Sheffield, & Nottingham Trent

1. Introduction

The discipline of Statistics connects with a very large number of subjects throughout the higher education curriculum. There is, therefore, tremendous scope for good teaching and

learning materials which will affect large numbers of students and teachers. However, if the subject is taught purely as a set of techniques, even with illustrative examples, there is a danger that students will not perceive its relevance and importance to their own disciplines. On the other hand, laboratory based teaching can be both labour and time intensive. With these problems in mind, a consortium of statisticians from seven UK university departments has been formed to create problem-based statistical learning materials in the form of computer software. The aims of the consortium are expressed through its title as STatistical Education through Problem Solving (STEPS). Initially, key application areas of Biology, Business, Geography and Psychology will be addressed. The consortium won funding from the UK university funding councils (UFC) through the Teaching and Learning Technology Programme. The materials produced by the consortium will be widely distributed.

Computer assisted learning began some decades ago and flourished for a while, largely in the form of question and answer tutorial sessions. Since then, computing equipment and standard statistical packages have become routinely available items of considerably greater power. In addition, a completely new generation of authoring tools has appeared in the form of Hypercard, Toolbook, and many other products. Some interesting pieces of statistical teaching software have already been produced in this medium. The new tools offer tremendous flexibility in the creation of attractive text, graphics and images. However, clear educational aims and structures are required to produce effective materials. The aims of the STEPS consortium is to base the material around real problems in students' own areas of interest. Statistical issues arise as these problems are explored and statistical methods play an integral and important part in reaching conclusions. The role of the computer is to provide a supportive, easily-used and flexible environment within which: (i) problems can be explored in a flexible manner; (ii) standard statistical ideas can be introduced and appreciated; (iii) standard statistical methods can be employed.

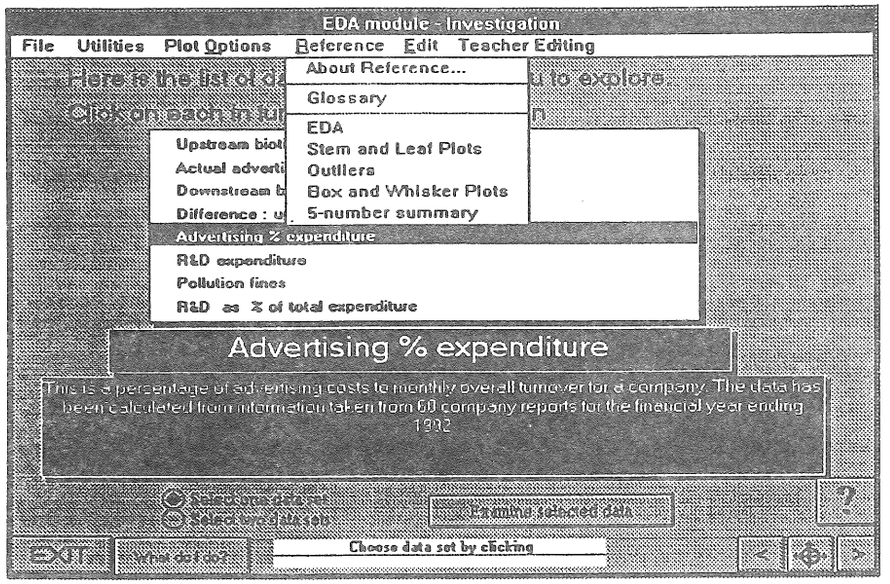


The third role can be fulfilled by a standard statistical computing package. The first two are being created by purpose built software. A major advantage of the computer based

approach is the flexibility it provides in allowing students to learn at their own pace. The diagram above illustrates the overall structure of the material.

Using problem-based material has the advantage of building on the interests of students in their main subject of study, and of allowing integration with laboratory and practical programmes. The problems will introduce a spectrum of statistical issues including most of the elements of the syllabus of a first course. There is also a wide range in the complexity of the problems. The role of interactive graphics is used mostly to explore and illustrate statistical ideas. Figure 1 is one of the early screens in the EDA module from which there is access to several routes for learning by 'doing'.

Figure 1. Screen for selection of data sets for problem solving using EDA.



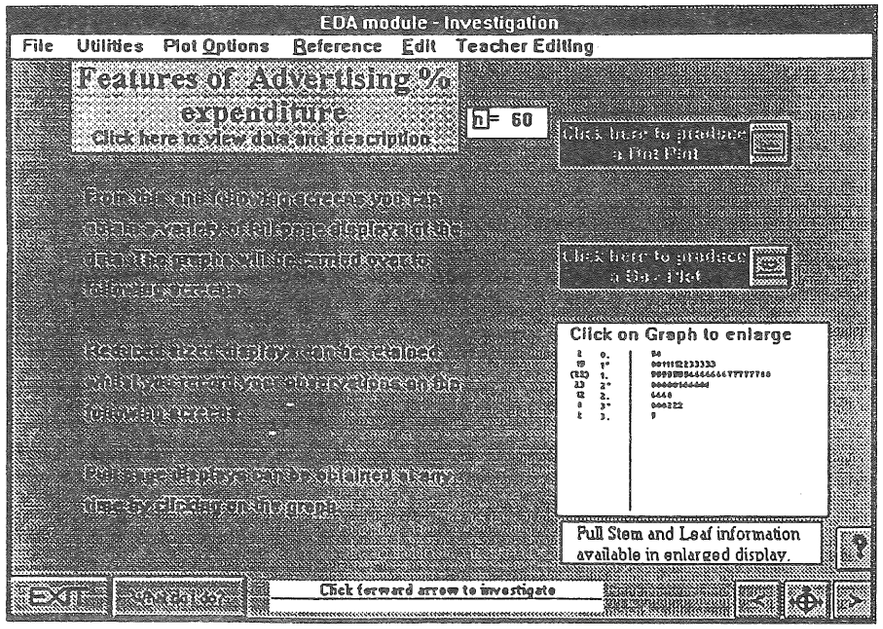
The menu bar at the top of Figure 1 may vary between modules, depending upon level and content. The pop-down window becomes available after clicking on **Reference**, a facility common to all modules. Branching into one of the topics itemised enables a student to refresh his/her memory about how, for example, Stem and Leaf plots are constructed. This facility is useful, especially for self paced learning. Clicking on **Glossary** provides an easily accessible reminder on the meaning of standard statistical terms and concepts, with some graphical illustrations. There are facilities that the teacher of the subject can use to customise the module with different data sets, and provide different descriptions for these data sets using the **Teacher Editing** option. Students will not, of course, be able to access this facility. The finished module will be accompanied by student notes, teacher notes and implementation notes. The authoring tool is capable of accessing standard statistical packages, such as Minitab, so that they can be linked into the teaching and learning environment. Also, the shareware Windows software XLISPSTAT is being linked to provide dynamic graphing and statistical capabilities from within some modules.

2 The Module in Exploratory Data Analysis (EDA)

The EDA module is one of several that have been designed to find solutions to problems being experienced by a fictional, large pharmaceutical company located next to a key river in the UK. Several data sets have been collected and after appropriate introductory screens, the student has to make a choice of one of those data sets in order to solve the problem of his choice. In Figure 1 the student has selected a data set that corresponds to advertising as expressed as a percentage of sales for a large sample of similar companies. The pharmaceutical company wishes to introduce a new product, and assessment of the patterns of advertising expenditure by other companies could be a useful yardstick.

An exploration of the data set can proceed, and the problem continues to be solved by the production of dot, box and whisker and stem and leaf plots. In Figure 2 we show the output screen after the dot plot has been produced and retained for comparison with the other two simple types of graphs. It is a useful learning exercise for the student to be able to make between-plot comparisons, since assessment of different data features shown up by the plots can be made.

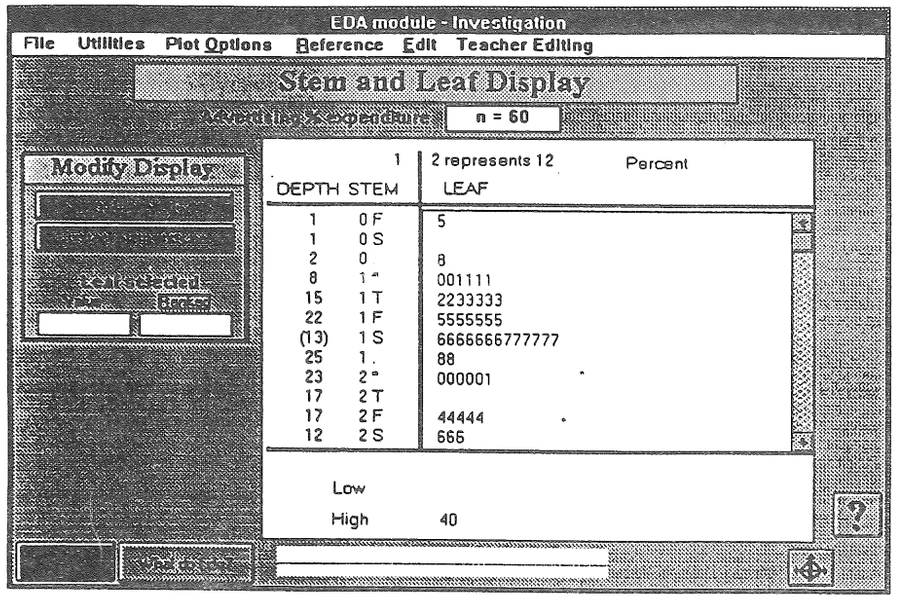
Figure 2. Screen showing the potential for retaining and comparing three different types of plots.



After clicking on the default stem-and-leaf plot for this data set an enlarged display fills the screen with further exploratory features being made available. In Figure 3 we show the

screen in which the stem and leaf plot has been expanded to enable the student to more easily see other features such as bi-modality, outliers and skewness.

Figure 3. Screen showing an expanded stem and leaf display

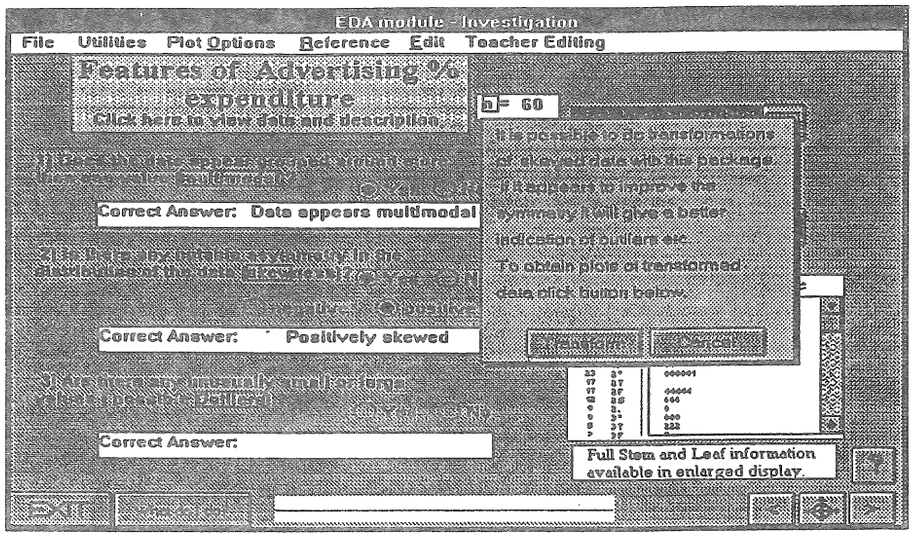


The main characteristics of the data set chosen will help solve the problem of assessing how future advertising campaigns should be costed in relation to expenditure. Interpretation of the plots will reveal basic statistics such as range, median and quartiles, and data features such as the presence of outliers and skewness. The student is tested to see if he can answer simple questions on these properties.

In Figure 4 we show a typical screen with simple Yes/No type answers as responses. Note that the simple plots selected are retained on the testing screen for easy reference. These responses are recorded by the module for later checking by the student. The **Utilities** option enables an electronic record to be made of any notes the student wishes to make. The Windows **'Write'** word processor is invoked each time the student accesses **Notepad** under **Utilities**.

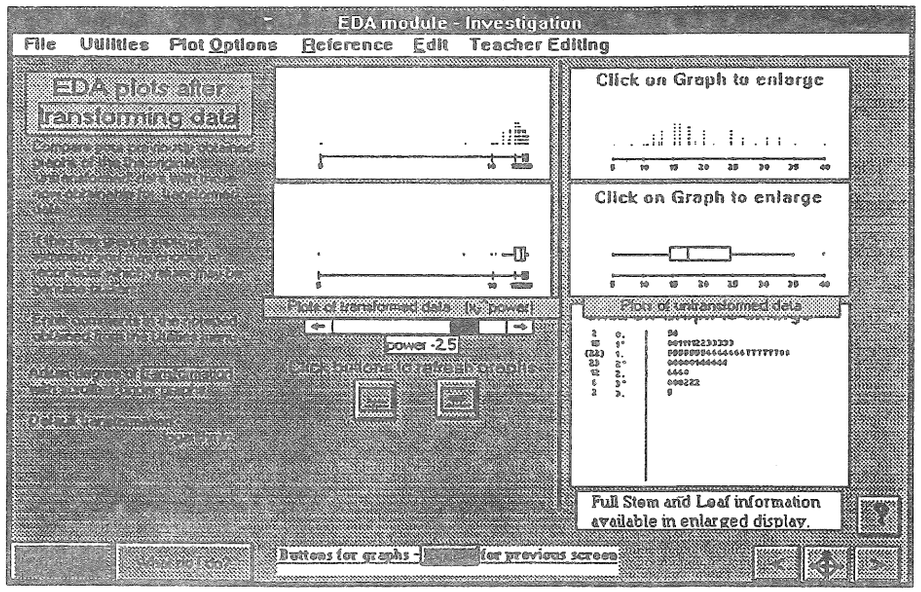
When a data set appears skewed, it is often appropriate to apply a simple power transformation to bring the data closer to symmetry. The overlay window in Figure 4 shows that the facility to carry out transformations is accessed once the data set is established to be asymmetric.

Figure 4. A typical testing screen for data properties



In Figure 5 we present the screen in which the student can dynamically apply a transformation to the data set selected.

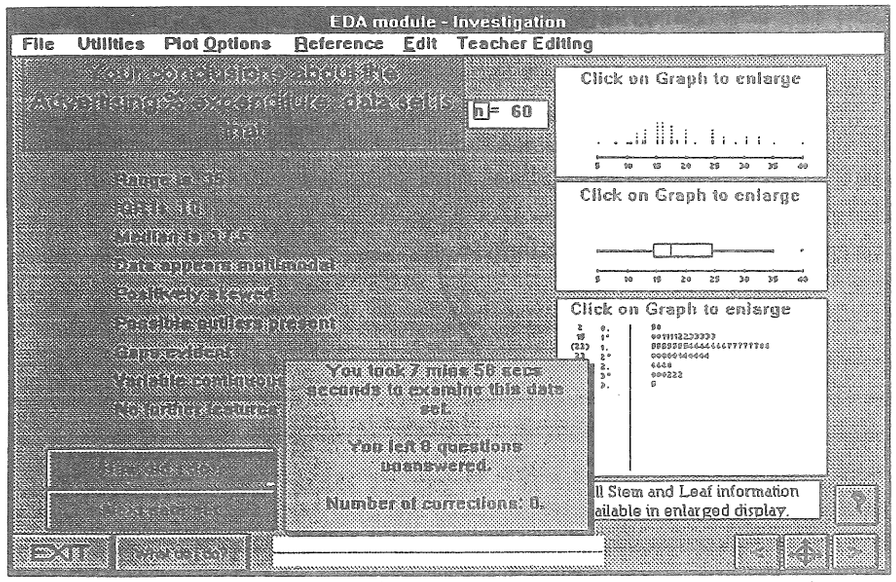
Figure 5. Screen for implementation of data transformations



This is done in two stages. First, the slider bar is used to select the transformation and then the refresh buttons are pressed to implement the transformation. The change to the original data that may take the transformed data set closer to symmetry can be assessed.

It is useful for students to check on their performance in self-paced learning and many modules produced by the consortium will have a facility to provide feedback in terms of answers given and time taken to carry out the tasks. In Figure 6 we present the results screen for the advertising expenditure data set. The button 'How did I do?' produces the overlay window containing a brief summary of the student responses.

Figure 6. Screen summarising some of the findings about the selected data set



4. Discussion

The module that we have described involves the use of EDA techniques to help solve a particular problem, but it also illustrates the general approach that the consortium has taken in the production of all its problem-based modules. All material produced goes through a continuous sequence of student and external staff evaluation. The consortium has established several independent volunteer evaluation sites in the U.K. as well as in Australia, New Zealand and the USA.

The independent feedback will be used to improve the design, implementation and use of the modules. Initial student response is very encouraging, with the relevance of the problem based approach, and the ability to work at one's own pace high on the list of attractions. From a development point of view, it has taken a great deal of time to develop acceptable navigational and screen design conventions, and to design well constructed problems. However, significant progress has been made and it is hoped that the work of

the consortium will produce useful materials of wide applicability, as well as providing a structural foundation on which other developers might build. The IBM PC-type machine predominates in the application areas being considered and all material developed throughout the consortium will be made available on this platform using ToolBook. The minimal specification is a 386 processor with a colour monitor, DOS 5.0, Windows 3.1, 4Mb RAM and 80Mb of hard disc space. However, material is also being developed for the Apple Macintosh using Hypercard, and for the X-Windows environment using Metacard.

We present a brief summary some of the other problems and the statistical content designed into the corresponding modules:

1. **Rainfall in the Pennines**: How do we compare the amounts of rain falling at different locations across the Pennines? (An exploration of histograms and stem-and-leaf plots.)

2. **Bullying in Schools**: The results of a questionnaire are available to investigate how common bullying is, who does it to whom, and what other factors are involved. (Use of tables and chi-square tests.)

3. **All Creatures Great and Small**: How do we assess whether someone is overweight or underweight? What factors do we need to take into account and how can we produce a helpful single number index? (Conditional distributions, adjusting one variable for another, correlation)

4. **Spatial patterns of plants**: How can we tell whether a particular pattern of plant positions is random or shows clustering or other features? (Quadrat sampling, Poisson distribution, parameter estimation)

5. **Trials and Tribulations**: How should we design a clinical trial to compare two drugs which aim to reduce blood pressure? How many patients should we involve in the study? How should the results be interpreted? (Power, sample size, confidence intervals, chi-squared tests)

6. **The Zenzia wheat scenario**: How does one compare the yields of different varieties of wheat? (Basic summary statistics for measures of location and spread)

7. **The case of Luddersby Hall**: How does one investigate an incidence of salmonella food poisoning at a university hall of residence? (Variable selection, hypothesis formulation and test statistics)

8. **Bank account blues**: How can one relate the weekly sales of a company to its press and TV advertising budget? (Linear regression, residuals and prediction)

Invited contribution to The 4th International Conference on Teaching Statistics (ICOTS4), Marrakech, July 1994

Experiences with STATGRAPHICS in statistics courses

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At this moment general and easy-to-use software-packages on statistics are available, such as SAS, BMDP, SPSS or STATGRAPHICS. These programs offer a broad range of techniques that can be used at an early stage of problem-solving. The widespread availability of these tools will have an impact on the use of statistics. In our teaching we have to anticipate on this. Especially in service courses on statistics the contents of the courses have to change. One of the reasons for this is that the importance of subjects changes, as eg. the emphasis shifts from technical details to the interpretation and use of results. Furthermore, as more techniques become available to solve problems, the choice of a technique for a specific problem becomes more important and one has to pay attention to this. However a good and general background on statistics remains important and one has to find a real balance between theory, techniques and numerical aspects. To obtain this it is insufficient just to put a computer in addition to an existing course. One has to redevelop the course and integrate these aspects from the beginning. At Eindhoven University of Technology we were able to do this for introductory courses in statistics for students in mechanical engineering and management sciences. I will report on this and pay attention to the general starting points, the contents and the organization of the courses. Furthermore I will discuss the actual use of the statistical package STATGRAPHICS during the course and present experiences with teaching these courses to large groups of students.

Reference:

Rijpkema, J.J.M. (1993). *Statistiek met Statgraphics*, Academic Service, Schoonhoven (the Netherlands)

Statistics Through Open Learning Down Under

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Australia

ORIGINS OF OPEN LEARNING

Open Learning is an exciting concept in university education; it has evolved out of Australia's long history of involvement with methods of flexible learning. These methods have been summarised as follows (Open Learning Agency of Australia Pty Ltd, September 1993):-

Correspondence teaching: The first universities to experiment in flexible learning were the University of Queensland (UQ) and the Royal Melbourne Institute of Technology (RMIT). UQ began correspondence courses in 1911 and RMIT in the 1920s. Lecture notes were mailed to students every few weeks, who in turn had to mail in tutorial problems regularly. Correspondence students had virtually no contact with their university other than by mail, until the end of course examination, which was held for all students at the university. The term correspondence teaching was used because of the reliance on regular communication by post.

External studies: The University of New England developed a new form of flexible learning

in the 1950s which was known as external studies. Study notes were sent to students at the start of the course, rather than periodically through the course, as with correspondence teaching. Students were required to submit regular assignments and also to attend specially organised residential schools held during the course.

Distance education: In the late 1970s Deakin University made a significant advance in flexible learning in Australia by incorporating many of the techniques used by the Open University in the UK. High quality study guides were produced with the aid of instructional designers, graphic designers and editors. Residential schools were largely replaced by telephone tutorials. This form of flexible learning is called distance education.

Open Learning: Open learning is an approach to teaching-learning based on the needs of individual learners. Johnson (1990) has defined the common elements and practices embraced in the various descriptions of open learning. These practices include open admission, student choice of subjects, student choice of modes (face-to-face, distance/external, full-time/part-time), student choice of timing and manner of assessment, and use of communication technology to facilitate choice and learning. Open learning has become prominent in Australia in the 1990s.

TV OPEN LEARNING PROJECT

Despite the Australian tradition of providing higher education for off-campus students, access has remained limited for the following reasons:

- admission to existing places was highly competitive;
- the usual residential component was an additional constraint for people from rural a n d isolated areas, sole parents, people with other family and/or work requirements, and for any other people for whom physical access to on-campus courses is difficult.

In 1990 the Commonwealth Government announced that money would be made available for a project aimed at extending access to first year degree courses by the provision of educational television with distance education materials. The project would:

- extend access to disadvantaged groups;
- incorporate television as an additional teaching mode;
- provide a "taste" of higher education to those in the community who would not normally be exposed.

Students could participate in three ways:

- watch the television programs only;
- purchase study materials, in addition to watching the television programs;
- watch the television programs, purchase the study materials, and pay to sit for a challenge examination - a pass in this examination would then gain credit towards a full formal higher education qualification.

A consortium of five universities, headed by Monash University, was appointed by the Australian Government to conduct the TV Open Learning (TVOL) Project over a two year period commencing in March 1992. The aim was to test the effectiveness of television as a tool in Australian higher education. The TVOL Project offered seven first-year university units, one being an introductory statistics course, by a combination of television programs, print and other study materials. The Australian Broadcasting Corporation (ABC) was selected to broadcast the television programs because it reaches a national audience, particularly those in rural and remote areas. More than 50,000 Australians expressed interest in the TVOL Project and 5,000 went on to study via this method in 1992.

STATISTICS THROUGH THE TVOL PROJECT

Statistics Unit Components

The statistics unit offered in the TVOL Project had three components.

Television: The American COMAP telecourse *Against All Odds: Inside Statistics*, which consists of twenty six half hour programs, was broadcast nationally by the ABC on Thursday mornings from 7:30am-8:00am, with each program being repeated on the Saturday morning of the following week. The unit ran over 26 weeks and was offered twice in 1992.

Study materials: These consisted of *Introduction to the Practice of Statistics, Telecourse Study Guide for Introduction to the Practice of Statistics* and *Unit Notes*. The cost was Aud $152.

Optional materials. Students who wished to pursue a career which relied on a solid statistical foundation, were encouraged to purchase the software statistical package MINITAB and the *MINITAB Handbook to Accompany the Introduction to the Practice of Statistics*. The cost was Aud $180.

1992 Enrolments

	Study Periods 1 and 2	Study Periods 3 and 4
Number who purchased study materials	285	143
Number who registered for assessment	176	90
Number who purchased optional materials	91	48

Note: A year is composed of four 13 week study periods

Assessment

Assessment was based on six assignments (24%) and a three hour challenge examination (76%); the assignments were due approximately every five weeks and were returned with comments and model solutions. The cost of assessment was Aud $185.

Student Support

Students, who were so inclined, were given the opportunity of becoming members of Study Groups in their region, together with advice on how such groups should operate. All students were encouraged to contact Deakin staff with any problems encountered, via telephone or electronic mail. Access to library support was also made available for a fee.

Demographic Profile of Statistics Students and Other Information

The following information is based in part on Deakin's student data base, and in part on a questionnaire received by all students who purchased study materials for the first presentation of that subject (see Keepes et al, 1993). For statistics students the response rate was about 40% (n = 113).

Sex The numbers of male and female students were approximately the same.

Age Half of the students were in the 30-49 age group, 28% were older and 22% were younger.

Education Just over three-quarters of the students enrolled had a post high school qualification while 45% had a university degree or diploma, or their equivalent; 23% of the students had

not been educated beyond high school.

Employment Approximately three-quarters of the students were employed.

Occupations of employed students Professionals made up 36% of the student body, para-professionals 19%, clerks 15%, managers/administrators 15%, sales and service workers 5% and labourers 3% .

Location of students relative to universities Four out of five students lived within a university catchment area (ie within 60 kilometres of a university)

Main reason for studying through TVOL Nearly a quarter of the students cited the main reason as "gaining credit/see if I am capable"; 14% gave as the main reason "it was not available/not able to enrol locally"; 14% cited "time factors/working full time" and 13% indicated "interest in subject/to refresh knowledge".

Main reason unable to attend on-campus courses The three most popular responses were work commitments, family commitments and isolation, which accounted for 62% of the respondents.

Equity and Access Eighty five percent of all respondents agreed that the TVOL Project was a way of increasing equity and access to higher education; 75% agreed that the TVOL Project motivated them to continue their education, and at least 52% indicated that they had access to higher education before the introduction of the TVOL Project.

Broadcast times and videotaping While students were happy in general with broadcast times, some 86% indicated that they planned to videotape the TVOL programs

Statistics Students Perceptions of Course Materials and Methods of Assessment

All TVOL students who sat for the challenge exam were sent a questionnaire by the author, to which 67% responded. Some of the outcomes follow:

Nearly nine out of ten students rated the TV programs good or excellent. Approximately three-quarters of the students rated both the text and the telecourse study guide as good or excellent. Of the 42% that used Minitab (version 8), 27% rated the software as poor, 29% as average, 24% as good and 20% as excellent. The students indicated that in general, they were happy with the challenge exam, although some found it too long. A pleasing outcome was the overwhelming perception that the exam was a fair test of the topics covered.

Retention Rates and Pass Rates

In 1992, only 51% of those who enrolled for assessment actually sat for the challenge examination. Of the final examinees, 82% passed the challenge examination and in general the standard of the exam submissions was very good.

OPEN LEARNING AGENCY OF AUSTRALIA

With the early success of the TVOL Project measured on a wide range of criteria, the Australian Government decided to fund a more ambitious Open Learning Initiative before the end of the first year of TVOL. This Initiative came into operation at the beginning of 1993. An independent organisation called the Open Learning Agency of Australia Pty Ltd (OLAA) was set up to act as a broker between universities and Open Learning students. OLAA is advised by an Academic Programs Board which comprises representatives from all the universities which have a significant involvement in Open Learning. Full membership of the Academic Programs Board is achieved when a university satisfies three major conditions; ie the university

(a) becomes a provider of Open Learning units;
(b) provides pathways to degrees of that university for Open Learning students;
(c) agrees to recognition of academic credit for Open Learning units of other university providers.

At the time of writing, there are fourteen provider universities.

Two of the most notable differences between the TVOL Project and OLAA are associated with the costs of unit assessments and the quality assurance procedures now used.

Statistics Through OlAA

In 1994 *Statistics: Against All Odds* was offered twice, with 268 being enrolled for assessment in the first course and 93 in the second course. Just over half of those enrolled for the first course sat for their examination, with the resulting pass rate being 77%. Students enrolled for the second course have not yet been assessed.

Assessment Costs

The costs of assessment associated with TVOL units of equal credit was quite variable, whereas the cost of assessment for OLAA units has been largely standardised. The cost of assessment for a one credit point Open Learning unit (normally a 13 week unit) is Aud $300 and Aud $600 for a two credit point Open Learning unit (normally a 26 week unit).

OLAA Quality Assurance Procedures

These procedures include the following:

- OLAA units are chosen by open competitive selection.
- all units must satisfy the provider university's own accreditation requirements.
- OLAA has agreements on the production and delivery of each Open Learning unit with the provider universities
- OLAA units are evaluated externally and the results are published.

FUTURE DIRECTIONS IN OPEN LEARNING

Communication

Communication is seen as critical to the quality and success of education. Improved communication in Open Learning will be achieved initially by using an electronic network based on personal computers, modems, a central computer and telephone lines. The Open Learning electronic infrastructure will be based on three key elements (Open Learning Agency of Australia Pty Ltd, September 1993):

- using working technologies.
- the application of these technologies to simple processes.
- assessment of cost effectiveness

Deferred payment scheme

As from the beginning of 1994, students can defer payment of Open Learning fees and repay them through the taxation system at a later date, which will make university education through Open Learning even more accessible.

Open Learning graduate programs

These programs will start to become available in 1994, especially in specialist professional areas such as health, computing and accounting.

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Teaching Statistics and Data Analysis at the University of the Air

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1. Outline of the University of the Air in Japan

The University of the Air (UA) is devoted to teaching arts and sciences by television (video) and radio (cassette) with textbooks. UA is a private University solely financially supported by the Japanese Government. The reason why UA is private in spite of the fact mentioned above is that UA has its own broadcast bureau (The Government can not have its own broadcast bureau by law). In the brochure of UA, the purpose and objectives are described as below.

"In today's complex and rapidly changing society, the lifestyles of people of all ages are changing and many people are looking for cultural enrichment. There has been an increasing interest in education and in learning. In response to this development, the University of the Air Foundation was established as a special corporation in July of 1981.

The University of the Air Foundation established both the University of the Air and its own radio and television broadcasting facilities. The aim of the University of the Air is to promote an effective, new, practical system of higher education, and to offer it to a broad spectrum of the populace, while at the same time striving to improve university-level educational broadcasts."

Broadcast System

●General

The course programs are transmitted from the UA transmission station to the Tokyo Tower and broadcast over the UHF TV system and on the FM radio. In Gunma Prefecture, the broadcasts received from the Tokyo Tower are re-transmitted from a transmission station in Maebashi City.

(1) Tokyo Tower Broadcasts (Tokyo Station)

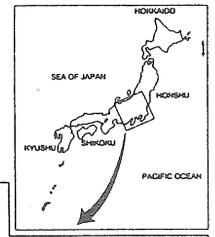
Class	T.V. Station	F.M. Station
Name	University of the Air Foundation Transmission Station	University of the Air Tokyo FM Station
Frequency	Channel 16 on UHF	77.3 MHz
Transmitter	Tokyo Tower at Shiba Koen, Tokyo	

(2) Gunma Prefecture Broadcasts (Maebashi Station)

Class	T.V. Station	F.M. Station
Name	University of the Air Foundation Machashi Transmission Station	University of the Air Macbashi FM Station
Frequency	Channel 40 on UHF	78.8 MHz
Transmitter	Futatsu Dake, Ikaho, Gunma Prefecture	Ushibuseyama, Yoshii, Gunma Prefecture

●Broadcast Areas

The map on the right shows the areas where UA broadcasts can be received. Cable TV is provided in some areas where UA broadcasts cannot be received. For details, call the Broadcasting Guide at 043-276-6227.



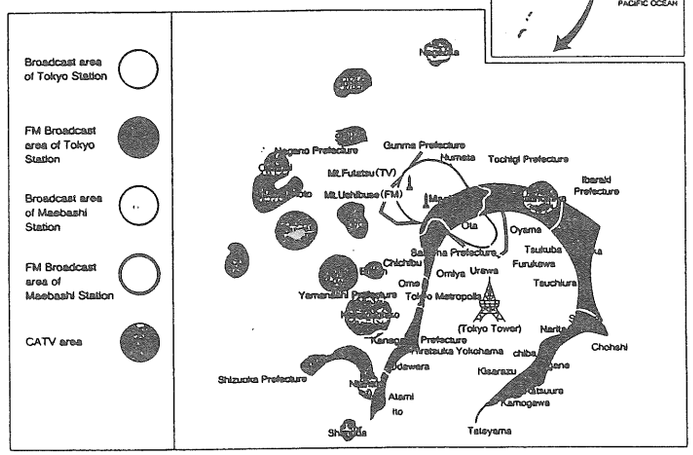


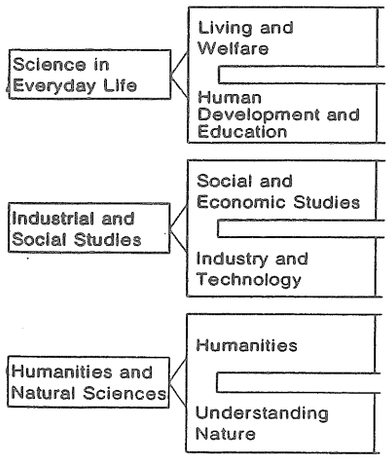
Fig. 1

From the Brochure of UA, 1993

As a result, UA (i) provides working people, housewives with the chance for higher (university) education, and then (ii) provides an innovate and flexible system of higher education which is open to all people, including students, who are interested in the classical and the latest knowledge, and the newest science and technology.

The broadcastsystem is shown in Fig. 1. UA has 9 centers in service areas where the students of UA have classroom teaching, " some questions and answers from assistant professors " and examinations, and 18 video centers in a nation-wide scale.

UA has only one faculty of arts and sciences which has three divisions as the following.



The branch of statistics and data analysis belongs to understanding nature with mathematics.

270 subjects are given in one semester (6 months) and are completed. Each subject has 15 units, the time length of each unit being 45 minutes. Every unit is regularly given only one time per week. 270 subjects are repeated two times in a year. Each subject continues for about 3 or 4 years as a rule.

6-8 subjects of statistics and data analysis are always taught with 6 subjects of mathematics among the total 270 subjects, that is to say, 6-8 units of different subjects are given per week.

2. Special Situations in Teaching System of Statistics and Data Analysis in Japan

There is a special situation, for statistics and data analysis, in Japan. There is no department of statistics and data analysis in Japanese universities. The lectures of statistics and data analysis are found in various faculties or various departments. The specialists are widely scattered. And so, the students usually receive some elementary lectures of statistics and data analysis by non-professional professors in statistics and data analysis or other lectures of special topics, in a limited number, by the professors of specialists in those disciplines. The knowledge of students concerning statistics and data analysis is diversified. In this point, the situation in Japan is rather promising as the teaching is not formalized in a fixed style of "mathematical statistics" as in U.S.A.

The Institute of Statistical Mathematics is only one national organization for research of statistics and data analysis where only specialists of statistics and data analysis (about 50 persons in total of professors, associate professors and assistant professors) study with a few amount of teaching for a few graduate students, has a duty that it plays a role as a center of specialists in statistics and data analysis and, as it were, as a melting pot of interdisciplinary fields and statistics and data analysis. In the training school attached to the Institute, some special lectures are irregularly held.

Many tutorial meetings of statistics and data analysis by special private organizations are very popular as adult education. There are many relevant participants. However, the contents of lectures are not methodology (theory) - oriented but rather practical.

At the University of the Air, I planned the establishments of an ideal department of statistics and data analysis by video tapes and cassettes by the very specialists of each discipline.

So, the lectures are intended not only for the students but also for the unknown public who are interested in statistics and data analysis.

This public includes specialists of statistics and data analysis, specialists of other scientific fields, researchers of various fields and other unknown kinds of people.
I think, it is very important that the unknown public exists as listeners, and it is necessary that the lectures is stimulating for these people and thus the lectures must be influential on the society.

This point is an important effect by broadcast that can not be attained by other means.

3. How Are Statistics and Data Analysis taught ?

At the university, lectures are given by television however, lectures have been recorded as video tapes. Or they are given by radio, however lectures have been already recorded as cassettes. Broadcast is only used for transmission of information in video and cassette . There are very few direct units of program without video and cassette.
The textbooks are carefully prepared. The students except for the unknown public can receive class room lecture at the centers. In statistics and data analysis, the course of computer exercises (15 hours) is open. Besides this, the course of exercise of sample survey practice has ever been held.

In every subject of statistics and data analysis, correspondence guidance is given, that is to say, the problems for exercises are given for the students once in one semester and then they must present the solutions by mail. Corrections and comments by the professor are sent to them by mail.
The students can freely view the video-tapes and listen the cassette in center. The public and students is permitted to reproduce the broadcast only for personal use. By the reproduced video or cassette, they can review the subject, however, the advance of video and cassette by the UA is prohibited by the law of the copyright.

The teaching method of statistics and data analysis has its own property depending on the kind of discipline. For example, the lecture of statistics in ecological science becomes more attractive and understandable by the explanation of concrete process of " design of data " and " collection of data ", " analysis of data ". Based on this pseud-experience and by the impression, learning by the textbook becomes more pleasant and so the

listeners can smoothly acquire skill in the subject. However, for example, the lecture of probability theory becomes rather effective by radio with a good textbook, giving the time of consideration.

4. What Subjects in Statistics and Data Analysis Are Taught ?

As I mentioned previously, I intended to establish an ideal department of statistics and data analysis from my standpoint. I thought that the lecture of every subject was to be given by the most suitable specialist for the subject. The subjects of statistics and data analysis were selected from my stand point of statistics and data analysis. The subjects are shown as below, where the figure in parenthesis means the number of units, and, (T) and (R) mean ' by Television ' and ' by Radio ' respectively.

Theory of Probability (15) (R)
Theory of Probability is discussed as foundation to statistics and data analysis

Mathematical statistics (15) (R)
General theory of mathematical statistics is explained concerning design of data and analysis of data. Only some spaces in a modest scale are allocated to the theory of statistical test and estimation.

Treatise on the philosophy of data theory and its method (15) (R)
the concept of data , fundamental concepts of statistics, the methods of design of data and fundamental idea and methods of data analysis, are reconstructed on the logic, methodology and philosophy science of mine based on positivism, experimentalism and skepticism.

Advanced methods of data analysis (15) (T)
Quantification theory and method which are developed on the extension of the logic, methodology and philosophy of science mentioned above, correspondence analysis, scaling method multidimensional scaling, classification and other methods of multidimensional data analysis are discussed.

Advanced methods of statistics (15) in total (R)

1 Akaike Information Criteria (A I C) and theory of model selection (5) (R)

2 Time-series analysis (5) (R)

3 Social survey techniques (5) (R)

Theory of numerical calculation (15) (R)

Method of data processing (15) (T)

Statistical data analysis and software (15) (T)

Theory and method of statistical decision making (15) (R)

Not only the idea of game theory but also general view of decision making are concretely discussed.

Theory of sampling and design of data (15) (R)

Fundamental theory of sampling and various sample survey techniques are explained.

Introduction: Data analysis (15) (R)

General methods of data analysis are explained free from a specific point of view mentioned above.

Quantification methods (15) (T)

Expository discourses are given without any philosophical discussion.

Statistics and data analysis in various fields (15) in total (T)

1. Statistics in biological and medical sciences (5) (T)
2. Data analysis in behavioral sciences (5) (T)
3. Statistics in ecology and environmetrics (5) (T)

Besides these, practical exercise of computing (15 hours) are given in the style of usual class room teaching in Centers.

5. An Example by Video Teaching

Here, one unit in statistics in ecology and environmetrics will be shown, where the problem of estimation of population size of an animal (a mammal) is treated. First, various existing methods are explained in comparison of our summarization with that by a specialist of this subject, Dr. A. R. Sen.
The comparison is given in Table 1 (* means the methods developed by us).

Wildlife sampling methods by A. R. Sen from "A Review of Some Important Techniques in Sampling Wildlife"	Sampling methods for animal population of a mammal by C. Hayashi from "Sampling from a mobile population"
1) Quadrat Sampling	1) Capture method (Sampling of area and partial enumeration)
2) Strip Transects	2) Observation method (Sampling of area and partial enumeration)
3) Line-intersect and Line-transect methods	3) Capture-recapture method
4) Capture-recapture method	4) Method based on home range
5) Change-in-ratio (CIR) method	5) Track method
6) Catch-effort method	* continuous counting for small area (· ha)
7) Indices	* survey by man power for medium area (1000~ 10000 ha) — based on a probabilistic model including geometrical probability
8) Pellet-group Counts	* survey by helicopter for large area (10000 ha~) — based on a probabilistic model including geometrical probability
	6) Interval method
	7) * Operational method—trace, damage and pellets survey and after an action (hunting etc.)—

The fundamental method in * , the story of development of research of population size of hare by man power for medium area (1000 - 10000 ha) will be shown by video-tape.

Table 1

Reference

The University of the Air. The University of the Air, 1993
(2-11, Wakaba, Mihama-ku, Chiba City, 261 Japan,
Tel. 81-43-276-5111)

DISTANCE TEACHING OF STATISTICS AT THE UNIVERSITY OF SOUTH AFRICA: FROM UNDERGRADUATE LEVEL TO PH.D.

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University of South Africa
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Pretoria
South Africa

1. Introduction

The University of South Africa (Unisa) was founded in 1873 as the University of the Cape of Good Hope. The purpose was to serve as an examining body for a number of constituent university colleges. In 1918 it was renamed the University of South Africa, and at the same time moved to Pretoria, at that time the administrative capital of the Union of South Africa. No tuition was offered by Unisa then, its function being only to set examinations and issue certificates. When the constituent colleges gradually became independent universities which set their own examinations, Unisa began a division of external studies. By the early 1950s the external studies had become the most important part of the activities of Unisa. The tertiary education at Unisa is today exclusively conducted by distance education. There are 58 academic departments in six faculties (Arts, Commerce, Science, Law, Theology and Education). Unisa presently has about 1,400 teaching staff, 1,200 administrative staff in addition to various other personnel. It has an impressive library, a huge modern printing press and, apart from the main campus in Pretoria, regional offices in Cape Town, Durban and Pietersburg.

The Department of Mathematical Statistics at Unisa was founded in 1959 by professor H.S. Steyn. The department, which has since been renamed the Department of Statistics, is in the science faculty. It has 25 faculty and 3 administrative staff.

2. The students

In 1993 Unisa had more than 120,000 students from all continents, although most of the students live in southern Africa. Apart from South Africa and the independent homelands, a large number of students live in Namibia, Botswana, Swaziland, Botswana, Zimbabwe and Mauritius.

The average age of Unisa students is 31 years, and individual ages range from under 19 to over 65. Most students are economically active, being employed in education, business, industry, research, health and welfare services or being self-employed. A substantial number are housewives, many study full-time and there are even some prisoners who study at Unisa.

About 500 students are physically disabled, often requiring special arrangements such as transferring study material to audio tape or to special apparatuses for blind students and special examinations for quadruplegic students.

One of our problems in Statistics is the heterogeneity of the students. They vary from a professor of Applied Mathematics to disadvantaged students who barely managed to pass mathematics at school. Many of the students who study undergraduate courses in Statistics have degrees in medicine, engineering and other sciences, but need a better knowledge of Statistics for their research work. For some students Unisa is a "last chance" university, because it admits students who are not admitted by the more prestigious universities. Bridging courses have fallen into disrepute; therefore all students have to enroll for the same courses, regardless of their background. The only solution is to provide additional help which may be bypassed by students who do not need it.

Personal circumstances are an important factor in determining the success of a student. It has been determined that a change in career, accommodation, marital status or

family size has a profound effect on the student's chances of success.

3. The academic year

The academic year stretches from January to December. Students register between November and February, as soon as the results from their previous studies are available. On registering, the student receives all the study material for that year. For each course the student has to complete a number of assignments, each of which has a due date. Admission to the examinations is based on the satisfactory completion of the assignments. The due dates are selected in such a way that the students are guided through the study material at a predetermined pace.

4. Statistics courses

The Statistics Department offers Statistics as a major for a bachelor's degree and in post-graduate programs in science, arts and commerce. A bachelor's degree takes three years full-time, but the typical Unisa student, being a part-time student, takes much longer. The science degree consists of 30 modules, usually with two majors and some ancillary subjects. The honours degree consists of 10 modules, all in the same subject. The courses offered include the following:

First-year service course: introductory Statistics and some Mathematics (about 3,000 students).

First-year science modules: Probability; Applied Statistics; Distribution Theory.

Second-year modules: Probability; Applied Statistics; Distribution Theory; Experimental Design; Sample Surveys; Geostatistics.

Third-year modules: Stochastic Processes; Multivariate

Distributions; Inference; Analysis of Variance and Regression; Quality Control; Geostatistics; Forecasting.

Honours modules: Probability and Stochastic Processes; Matrices; Distribution Theory; Linear Models; Regression; Time Series Analysis; Graphical Display of Data Matrices; Multivariate Analysis; Survey Sampling; Statistical Techniques.

Master's degrees: The ideal is five modules and a dissertation, although alternative options are a (more extensive) dissertation only or ten papers and no dissertation. The latter option is sometimes selected by students whose personal circumstances make it impossible for them to visit a library on a regular basis.

Doctoral degrees: A thesis only. Theses are sent to at least two external examiners who are not associated with Unisa. No oral examination or thesis defence is possible, since students may live far from Pretoria. In the case of students who live far from Pretoria, a joint supervisor is usually found within the student's own environment, e.g. a colleague who has a Ph.D. Unisa retains the responsibility for the standard of the thesis.

One area in which our courses are presently deficient is the practical work. In the applied modules small data sets are selected such that the students are able to do the analysis on a pocket calculator. However, our students are not required to work on a computer during their training. Such a requirement would exclude many prospective students. While it is estimated that about 80% of our students have access to personal computers, the software is still a problem, being expensive and placing severe demands on hardware. The solution would be to develop our own software or use public software (which is usually restricted to fairly simple analyses). Our present solution is to teach the students how to interpret the output

from a number of statistical packages. Thus the lecturer runs the programs and presents the students with the output.

5. Study material

In the undergraduate modules the student receives a "study guide" and a number of tutorial letters. The study guide is actually a somewhat user-friendly textbook written by the lecturers in the department. Due to the serious drop in the value of the South African rand, imported textbooks have become prohibitively expensive for many students. At registration the student receives the study guide and the first tutorial letter, which contains all the assignment questions for the year. Subsequent tutorial letters are sent out as needed, and to provide the solutions to the problems asked in the assignments. A trial examination paper (usually the previous year's examination paper) is also provided.

At honours and master's level students study from prescribed books, e.g. Graybill (1983), Muirhead (1982) and Searle (1971). In some cases journal articles form part of the study material.

6. Student contact

Students may contact their lecturers by letter, telephone or in person if they have problems. Determining the student's real problem and solving it while the meter is counting the minutes, requires a special talent, in addition to experience and patience.

Most of the lecturers are available during the day only, while most students study at night and are not able to contact the lecturers during the day. For this reason some lecturers have been appointed to help students after hours.

For the larger courses, lecturers arrange lectures at the

main campus and at the regional offices two or three times per year. Only about 5% of our students attend these lectures (due to their personal circumstances), but they enable the lecturers to make contact with their students and to discover what problems the students may experience. Many students do not know how to calculate a mean and standard deviation using their pocket calculators, for example, and this is a good opportunity to demonstrate it to them.

7. Library

Unisa has a very extensive library for the subjects offered, but no medical or engineering books, for example. Branch libraries are available at the three regional offices. Multiple copies of books which students have to work from (apart from their prescribed books) are kept in the library. Students who do not live within reach of the library may order the books by mail.

Subject librarians are available to help research students and faculty in searching for literature on specified topics. Many students at this level are at a university or research organisation, where a local library is available.

8. Study Aids

Video tapes are available in the library, but because they are expensive and not generally accessible, it is not a viable option at this stage. Audio tapes are regarded as an essential aid, particularly to teach students how to pronounce a formula and also to provide them with some encouragement and orientation.

Unisa has an active research group in the field of computer aided learning, and lessons are being developed to help students overcome particular problems. Although computers

are not available to all students, microcomputer laboratories are available at the regional offices and on the main campus.

9. Examinations

Unisa examinations are written in about 500 examination centres world-wide. In southern Africa the examination centres are located in even the smallest villages, often in a church hall or on the veranda of a private home. Examination centres abroad are mostly in South African embassies and consulates. Undergraduate examinations are written in October and November with supplementary examinations in January, while the post-graduate examinations are written in January and February. The final mark is based on the examination paper alone. The assignments determine admission to the examinations only.

Because the examinations represent such a huge undertaking, especially in the case of the undergraduate examinations, seats at the examination centres are at a prime. Open-book examinations for postgraduate students are feasible because there are not so many of them. They typically bring so many books that two desks have to be allocated to each student. In the case of undergraduate students, there would simply not be sufficient desks for that to happen. A problem which has recently arisen in this regard, is that pocket calculators have appeared which have a huge memory and a search function. Such a calculator may in fact be used to store inadmissible information, and we cannot expect the invigilators (who are not necessarily technical people) to distinguish between various types of calculators. A solution to this is being investigated, namely to have a special Unisa calculator manufactured, with distinguishing features which all invigilators can recognise.

10. Some special problems

Due to the varied social and cultural backgrounds of the students, we have to be very careful in compiling our study material. Many students do not know what a deck of cards looks like, and they do not know the rules of baseball or American football. They do not appreciate Republican senators from Idaho who are against subsidies for potato farmers. Some students do not know how to operate a bank account. Therefore, in choosing illustrative examples, we have to be careful that the non-essential details of the example do not create insurmountable problems for the student who studies far away, maybe at night, with nobody to explain these things to them. Care also has to be taken to ensure that the English and Afrikaans versions of the examination papers ask the identical questions, especially in the case of multiple choice questions which are marked by computer. Statistical analysis of the outcome of such tests is indispensable.

In conclusion, it would be true to say that Unisa is a truly national institution, bringing university education into every home in southern Africa.

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AN INTERACTIVE LEARNING ENVIRONMENT TO SUPPORT STUDYING STATISTICS

by
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Abstract of a paper to be presented at the 4th International Conference on Teaching Statistics, to be held in Marrakech, Morocco, July 25-30, 1994.

The present written learning materials on statistics often do not fit well enough into the specific needs of a student, are only weakly related to his or her prior knowledge, and require time consuming and expensive development and innovation processes. One of the central aims of the OTIC research program is to gain insights into the realization of more flexible course materials. Recent years of research have contributed to the development of new technology-based instructional systems which allow the learner to browse through enormous databases in a relative short time. Besides the large quantity of information which can be accessed, these systems also provide the user with a variety of tools for exploring, exploiting and studying the learning materials. It is assumed that flexibility can be realized by using smaller modular building blocks that (1) can be selected in any desired order, (2) are supported by a set of affiliated text-embedded support devices (such as examples, exercises, illustrations, etc.), which is adapted to the individual requirements of the student, (3) are more appropriate to relate to the students' prior knowledge, and (4) leads to a more individualized (electronic) delivery of course materials. To this end, it is investigated which procedures have to be followed and how the use of information technology can contribute to this innovative course approach. The present paper is focused on the development of an interactive learning environment for teaching and studying statistics. At the conference we will report two empirical studies in which prototypes of interactive learning environments were tested in a real-life educationai setting. In order to allow the flexible selection of learning materials and affiliated support devices, these were separately stored in the database. The basic approach of the prototypes was to give the participating students a fairly large amount of learner control, especially with regard to the selection of embedded support devices. The default setting of the prototypes was that the student only received the basic learning materials. Support devices had to be selected explicitly by means of clicking the required devices from a pull-down menu. The general results showed that experimental students do not achieve worse than a group of controls (who received the traditional program). Moreover, it appeared that the active selection of embedded support devices depends on the level of prior knowledge. High prior knowledge students were more engaged in selecting or deselecting embedded support devices than low prior knowledge students. Finally, recent insights will be presented whether detailed insight on the prior knowledge level of students can be used as a criterium to determine default settings of embedded support devices.

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UN EXEMPLE D'ENSEIGNEMENT DES STATISTIQUES PAR CORRESPONDANCE EN 1er CYCLE UNIVERSITAIRE (SCIENCES DE LA NATURE ET DE LA VIE)

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Origine de l'enseignement

La préparation par correspondance du Diplôme d'Enseignement Universitaire Général (DEUG) option Sciences de la Nature et de la Vie a été mis en place à la demande du CNED (Centre National d'Enseignement à Distance) (*) et a donné lieu à une convention en avril 1990 avec l'Université Pierre et Marie CURIE (**).

Cette formation permet naturellement aux étudiants ayant le baccalauréat d'accéder à la licence de Sciences Naturelles. Ainsi, en suivant les cours du CNED on peut effectuer sa scolarité jusqu'à la licence par correspondance.

Alors que le diplôme est préparé en deux ans à l'université, les enseignements par correspondance s'étale sur quatre ans : chaque année, les étudiants préparent les matières d'une demi-année et le programme est strictement le même que celui du DEUG SNV (option biologie) de l'université.

Organisation générale

Chaque discipline a dû s'adapter à la structure suivante :

-réalisation d'un fascicule de cours avec des conseils bibliographiques et un calendrier précisant l'organisation du travail à faire chaque semaine,

- réalisation d'un fascicule d'exercices "autocorrectifs" destinés à remplacer les travaux dirigés ; en réalité, il s'agit de textes d'exercices illustrant le cours avec des corrigés détaillés, une série de devoirs envoyés à des correcteurs à des dates fixes. En plus des annotations des correcteurs, les étudiants reçoivent un corrigé détaillé,

-rédaction d'une série de devoirs et de leurs corrigés détaillés. Chaque devoir est envoyé à un correcteur à des dates fixes.

L'ensemble de ces documents (sauf le corrigé des devoirs) est envoyé au début de l'année aux étudiants. Pour certaines disciplines, une semaine par semestre est prévue à l'université pour effectuer les travaux pratiques (biologie, géologie, chimie, physique, biochimie.....).

Les examens ont lieu en juin et septembre si possible aux mêmes heures, avec les mêmes programmes et les mêmes sujets que la section correspondante à l'université.

* 60, boulevard du Lycée 92171 Vanves Cédex - France
** 4, place Jussieu 75252 Paris Cédex 05 - France

Enseignement des statistiques

En DEUG, les statistiques sont enseignées à l'université sous la forme de 13 heures de cours et de 12 heures de T.D. au premier semestre de la 2ème année. Les notions de probabilités sont acquises en première année et font partie du cours de mathématiques.

Le calendrier des enseignements par correspondance est réparti sur un semestre, c'est à dire sur 12 semaines :

SEMAINES	CHAPITRES DU COURS	EXERCICES	DEVOIRS
1 2	Ch 1 Statistique Descriptive	Séquence 1 Séquence 2	
3 4 5	Ch 2 Variables Aléatoires	Séquence 3 Séquence 4 Séquence 5	Numéro 1
6	Ch 3 Echantillonnage Estimation	Séquence 6	
7 8 9	Ch 4 Tests statistiques	Séquence 7 Séquence 8 Séquence 9	Numéro 2
10	Ch 5 Analyse de la variance	Séquence 10	
11 12	Ch 6 Analyse à deux dimensions	Séquence 11 Séquence 12	Numéro 3

Le fascicule de cours comprend 80 pages, les 36 exercices sont répartis en 12 séquences de façon à ce que les étudiants aient un programme de travail hebdomadaire.

Il ressort que les étudiants doivent être capables de travailler de façon très autonome ; seuls les devoirs permettent d'établir un dialogue entre l'enseignant et l'enseigné. Avec trois devoirs, les échanges sont forcément limités et les conseils portés sur un devoir s'appliquent difficilement au devoir suivant puisque les trois sujets abordent des parties différentes du cours.

A l'université, l'examen de statistiques a lieu à la fin du premier semestre en même temps que les partiels des autres disciplines ; mais par correspondance, il a lieu en juin en même temps que les autres épreuves afin de réduire les déplacements des étudiants. Il s'ensuit un décalage important (un semestre) entre la fin des cours et le contrôle.

Conclusions

Il est peut-être un peu tôt pour tirer des conclusions définitives : l'enseignement des statistiques n'en est qu'à sa deuxième année. Les étudiants ont beaucoup de mal à travailler régulièrement chaque semaine et à envoyer tous les devoirs aux dates indiquées. Néanmoins, les résultats semblent bons et supérieurs à ceux obtenus par les étudiants classiques ; toutefois, il est possible que l'explication provienne de la plus grande motivation des étudiants travaillant par

correspondance. Cette motivation et une plus grande maturité compensent donc largement le manque de temps dû à une activité professionnelle.

Ce type d'enseignement par correspondance à fait ses preuves et s'avère efficace pour un public qui est entré dans la vie active et souhaite poursuivre des études. Cependant quelques propositions peuvent être faites pour améliorer l'enseignement et en particulier celui de la statistique.

Pour encourager un rythme de travail régulier, il conviendrait que seuls les textes des exercices soient envoyés avec le cours en début d'année. Les corrigés seraient envoyés semaine après semaine ou à la rigueur chapitre par chapitre.

Afin de raccourcir le temps qui sépare la fin des enseignements de l'examen et également de permettre une meilleure assimilation des concepts statistiques, on répartirait les séquences de quinzaine en quinzaine.

Pour améliorer les contacts entre l'enseignant et l'enseigné on pourrait offrir la possibilité, à des périodes et à des heures précises, de joindre téléphoniquement l'enseignant de la même façon qu'il existe des conseils téléphoniques fournis par les fabricants de logiciels. Pourquoi n'envisagerait-on pas dans le futur des "téléconférences" qui permettraient à l'ensemble des élèves de communiquer avec l'enseignant comme cela se fait pour les réunions professionnelles à distance.

Pour faciliter l'apprentissage et rendre plus concrètes les méthodes statistiques, ne serait-il pas souhaitable d'élaborer des cassettes vidéo qui seraient prêtées aux étudiants ?

Enfin, pour remplacer au moins en partie un enseignement par correspondance classique, ne devrait-on pas encourager la création et l'usage de didacticiels ?

Television Documentaries : Opening Statistics to the World

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John Jaworski, BBC and Open University

By 1995 the United Kingdom's Open University will have an introductory statistics course on offer that makes use of eight high-quality broadcast TV programmes. Why?

Modern methods of teaching statistics pay a great deal of attention to statistical ideas and concepts, preferring to play down the more traditional mathematics based approach. Indeed, with the advent of cheap, powerful micro- computers and user-friendly statistical packages it is possible to produce courses up to a fairly advanced level which have little or no formal mathematical content. The traditional blackboard-and-chalk style of teaching, where tidy theories are complemented by equally tidy artificial data sets has given way to common-sense analysis of real data on a computer. The underlying theoretical assumptions are now understood via advanced graphics with the speed and power of the computer allowing a range of displays and methods to be tried and tested.

Whilst few of us would argue against such an approach, we are all aware hat its main strength, namely the early development of statistical intuition, is also its main weakness. For the most part, the real data used are acquired second hand. In practice, it is difficult to understand data structures without direct involvement in the data collection process but it is logistically impossible to teach to a viable schedule without using data which the students have to take on trust and, sometimes, struggle to understand fully. Furthermore, it may be difficult to motivate students when data without obvious relevance are presented directly to them.

One possible way round these problems is to present data situations via documentary TV/film. Clearly this is an expensive resource which most educational establishments cannot afford, but what they can do is be aware of the available material which has already been produced, particularly when such material has been designed to fit an introductory course which uses a commercially available book.

The eight television programmes have been made in an investigative documentary style with the objectives of showing the statistician in action and of conveying some of the excitement of discovery. The statistician is not shown as a person who identifies statistics as the discipline by which problems are solved, but rather as the key figure who actually solves the problems. The statistician is seen as a real individual who plays a central, active role in the planning of statistical investigations and the analysis of their outcomes. The viewers are invited to join in and adopt this role themselves, following the example they have seen.

The programmes themselves cover a wide range of statistical ideas and also a wide range of application areas. They have been planned around subjects which are interesting and relevant and which will continue to be topical throughout the late 20th and early 21st centuries. In order, they are about :

1 Government statistics
2 Pollution and spatial pattern
3 Ecology and forestry
4 Radioastronomy and archaeology
5 Clinical trials and medicine
6 Manufacturing undersea oil pipelines
7 Vision, dyslexia and epilepsy
8 Sporting performance and records

Open University programmes are transmitted nationwide and seen by hundreds of thousands of viewers in addition to the students. The programmes have been made with this in mind and it is hoped that they will prove effective in demonstrating the power and interest of statistics.

In our talk, we shall discuss the techniques which lie behind the planning and making of the statistical documentaries. We shall show how they were designed to fit into the structure of a basic course written round a statistical computer package and how the objectives outlined above were incorporated. Style of presentation and integration of graphic sequences will be discussed in terms of the synthesis of the educational objectives within a programme story line. Illustrative extracts from the programmes will be shown.

A Hypermedia Environment for Navigating Statistical Information Resources

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Business corporations, universities and other organizations share the problem of storing, accesssing, and transmitting large volumes of information. The volume of stored information resources, including research results, published materials and software, is increasing so rapidly that it can no longer be dealt with sufficiently by conventional separate databases and information management systems. In addition, increasing diversification and decentralization in the media used by individual researchers in different research areas are interfering with the rapid retrieval and use of information needed by users. Because statisticians often work on the the boundaries of various other sciences, they face this problem in acute form. Hence, the development of a system that can fully organize and integrate strategic information in statistical science is essential.

To enable users to obtain a clear understanding of the value and effectiveness of using the vast amount of such diverse statistical information, a new system that realizes a *knowledge presentation environment* based on new concepts is needed. This paper introduces a Statistical Meta-Information Navigation System (called *Meta-Stat Navigator*) developed to create a hypermedia environment for using these resources as effective research support information, together with the related research results. The Meta-Stat Navigator has been developed as one of the large-scale projects conducted by the Institute of Statistical Mathematics of Tokyo. It has now undergone more than a year and a half of successful trial operation. The main objective of this paper is to propose the conversion of statistical information resources to hypertext for effective management of the resources that will make it possible to find out with ease *what information is stored where, in what form*, and how it can be utilized. The other objective is to discuss the new system to be built using a hypermedia environment.

The Promise and Pitfalls of Multimedia Technology for Teaching Statistics

Paul F. Velleman
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Multimedia technology is becoming increasingly common in all developed nations. In addition to its extensive entertainment capability, multimedia offers unique opportunities for education. We are developing a multimedia introductory statistics course that attempts to combine this technology with insights from the movement to reform the teaching of statistics. We discuss here some general principles and report on our early progress.

Multimedia combines computing, video, sound, and animation with student interaction through typing and mouse actions. Each of these channels has its own strengths and weaknesses. Different individuals learn more readily from different media. Multimedia can take advantage of this variation, provide self-pacing, adapt to different levels of student motivation and preparation, and encourage frequent interaction. The computer can help students to visualize abstract concepts via simulations and dynamic graphics.

The reform of instruction rests on the principle that students learn best by their own activity, not by passively receiving information. A multimedia learning environment should be highly interactive. Students will constantly be called on to manipulate animations, respond to questions, and analyze data in an integrated statistics package.

Statistics is an ideal subject for multimedia instruction. The practice of statistics focuses on analysis of data with software tools, often in an exploratory fashion guided by interaction with the data. Instruction in statistics has increasingly adopted a similar focus. Moreover, there are ample real-world motivations for statistics lessons and legitimate reasons for students to become proficient with a statistics package.

There are many unanswered questions, both educational and technical, about multimedia learning systems. While suitable hardware and software are now available at attractive prices, the technology is still changing rapidly, making it difficult to select the best development path. Some methods enhance portability (for example, between the Macintosh and Windows platforms). Multiple channels for information can generate a confusing and cluttered environment for the student. The balance between adequate structure to keep students oriented and sufficient freedom to use the system flexibly poses a challenge.

Human instructors are particularly effective at motivating students through personal interaction and at assessing students' problem solving. We doubt that a free-standing system can replace this human input, so the integration of human instructors with a multimedia system is an additional challenge.

Panel Discussion
The Place of New Technologies in Statistical Education

Jacqueline Dietz, North Carolina State University, USA
Solomon Garfunkel, COMAP, Inc., USA
Ross Gollan, Deakin University, Australia

Technology in the form of computing has long been important to statistical education. Video has found less widespread but important use, particularly in distance learning and in employee training in business. Electronic communication via the Internet and other networks local, national, and global is beginning to influence education.

Now a new generation of technology is rapidly becoming common. "Multimedia" systems allow combination of on-screen text, audio, video, animation and graphics, and computing in a single system with which the learner interacts via keyboard and mouse. The entertainment potential of multimedia ensures that these systems will become widely available in developed nations. (It is estimated that 35% of personal computers sold in the U.S. in 1994 will be equipped with the CD-ROM drives whose storage capacity makes multimedia possible.)

The panel, with help from the speakers in the first part of the session, will address the issues raised by changing technology. What is wise use of technology? How does wise use change in various educational settings? What do communications networks and multimedia add to statistical education? What is the essential role of human teachers? Will changing technology increase the gap between developed and developing nations, or (as in the case of portable telephones not requiring wire networks) allow developing nations to catch up by skipping earlier technology? The audience will have substantial opportunity to comment and to question the panel.

Teaching Statistics to Future Statisticians in Italy

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1. Introduction

A new body of legislation was introduced in Italy on 20 January, 1993, lending greater scope and depth to the training of statisticians. The Italian University system must apply this legislation within two years from this date.

The importance of these normative guidelines, both today and in the training of statisticians in the future, lies with the fact that the University as a body is subject to state legislation.

The situation as it is today and in the future may be understood better by making a quick trip into the past, followed by a detailed analysis of current norms and regulations regarding degree and diploma courses in statistics. The general picture may then be completed by looking at the Doctor of Research courses, introduced in 1983, and which are a major step on the path to a university career for recent graduates.

2. From the Faculty of Statistical, Demographic and Actuarial Sciences to the Faculty of Statistical Sciences

The acknowledged prestige of statistics at a University level and the realization that statistics, grouping as it does a variety of disciplines, could constitute a Faculty per se, led to the founding in 1936 of the Faculty of Statistical, Demographic and Actuarial Sciences at the University of Rome. With this, a Diploma in Statistics was conferred (in two years, following 11 exams and a final

diploma exam) which permitted access to the Degree Course in Statistical and Demographic Sciences (SDS) (2 years, 10 exams and a final thesis) or in Statistical and Actuarial Sciences (SAS) (2 years, 11 exams and a final thesis).

The Faculty integrated research and teaching in mathematics and probability as well as in methodological and applied statistics, and also covered economics, sociology, geography and law, which were deemed to provide a valid background for the quantitative interpretation of social phenomena, a field of application which has always been awarded a special place in statistics in Italy.

While the Diploma in Statistics was introduced in other Italian universities, Rome University was the only one to hold the degree courses.

How the courses were run was radically altered in the University of Rome in 1960. A degree now took four years, while the diploma was no longer a preliminary to doing a degree. The 1960 reform laid down that both degree courses, as a necessary tool in statistics, should include four compulsory courses, the standard being similar as for a degree in mathematics: mathematical analysis, calculus, linear algebra and probability. These were aimed to lend further scope and breadth to the teaching of statistics which now comprised four courses, including the theory of sampling techniques. Before doing the final exams it was necessary to pass a total of 24 exams for the SDS degree and 25 for the SAS degree, plus a final thesis. Regulations regarding the Diploma course remained unchanged.

In 1968-69 the University of Padua also established a Faculty of Statistical, Demographic and Actuarial Sciences. A particular feature was the introduction of a new degree course in Statistical and Economic Sciences (SES) (4 years, 24 exams, final thesis), with the economy as the privileged area for statistical applications.

Bologna set up a Faculty in Statistical, Demographic and Actuarial Sciences in 1986, and Messina in 1993.

While currently (December 1993) there are only four faculties of Statistical, Demographic and Actuarial Sciences, the number of courses held are much more numerous, with 16 Diploma courses, 5 SAS degree courses, 4 SDS degree courses and 6 SES courses. The reason for this being that University regulations also permit such courses to be organized outside the Faculty.

3. The Faculty of Statistical Sciences

As the system as it stood was somewhat outdated - the Diploma course dated back to 1938 and the more recent SES degree to 1969 - a complete overhaul was called for so as to better stream the existing degree courses as well as introduce others which would provide better focus and more depth in methodology as well as application in statistics, particularly in the fields of experimental sciences and operational research. This reform was also opportune given the recent introduction of the 3-year University Diploma in 1990. Indeed the Diploma in Statistics was an anomaly, being something of a rarity and non-existent in any other scientific field.

The 1993 reform was the fruit of much discussion and mediation, between tradition and innovation, basic training and professional skills, small universities, big universities, etc.

The most immediate sign of this transformation was the fact that the faculty changed name, from the Faculty of Statistical, Demographic and Actuarial Sciences, which privileged two main streams of application, to the more all-embracing Faculty of Statistical Sciences.

To promote greater flexibility at a local level, the decision was taken not to indicate, as had been the case to date, the single topics, with the same previously decided title for all the universities, but to allow each university to choose the courses it wishes to hold within the so-called "discipline areas". A discipline area is a number of scientifically similar disciplines, grouped together to attain didactical-training goals. In short what we are dealing with are long lists of subjects, drawn up by the Ministry of the University and Scientific Research, which it is possible to choose from.

To frequent the Degree or Diploma courses an upper secondary school eaving certificate is required, usually obtained in Italy around 19 years of age.

Regulations regarding transfers between the Degree and Diploma courses are laid down by the individual faculties.

3.1. University Diplomas in Statistics

With the new reform the Diploma in Statistics was extended by a year and there are now three such diplomas available: a Diploma in Statistics, a Diploma in Statistics and Computer Science for Business, a Diploma in Statistics and Computer

Science for the Public Sector. The aim is to provide a professional training and background to be used in various sectors of society in both Italy and Europe, with particular focus on applications.

Whatever the stream, a similar number of compulsory courses in each discipline area for all the Diploma courses are taught. In addition each stream covers a number of elective topics specific to that stream, and other courses which each Faculty may hold, chosen from the list of topics in the pertinent discipline areas.

The compulsory courses are annual (70 hours teaching), and the others may also be half-yearly (two half-year courses are equal to one annual course).

To get a diploma the student must pass the exams for the compulsory, elective and other optional courses, equivalent to a minimum of 13 and a maximum of 15 annual courses. Each Faculty decides the number. The body or University holding the Diploma course are responsible for organising a type of statistical-computer technology laboratory providing the students with professional training. Moreover, faculty supervized internships in industry or other relevant bodies may also be organized. Having passed these exams and gained some practical experience in the manner decided on by the University in question, the student must then pass the final Diploma exam. This consists of a thesis discussion of either a typical professional-type problem, a report documenting the activities performed in the laboratory or a report describing the experience or applied research performed during the intership, where this took place.

What emerges from the reform of the Diploma is the professional focus of the courses, which distinguishes this from the Degree course.

The discipline areas covered in the Diploma courses and the number of syllabus courses are shown in Table 1. As can be seen the actual topics covered distinguish the various streams. The Diploma in Statistics proposes to provide a technical- professional training based on a practical knowledge so as to be able to tackle, from an empirical stance, issues arising with regard to various phenomena as well as in different aspects of production and decision making.

The Diploma in Statistics and Computer Science for Business aims to provide a professional training and background to be used in the various sectors of the company, fusing statistical techniques and computer know-how to tackle such

areas as marketing, data control, strategy and operations, production.

Table 1 - Compulsory and elective courses for each Diploma courses and number

Compulsory courses and number		Elective courses and number			
		Diploma courses			
		Statistics	Statistics & Comp. Scie. for Business	Statistics & Comp. Scie. in Public Sect.
Disciplinary areas		*Disciplinary areas*			
Mathematics	1	Appl. Statistics*	2		
Statistics	2	Social Statistics	1		
Probability	1	Demography	1		2**
Comp. Tech.	1	Ec.& Comp. Stat.	1	2	
		Econ. & Company		2	1
		Comp. Science		1	
		General Sociology			1
		Legal			1

* Economic statistics, company statistics, demography, social statistics, biomedical statistics.
** Demography, social statistics.

The Diploma in Statistics and Computer Science in the Public Sector aims to train experts for the public sector. Statistical techniques and technology are particularly essential in central and periphery public statistics units, for economic programming and analysis, social and environmental policies, for the administrative and technological running of various intervention bodies, etc.

3.2. Degree courses in statistics

With the new reform there are now 5 as opposed to the former 3 Degree courses. The Degree in Statistical and Demographic Sciences has been changed to the Degree in Statistical, Demographic and Social Sciences (SDSS) and the content broadened. The Degree courses in Statistical and Actuarial Sciences (SAS) and in Statistical and Economic Sciences (SES) have remained unchanged in name while a Degree in Statistics and a Degree in Statistics and Computer Science for Companies have been introduced. All the courses provide a methodological and critical training as well as offer the student a professional preparation and background, open to the

wide range of cognitive and operational areas where a statistical methodology is called for.The five streams aim to provide each student with a sound knowledge of the basic logic and methodology, a critical capacity in their use and in interpreting the empirical context in question. The Degree courses are distinguished by the type of phenomena to which the method is applied. Each Degree course offers compulsory annual courses, elective annual courses and other optional courses. To get a degree the student must pass a minimum of 22 and a maximum of 24 annual syllabus courses. Each Faculty decides the number. Then the student must pass the final exam which consists of a discussion of a written thesis on a topic decided on by the student and their professor. All the streams cover the following compulsory courses: 3 in mathematics, 1 in probability, 3 in statistics, 1 in computer science. The elective courses in the various streams are shown in Table 2.

Table 2 - Elective courses for each Degree course and number

	Degree courses				
Elective Courses	Statistics	SDSS	SAS	SES	Stat. & Comp. Scie. for Companies
Disciplinary areas					
Mathematics	1				
Probability	1				
Statistics	3	1	1**	1	
Applied statistics*	1	1		1	1
Demography		2	1		
Social statistics		1			
Economic statistics			1***	2	
Company statistics					2
Comp. tech.	1				2
O. R..	1				1
Financial mathematics			4		
Financial mathematics for econ. decisions			2		
General sociology		2			
Economy		1	1	4	1
Legal		1	1		1
Company					3

* Economic statistics, company statistics, demography, social statistics (& biomedical statistics for SAS and SDSS).
** Statistics, probability.
***Economic statistics, company statistics.

From this it can be seen that the Degree in Statistics attempts to cover

aspects related to an in-depth theoretical understanding of the method from the point of view of inductive logic, as well as constituting a conceptual and practical tool in research. This necessitated expanding the syllabus to include courses to consolidate the mathematics content and the technological know-how available to statisticians. The Degree in Statistical, Demographic and Social Sciences (SDSS) covers the statistical analysis of populations and their demographic and social interpretation. The Degree in Statistical and Actuarial Sciences deals with actuarial statistics regarding insurance and finance, and comprises 11 specific courses. The Degree in Statistical and Economic Sciences aims to further a statistical understanding of the economy and the ability to act thereon. The Degree in Statistics and Computer Science for Companies (11 specific courses as SAS) is more applicative, less methodological-critical, and more geared towards company needs and the use of technology and operational research.

4. Doctor of Research courses in statistics

While the reform of the diploma and degree courses for future, prevalently technical-professional or methodological statisticians has just got off the ground, the training of future scientific researchers in statistics has been underway for some time.

In 1980 a Doctor of Research was introduced in the Italian university system, a primarily academic title within the field of scientific research. This is conferred by the pertinent Faculties or Departments and consists of a three-year post-graduate course where research methodologies and scientific training are further investigated and perfected. The Doctor of Research is conferred to those who at the end of the course achieve scientifically valid results, documented by a written dissertation. The first Doctor of Research courses were held in the academic year 1983-84. It emerges that Statistics and Demography have been central to some of these courses, both in the arranged seminars, a key feature in the training of these post-graduate students, and in the areas of research chosen for the final research thesis.

By December 1993 the community of Italian Statisticians comprises 15 Doctors of Research in demography, 18 in statistics, 29 in statistical methodology,

1 in applied statistics, 8 in computational and applied statistics. To date those with Doctors of Research tend to continue their career in the academic world, being less frequently found in companies or the public sector, perhaps due to the fact that their training is highly specialized and primarily geared towards theoretical research.

5. Conclusions

In the light of the above, the present moment could be termed a period of transition in the training of future statisticians in Italy. Currently each university is coming to grips with the new legislation, taking into account, on the one hand, the needs of the local labour market that must absorb the various types of statisticians available and, on the other, the expertise and chosen fields of research of the academic body, without overlooking the constraints imposed by the law or the flexibility this offers.

Moreover, it is also necessary to emphasize the importance of the reform from a cultural point of view. First, what should be stressed is the concern expressed by the new legislation to clearly delineate between the diploma and degree courses, the former being more technical-professional and the latter more methodological-professional. Second, the reform devotes much attention to establishing the right equilibrium between theory and applications. Finally, there is the awareness of the statistical community that the teaching of future statisticians, regardless of the depth and breadth of the methodology acquired and their critical capacity, will have achieved the target set if it succeeds both in enhancing the practical, cultural and scientific role of statistics, not only in the cultural and scientific spheres but also in society, and, in particular, if it can promote a multi-disciplinary approach to tackling problems in the real world and contribute to their solution.

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FUTURE STATISTICAL TRAINING - SOME OBSERVATIONS

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ABSTRACT

Statistical thinking and ideas have been evolving rapidly over the past few decades and will no doubt, continue to do so. The big question is whether we can predict the future direction of this evolution and plan accordingly, in training our students.

INTRODUCTION

Statistics, which has its origins in Statecraft (mainly rulers trying to gauge how much they can collect in taxes) goes back in history, perhaps several hundred years. The subject has come a long way from these modest origins, to what has become in modern times, an important tool in all scientific investigations. In generalizing from samples to the entirety through inductive logic, statistics plays an important role in the advancement of scientific theories, in virtually every field of human endeavor.

In an earlier article (Jammalamadaka, 1991), I outlined some of my views on statistical education at the University level and in particular, what we do to train students at the University of California, Santa Barbara for our Bachelor's, Master's and the Ph.D. degree programs. I will summarize some

of these ideas, since after all, these programs were put in place to train "future" statisticians. At the undergraduate level, I believe that such training should have roughly in equal parts, (i) mathematics, (ii) statistics (iii) computing, and (iv) one or more substantive areas. Mathematics is clearly a prerequisite for understanding and developing many of the analytical tools that we use. I believe statisticians, like the physicists and engineers can not have too much mathematics. Computers, besides taking the drudgery out of routine statistical analyses, have made the teaching of our subject more realistic, with real data sets. It is not too long ago that we had desk calculators with which, inverting more than a 4x4 matrix was an extremely difficult chore. Now, on the other hand, the more interesting and realistic problems in regression or response surface analysis start with that minimum dimension and can be handled routinely, thanks to computers and packaged programs. I believe strongly in statisticians learning one or more substantive disciplines, like biology, economics, etc. All of us agree that our discipline draws its strength and motivation from problems that arise in other fields. Therefore, it is only natural that we attempt to understand the language of these other disciplines before we attempt to solve their problems.

At the Master's degree level, there is scope for specialization, so that some of the students learn more mathematics and statistical theory (with the aim of eventually doing research), while others can learn more methods and computational techniques so they can become problem-solvers. Even those who pursue a Ph.D. in statistics will do well to remember that their work is not meant to embellish the subject of statistics for its own sake, but to solve practical problems dealing with the real world. The training, no matter what level, should emphasize the practical nature of our subject with real world examples, to motivate even the abstract theory.

THE FUTURE

"It is impossible to predict -- especially the future," says a Chinese proverb. But at the same time, predicting the future seems to be a relatively safe exercise, since I am told, rarely does anyone check the accuracy of such predictions. I will now make a few predictions regarding the future of our profession and these predictions, in turn, have implications for the training we provide our students.

a. More and better use of computers.

It is one of the safest bets, to say statisticians will continue using computers more and more, not only to reduce the strain of extensive calculations but to "explore" data as well as to get Monte Carlo solutions for analytically intractable problems. Many of the chores like data editing, looking for outliers, exploratory data analysis, locating influential observations, studying the effects of transformations etc. can all be done through interactive computer graphics. Increasing availability of such software enables a statistical analysis to be done interactively, in front of a terminal.

Computers can help us, through Monte Carlo or resampling techniques (jackknife, bootstrap, cross validation etc.), to explore the use of non-normal models, where the analytical methods may not be readily available. The extreme reliance on the univariate and multivariate normal model and distributions arising from it in the present day statistical analyses, can be explained by the nice analytical results one can derive for statistics based on such data. Clearly without the F- ratios and Hotelling's T^2 etc., our pre-computer age would have been a nightmare. But now, resampling techniques like bootstrap can be used in a wide variety of contexts and models as well as in semiparametric and nonparametric situations. This

trend towards greater use of the computer to free us from the traditional assumptions, will continue. The implication in terms of student training is that we should ask our future statisticians to be extremely computer-literate- not only know standard packages like SAS or BMDP but programming or semiprogramming languages l such as the S, Mathematica, Gauss, LISP-STAT . See e.g. Becker et al(1988), Tierney (1990).

I would not go.so far as to say that anytime soon an expert system in statistics will eliminate the need for consulting a real live (and smart) statistician. Indeed there is a real possibility that a computer and a statistical package in the wrong/ill-trained hands can pose a hazard to the profession and bring us all a bad name.

b. Less reliance on mathematics and more interaction with substantive disciplines.

We all recognize, no matter how high (or low) level mathematics we use, finally what counts in statistical research are the statistical ideas and how these can be successfully applied. It is somewhat unfortunate that during the past 2 or 3 decades, especially on the American scene, there has been an overemphasis on the highly technical and mathematical statistics (or statistical mathematics?). There is also general awareness that research in our discipline, unlike in many other basic sciences, makes sense only if it solves a problem in some other discipline. The best scientific and/or statistical investigation is often carried out by a biologist, a geologist or a physician, teaming up with a statistician, who speaks their language. If we continue to train statisticians within the confines of mathematics departments, who try to prove very general theorems under the weakest assumptions but whose applicability is nil, statisticians will become second rate mathematicians and cease to be useful. We need to train team members who can participate in scientific inquiries as full partners. In my own personal experiences, I found it tremendously rewarding to participate in the

field trips and the scientific work of a group of scientists (geologists, environmentalists etc.), advising them, starting with the sample-size and design issues and finally work on the data analysis. In one case involving paleocurrent analysis, each step along the way, required having to think anew and sometimes having to do substantial new research in statistics since the observations being collected were "directional data", to which the "linear" methods of analysis did not apply.

c. More emphasis on non-normal modeling.

More and more, we should incorporate methods of statistical analyses that go beyond the Gaussian distribution. As mentioned before, computers have freed us somewhat from having to have a neat closed form expression for everything before we use a statistical technique. This trend will lead us towards more sophisticated and complex parametric modeling (sometimes for specialized uses such as Cox regression models, generalized linear models, state-space modeling, EM algorithm etc.), as well as towards more semiparametric and fully nonparametric modeling (nonparametric regression, functional estimation etc.). In our teaching, we could move more rapidly through the normal and related models, to make space for these new ideas.

d. Statistics without statisticians and on-line data processing..

Because of the technical and technological revolution sweeping us, it is estimated that our knowledge base is doubling every 17 years. If this pace keeps up in our own discipline, there will be further fragmentation of the subject and as a result, even more narrowly trained specialists. Data is being collected at even more furious pace. For instance, the National Aeronautics and Space Administration in the USA, through it's' satellites, gathers data at a rate that can not be processed in any meaningful way in real time. Geographical Information Systems, that combine data on say health,

environment etc. with the geographical or spatial information, are proliferating faster than any statisticians or other scientists can adequately study and analyze them. The best one can hope for, with such vast amounts of data, is some sort of automated real-time "on-line processing", providing brief summaries, displays and giving one the ability to catch "out of the ordinary" events. Most such analyses will probably not involve statisticians directly.

CONCLUSIONS

Computing is becoming more and more central to our profession and it opens up new opportunities for the kinds of statistical analyses one can do. Statisticians should become expert at one or more substantive disciplines and contribute to the advancement of science through team work with other scientists. Thus, the training of future statisticians should involve more computing, somewhat diminished emphasis on mathematical work and gaining expertise in one or more substantive disciplines.

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Propositions et Perspectives pour la Formation des Statisticiens-Economistes

Enseignement de la Statistique à l'ENSAE-PARIS

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Dans notre exposé nous allons présenter la formation des Statisticiens Economistes telle qu'elle est conçue actuellement à l'Ecole Nationale de la Statistique et de l'Administration Economique (E.N.S.A.E. - division S.E.A.) à Paris.

Notre exposé sera composé des parties suivantes :

1. Recrutement des Elèves
2. Programme d'Enseignements Généraux
3. Les Options
4. Supports d'Enseignement et Contrôles
5. Perspectives

I. Recrutement des Elèves

La scolarité au sein de l'Ecole se fait en trois ans, néanmoins un certain nombre d'élèves sont admis, sous certaines conditions, en deuxième année.

En première année d'Ecole, on distingue deux filières, correspondant à deux recrutements distincts, sur 2 concours distincts.

a- La filière "Economie"

Les élèves viennent en général des classe préparatoires Khâgnes S, HEC, ou bien ont préparé une licence ou une maîtrise d'économie, ou bien sont des élèves administrateurs (appartenant à la Fonction Publique Française) recrutés par concours externe ou interne.

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b- La filière "Mathématiques"

Les élèves ont suivi des classes préparatoires de Mathématiques Spéciales M', ou bien sont recrutés sur titre avec une maîtrise à dominante mathématiques.

Les formations des élèves correspondant à ces deux types de recrutement étant différentes, la première année de l'Ecole a pour but de leur offrir un enseignement diversifié afin de les amener à un même niveau de connaissance en fin de première année.

En seconde année d'Ecole, on trouve les élèves rentrés la première année, et des élèves provenant soit de l'Ecole Polytechnique, soit de l'Ecole Normale Supérieure, soit des élèves titulaires d'une double maîtrise de mathématique et d'économie.

La troisième année ne recrute pas d'élèves extérieurs, néanmoins, certains cours peuvent être validés pour des étudiants qui suivent des CESS ou le MASTER d'économie et de modélisation ainsi que des DEA de Statistique ou d'Economie, extérieurs à l'Ecole, suivant des conventions particulières, (ceci ne permet pas à ces étudiants extérieurs de prétendre au diplôme de l'Ecole).

On constate ainsi une grande diversité dans le recrutement des élèves de l'Ecole. Le but étant de former des jeunes ayant un savoir pluridisciplinaire, qui leur permette de s'adapter à des situations diverses. Comme nous allons le voir, les enseignements de première et deuxième années doivent leur donner des bases solides dans les deux disciplines Statistique et Economie, la troisième année leur permettre de se spécialiser dans l'un ou l'autre de ces domaines.

Annexe: Recrutement 1993.

II. Programmes d'Enseignements Généraux

Durant les deux premières années, les cours de base se répartissent suivant les 3 disciplines Mathématiques, Statistique et Economie. En première année, on trouve une répartition différente suivant les 2 filières ci-dessus mentionnées.
L'enseignement de la statistique dans l'école est fondamental. en première année il a pour objectif de dournir les bases des connaissances probabilistes et statistiques. En 2ème et 3ème années il ne peut pas être dissocié de la formation complémentaire que les élèves reçoivent en économie, ainsi que des filières choisies et du type de débouchés que les élèves souhaitent
Nous précisons maintenant comment s'organise cet enseignement dans le contexte global de chaque année.

1. Première année "Economie"

Durant cette année, l'accent est essentiellement mis sur une remise à niveau des élèves en mathématiques. La répartition des enseignements est alors la suivante : 60% en mathématiques, 25% pour la probabilité et la statistique descriptive, 15% pour la formalisation économique.

Les élèves suivent un cours de Probabilité ainsi qu'un cours d'introduction aux Statistiques Descriptives. Les enseignements de mathématiques comportent un cours d'Analyse, un cours de Calcul Différentiel, Intégral et Optimisation, un cours d'Algèbre et un cours de Topologie.

En économie, les élèves suivent deux cours, un de formalisation micro-économique et un de formalisation macro-économique.

2. Première année "Mathématiques"

Pour les élèves qui appartiennen t à cette filière, l'accent est plutôt orienté sur l'enseignement des probabilités et de la statistique (40%), de l'économie (40%), avec un faible enseignement de mathématiques (20%). Les élèves reçoivent deux cours de Probabilités, un cours de statistique descriptive, un cours d'Analyse des données et un cours de sondage. Ils suivent aussi un cours de topologie et d'analyse convexe, un cours de calcul différentiel et d'optimisation, ainsi qu'un cours d'introduction à l'analyse numérique matricielle. L'enseignement de l'économie a pour but de donner aux élèves une culture économique de base: ils ont deux cours d'économie descriptive, l'un orienté sur les structures de l'économie nationale, l'autre sur l'étude des institutions et des échanges internationaux, qui sont suivis d'ateliers d'économie descriptive et d'un cours sur l'économie et la société en France. Ils suivent aussi des cours d'initiation l'un à la microéconomie, l'autre à la macroéconomie et un cours de comptabilité générale d'entreprise, et de comptabilité nationale.

3. 2ème année

La plupart des cours de deuxième année sont communs à l'ensemble des élèves. Certains cours sont cependant réservés aux élèves rentrant directement en deuxième année : ils ont lieu dans les premiers mois de l'année scolaire et visent à compléter la formation de ces élèves dans certains domaines spécifiques. Il s'agit des cours de statistique descriptive, de compléments de probabilités et d'informatique.
Les élèves issus de la première année "Economie" suivent, en commun avec les deuxièmes années "directes", quatre cours: analyse de données, comptabilité nationale, sondage et comptabilité générale d'entreprise.

C'est au cours de la deuxième année que les élèves de la Division SEA reçoivent le noyau central de leur formation dans les trois grandes filières qui font la spécificité de l'ENSAE: statistique et économétrie, microéconomie, et macroéconomie. Les enseignements de la deuxième année cherchent également à compléter la culture des élèves dans des domaines connexes, à les aider à maîtriser l'expression écrite et orale, et à leur faire réaliser leurs premiers travaux appliqués importants.

L'enchaînement des trois cours de statistique mathématique, d'économétrie et de séries temporelles donne aux élèves une formation solide pour aborder en troisième année les applications de statistique, d'économétrie et de finance.

Ces cours théoriques sont complétées par les groupes de statistique appliquée, constitués de quelques élèves et d'un animateur autour d'un sujet proposé par celui-ci. Chaque groupe doit analyser un problème réaliste au vu de données qui lui ont été fournies en début d'année ; les techniques utilisées relèvent en général de la statistique descriptive, de l'analyse des données de la modélisation et des tests, et utilisent les différents outils informatiques de l'école.

Les enseignements de microéconomie comportent également des cours théoriques et des cours plus proches de la vie des entreprises. La partie théorique consiste en des cours de microéconomie. Les cours d'introduction, à la comptabilité analytique, et au contrôle de

gestion et d'analyse financière, et au diagnostic d'entreprise visent, en revanche, à sensibiliser les élèves à l'importance de certains indicateurs chiffrés pour les dirigeants des entreprises.

Les cours de macroéconomie constituent l'ossature des enseignements de macroéconomie. Un cours introduit aux mécanismes monétaires et financiers présentant le système bancaire et les marchés de capitaux. Un cours d'histoire des faits économiques permet aux élèves d'acquérir une vue perspective sur l'évolution des grandes économies aux XIXe et XXe siècles, notons aussi un cours de "devoirs et d'exposés d'économie.

III. Les Options

Comme nous l'avons vu précédemment, les élèves de cette école sont iuuss de formations très diverses. Si les deux premières années ont pour but de leur donner un "background" de connaissances classiques tant en statistiques qu'en microéconomie, la spécificité de l'Ecole est de permettre aux étudiants de choisir une formation finale fonction de leurs intérêts particuliers et de leurs compétences particulières.

Ainsi la troisième année propose aux élèves sept voies d'approfondissement : Econométrie et Séries Temporelle, Analyse et Production Statistique, Informatique et Recherche Opérationnelle, Modélisation et Politique Macroéconomique, Economie Industrielle et Microéconomie Appliquée, Finance et Actuariat, Economie du développement. L'enseignement comprend 150 à 200 heures de cours.

Les étudiants sont libres du choix de leurs enseignements parmi un très grand nombre d'options. Dans chaque voie, il existe un certain nombre de cours optionnels fondamentaux. Il est souhaitable que chaque élève suive la presque totalité des cours d'une voie d'approfondissement, qui lui servira ainsi de formation principale en sa dernière année d'études.

Si la maîtrise d'une spécialité est fortement recommandable, il semble également important que l'élève ménage l'équilibre de sa formation de statisticien-économiste en complétant les cours de sa voie d'approfondissement principale par des enseignements d'économie si celle-ci est à dominante statistique, ou par des enseignement de statistique ou d'informatique si elle est à dominante économique.

Nous allons développer maintenant la formation de trois des sept voies d'approfondissement où les statistiques jouent un role non négligeable: la voie "Econométrie et Séries Temporelles", la voie "Analyse et production statistique" et la voie "Finance et Actuariat".

1. "Econométrie et Séries Temporelles".

La voie d'approfondissement "Econométrie et Séries Temporelles" propose une formation approfondie à la théorie et à l'application des méthodes récentes les plus utiles à l'analyse statistique des phénomènes économiques, en portant un intérêt particulier à celles qui ont une dimension temporelle.

Cette voie d'approfondissement comporte trois cours d'économétrie. Les deux premiers, compléments d'économétrie linéaire et d'économétrie non linéaire, complètent la formation reçue par les élèves en deuxième année en méthodes statistiques de l'économétrie. Le premier de ces deux cours joue le rôle de cours optionnel fondamental. Son programme débute par l'éude des modèles d'analyse de variance et de covariance, avec des rappels sur les

propriétés essentielles du modèle linéaire. Il porte ensuite sur les modèles de panel et les modèles à équations simultanées et conclut par une introduction aux méthodes d'estimation des modèles non linéaires. Le second des cours théoriques d'économétrie se consacre aux modèles pour variables qualitatives ou tronquées. Une part importante de cet enseignement traite des modèles de déséquilibre et des modèles de durée. A côté de ces nouveaux développements, un cours entier est consacré à l'économétrie appliquée : à partir de plusieurs thèmes économiques, on insiste sur les choix de modélisation et sur leur validation empirique, les nouvelles techniques d'analyse et de prévision des séries chronologiques, sont enseignées aux étudiants.

Les étudiants peuvent en particulier choisir entre plusieurs cours spécifiques dont : un cours sur la théorie des processus aléatoires du second ordre qui propose une approche théorique rigoureuse des fondements statistiques des séries temporelles ; un cours d'analyse multivariée stationnaire qui explicite les fondements théoriques des techniques de prévision développées par Box et Jenkins. Ce cours présente de manière générale la modélisation dynamique et les résultats économétriques associés dans le cadre stationnaire ; un cours d'analyse des séries non stationnaires qui complète le précédent cours dans un cadre non stationnaire. Ce cours s'intéresse aux nouveaux domaines ouverts par les techniques de co-intégration et de tests de racine unité pour la spécification et l'estimation des modèles dynamiques ; un cours de séries chronologiques non linéaires qui présente quelques modèles non linéaires (bilinéaires, à seuil, ARCH) dans leurs aspects probabilistes et statistiques, ainsi que leurs applications en économie et finance ; un cours de méthodes économétriques récursives et simulées qui montre comment les moyens de calcul actuels permettent de perfectionner la modélisation économétrique et les techniques d'estimation.

2. Analyse et Production Statistique

L'étude des techniques mises en oeuvre dans la collecte des données, puis dans leur analyse, fait l'objet des enseignements de la voie d'approfondissement intitulée "analyse et production statistique", dont le champ d'application s'étend bien au-delà de l'économie.

La collecte des données socio-économiques se réalise généralement par sondage. Le cours de sondages dresse un cadre méthodologique où l'élève apprend à définir avec rigueur un protocole d'échantillonnage adapté aux diverses applications possibles et où il acquiert les outils statistiques nécessaires à l'estimation des grandeurs mesurables et à la détermination des erreurs aléatoires. Les élèves intéressés par ces outils peuvent aussi bénéficier du séminaire de sondages.

En liaison étroite avec le cours précédent, le cours de sociologie appliquée a pour objet de décrire complètement les différentes étapes de la réalisation d'une enquête sociologique : de la conception du questionnaire et du plan de sondage, à l'analyse en passant par l'organisation de la collecte sur le terrain et la définition du chiffrement et de la saisie. Il est le complément logique, tant du cours de sondages que du cours de sociologie de deuxième année.

Enfin, le cours de statistique des populations développe tout un ensemble de techniques récentes et de modèles utilisés en démographie et épidémiologie. Il apporte tout à la fois un éclairage différent et un prolongement du cours de démographie enseigné en deuxième année, en tirant profit des connaissances acquises en statistique et économétrie en deuxième année.

La deuxième partie de cette voie d'approfondissement est consacrée au traitement des données. Pendant les deux premières années de scolarité ont eu lieu des enseignements théoriques et appliqués d'analyse des données. Le cours d'analyse de données approfondie

proposé ici vise à apporter des compléments de connaissances dans ce domaine de la méthodologie statistique. En particulier, il aborde de manière originale les liens qui unissent les méthodes dites "françaises" et l'analyse "multivariée" des anglo-saxons.

Le cours d'algorithmique numérique vise à initier les élèves aux modes de traitement des grands ensembles données et aux méthodes de calcul intensif sur ordinateur. Ce cours se fixe pour objectif d'aider les élèves dans leur compréhension des méthodes et des algorithmes, notamment quant à leurs degrés réels de précision et de stabilité.

Les cours de statistique mathématique de deuxième année ne traite que des modèles statistiques paramétriques qui reposent sur la donnée d'une structure bien définie. Ces hypothèses sont remises en cause dans le cours de statistique non paramétrique qui présente les méthodes d'estimation et de test dans ce contexte. Le cours de statistique robuste vise quant à lui à étudier les propriétés de stabilité des statistiques classiques optimales lorsqu'on s'écarte légèrement de la loi spécifiée.

3. Finance et Actuariat

La formation à la finance et à l'actuariat comporte trois volets. Une forte composante de mathématiques financières et d'économétrie apporte les compléments théoriques utiles à tous les métiers de la banque et de l'assurance. Puis viennent des enseignements de spécialisation en finance ou en actuariat, d'ordre technique ou institutionnel.

Les cours d'instruments, calcul et marchés financiers permet d'acquérir les techniques fondamentales de l'actualisation et de l'évaluation des risques et passe en revue sous un aspect pratique les principaux produits. Les cours de sélection de portefeuille et valorisation par équilibre et d'approches par arbitrage présentent les principales techniques de valorisation d'actifs financiers en temps discret. Les méthodes permettant de les mettre en oeuvre et de tester leur validité sont étudiées dans le cours d'économétrie de la finance. Le cours de calcul stochastique appliqué à la finance donne aux élèves les outils mathématiques nécessaires à la valorisation d'actifs en temps continu et en présente les principales applications. Enfin, le cours de statistique de l'assurance présente dans un cadre dynamique les méthodes de constitution de classes de risques et le calcul des primes associées.

Les problèmes spécifiques aux marchés du crédit sont étudiés par les cours de sélection de clientèle et risque de défaillance et de titrisation et remboursements anticipés.

Les méthodes de l'analyse microéconomique, dont l'acquisition s'est faite en deuxième année, sont utilisées dans cinq enseignements. Le cours de théorie microéconomique de l'assurance I développe une modélisation des phénomènes propres à l'assurance (sélection de risque, incertitude sur le comportement, ...) et permet de mettre en regard, en matière de concurrence et de réglementation, les résultats déduits des modèles et les pratiques observées. Le cours théorie microéconomique de l'assurance II approfondit ces concepts dans le domaine intertemporel, à la lumière des récents développements de la théorie des contrats. De même, le cours de théorie microéconomique de la banque modélise le comportement des organismes bancaires (en particulier l'intermédiation financière, le fonctionnement du marché du crédit, la réglementation). Le cours de théorie de la structure financière des sociétés étudie les choix financiers des entreprises quand les marchés de capitaux sont imparfaits. Enfin, le cours de microéconomie des marchés financiers utilise les concepts de l'économie de l'information pour analyser les marchés financiers d'un point de vue normatif. Le cours sur les marchés de

capitaux en étudie le fonctionnement, les mutations récentes et les problèmes posés par leur développement. Le cours de droit bancaire et de l'assurance décrit l'environnement juridique du métier de financier ou d'actuaire. Plusieurs cours à plus fort contenu réglementaire et institutionnel complètent la formation dans le domaine de l'assurance : théorie du risque et réassurance, actuariat de l'assurance dommages et assurance vie et assurance par répartition. Enseignés par des professionnels, ils permettent d'acquérir une bonne connaissance du contexte institutionnel et technique dans lequel évolueront les futurs actuaires.

Cette voie d'approfondissement a été mise en place en coopération avec l'Institut des Actuaires Français, afin de permettre à certains élèves d'en devenir membre diplômé dès leur sortie de l'Ecole. Les actuaires sont le spécialistes de l'évaluation du risque, traditionnellement dans les compagnies d'assurance, mais leur champ d'activité s'est élargi aux banques, aux organismes financiers et même aux entreprises industrielles.

IV. Supports d'enseignement et Contrôles

1- 1ère année

Indépendamment des examens relevant de chaque enseignement, les étudiants en 1ère année font un stage en entreprise d'un mois, type stage ouvrier avec découverte d'entreprise. D'autre part, ils doivent faire un mémoire d'économie descriptive.

2- 2ème année

Durant cette année, les élèves font un mémoire de statistiques appliquées avec traitement de données qui a essentiellement pour but de leur apprendre à manipuler le logiciel SAS et de mettre en oeuvre les techniques de modélisation et de tests. Ils effectuent un stage de 2 à 3 mois en entreprise en fin de 2ème année avec soutenance au début de la 3ème année.

3- 3ème année

Les étudiants peuvent s'inscrire à un groupe de travail, en général, encadré par un responsable extérieur à l'ENSAE. L'encadrement est de 40 à 60 heures sur l'année. Ce travail peut être théorique ou sur des données à traiter. Un prix est remis au meilleur groupe de travail.

Ainsi à la fin de ces trois années les étudiants, par les différents enseignements de statistiques et de probabilité reçus, tant théoriques qu'appliqués, et par les différents stages, mémoires ou groupes de travail qu'ils ont suivis, ont une bonne connaissance en tant que théoricien et que praticiens des données statistiques.

Ils ont d'autre part été amenés à se servir de matériel informatique assez complet: gros systèmes ou micro ordinateurs. Ils ont eu aussi à manipuler à la fois des logiciels comme SAS ou des séries temporelles comme STATGRAPHICS ou ANAR.

Il est très important de noter que le support informatique est fondamental dans la formation de tout statisticien quelque soit son domaine d'application.

V Perspectives

Notons tout d'abord que les élèves qui sortent de l'ENSAE trouvent assez facilement des places sur le marché du travail. On peut succintement noter deux types de débouchés:

1- Les élèves ayant passés le concours administrateurs vont travailler à l'INSEE ou dans des services relevant de l'INSEE, ou dans d'autres administrations.

2- Les élèves statisticiens-économistes trouvent à présent facilement du travail. Les entreprises d'accueil sont nombreuses et diversifiées : banques, assurances, EDF, entreprises de pétrôle, de gaz, transports, sociétés de conseil, recherche, organismes internationaux.

Néanmoins un problème lié à la diversité de recrutement des élèves est celui de l'hétérogénéité du niveau de ceux-ci suivant leur formation de base. Ainsi l'école est de manière continuelle, tout en maintenant une certaine uniformité, soumise à repenser l'organisation de ses enseignements afin d'aménager au mieux possible ceux-ci en fonction de la demande. Dans ce contexte, il est prévu de réorganiser les enseignements de deuxième année pour la rentrée prochaine en proposant aux étudiants le choix entre une voie "courte" et une voie "longue" de statistiques, (et la même chose parallèlement en économie), où la base des cours dans ces deux disciplines passerait de 60 heures à, soit 40 heures, soit 80 heures. Les étudiants choisirait la voie en fonction de la connaissance qu'ils ont de leur cursus précédent, étant entendu que certaines voies permettraient de suivre plus facilement certains enseignements de la troisième année. Il est important de noter que les étudiants restent toujours maitre de leurs choix.
Cette réforme permettrait pour l'enseignement de la statistique de proposer aux étudiants des cours moins dispersés qui auraient une plus grande cohérence dans leur contenu, en particulier pour l'approche des séries temporelles. La voie courte conduirait à une présentation succinte des processus du second ordre avec comme exemple les processus ARMA, la voie longue permettriat d'approfondir cette approche avec l'approche économétrique.

On espère ainsi permettre aux étudiants qui choisiront l'une ou l'autre de ces voies de pouvoir être encore plus performants en troisième année et pour certains de s'orienter dès la deuxième année vers des DEA, ou d'être plus ouverts aux problèmes de la recherche.

L'enseignement de la Statistique aux Statisticiens Economistes : sur l'Expérience Marocaine

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1- Introduction

L'expérience marocaine de l'enseignement de la statistique aux statisticiens économistes s'étend à présent sur prés d'un tiers de siècle. Elle peut être subdivisée en cycles d'une périodicité approximativement décennale. Chacun de ces cycles comporte quatre parties d'importance plus ou moins égales relatives respectivement à : la réflexion, la restructuration, la mise en oeuvre et au perfectionnement des structures élaborées. Ainsi quatre périodes correspondant aux décennies 1960, 1970, 1980 et 1990 sont analysées ici.

2- La décennie 1960

1960 correspond à la décennie du développement. L'objectif principal poursuivi alors notamment dans les pays en développement était la formation des cadres nationaux pour les organismes presque exclusivement officiels de statistique et de planification.

Les tâches essentielles de ces cadres étaient alors principalement la collecte des données statistiques de base et leur synthétisation pour l'élaboration des plans de développement économiques et sociaux.

L'étape de réflexion et de création d'une structure de formation de cadres répondant à ce besoin peut être identifiée à la période allant de 1961 à 1967. 1961 correspond à la date de création du CFITS (Centre de Formation des Ingénieurs des Travaux Statistiques) de Rabat. En 1967 l'Institut

National de Statistique et d'Economie Appliquée INSEA se substitue au CFITS.

Ainsi, les enseignements de la statistique et de l'économie appliquée ont été liés dès le départ et le texte de création de l'INSEA précise que l'Institut "assure la formation des cadres supérieurs et moyens dans les domaines de la statistique et de l'économie appliquée destinés à servir dans les administrations publiques et dans le secteur privé [11].

Les programmes d'enseignement de la statistique de l'INSEA : cours, travaux dirigés, séminaires, conférences, groupes, stages pratiques sur le terrain étaient essentiellement centrés sur l'élaboration des statistiques de base : questionnaires d'enquêtes lourdes et recensement nationaux, organisation des tabulations dépouillements exploitations et publications d'opérations d'envergure sur des thèmes nationaux, régionaux et sectoriels.

La période allant de la création de l'INSEA à sa substituant au CFITS à la fin de la décennie 1960 correspond au renforcement de l'ensemble des structures de l'INSEA, de l'amélioration de ses programmes et du perfectionnement de ses enseignants marocains destinés à prendre la relève de leurs homologues professeurs des Nations Unies.

3- La décennie 1970

La réflexion sur la restructuration des enseignements de l'INSEA peut être caractérisée par les résultats des travaux du comité consultatif de l'INSEA en 1971. En effet, 1971 coïncidant avec la 10° année de création de l'INSEA, le Comité Consultatif a été élargi à des personnalités nationales et internationales pour analyser ce qui a été réalisé et proposer des mesures propres à une amélioration et à un perfectionnement ultérieurs.

Pour la restauration comme pour l'amélioration et le perfectionnement des structures existantes trois éléments peuvent être notés : l'allongement de la période des études, la vocation de formation d'analystes spécialistes et enfin l'introduction de l'informatique. Ainsi, le cycle des Ingénieurs d'Application de la Statistique (IAS) a été renforcé notamment par le

développement de l'enseignement de l'informatique [2], [3] et par la création d'une option actuariat au sein de ce cycle IAS introduisant ainsi de nouvelles matières de statistique pour les statisticiens économistes.

La création du cycle des Ingénieurs Statisticiens Economistes (ISE) proprement dit a eu lieu en 1974 en coopération avec le Canada. Ce cycle ISE d'une durée d'études de deux ans après le cycle des Ingénieurs d'Application de la Statistique [2], [5] a visé plusieurs objectifs dont notamment : renforcer la formation théorique des lauréats de l'INSEA, ouvrir la possibilité de former des analystes spécialistes statisticiens économistes, initier au travail personnel d'études et de recherche traduit pour la réalisation d'un mémoire de fin d'études où toutes les matières de l'enseignement de la statistique depuis l'élaboration statistique, le calcul des probabilités, la statistique mathématique peuvent trouver des applications concrètes et originales. Certains mémoires de ce cycle ISE au cours de la décennie 1970 ont même eu pour thème à dominante majeure l'information.

C'est au cours de cette décennie 1970 que le passage de la formation de techniciens de la statistique et de l'économie appliquée à celui d'analystes voire de spécialistes statisticiens économiste a été étudié et mis en oeuvre à l'INSEA.

4- La décennie 1980

La décennie 1980 correspond à la période de préparation et de mise en oeuvre en 1983 du programme d'ajustement structural au niveau-économique au Maroc et par conséquent à la libéralisation et l'ouverture plus marquée de l'économie marocaine de même que le secteur privé à s'affirmer comme moteur de l'économie à la place du secteur public. La réflexion pour une formation plus adaptée à la nouvelle situation économique est menée à tous les niveaux et notamment au sein du Conseil de Perfectionnement de l'INSEA en 1981 et au cours des journées maro-canadiennes de statistique et d'économie appliquée en 1982 [5].

La décennie 1980 peut être caractérisée à l'INSEA par la recherche d'un nouveau souffle, d'une dynamique de formation ayant une plus grande harmonie avec un environnement en profonde mutation : l'administration de tutelle de l'INSEA cédant la place de principal utilisateur des lauréats de l'Institut, le secteur privé n'assurant pas encore effectivement le moteur de l'économie marocaine en affichant des objectifs précis et emettant des messages et signaux nets, les étudiants de l'INSEA de "fonctionnaires étudiants" évoluant avec difficulté vers le statut d'étudiants statisticiens économistes à la recherche d'emploi dans un marché de travail encore en formation ... De cette décennie 1980 quelques éléments peuvent être mis en évidence notamment : la consolidation de la formation des statisticiens économistes, le renforcement de certaines displines et des réflexions menées sur d'autres possibilités de cycles d'enseignement.

La formation des ingénieurs statisticiens économistes a mûri au cours de cette décennie 1980, s'est consolidée et s'est fait connaître. Les matières qui ont été renforcées à l'INSEA au cours de cette période sont principalement l'informatique et la démographie.

Ces deux matières ont à leur tour renforcé de manière directe et indirecte l'enseignement de la statistique aux statisticiens économistes.

Parmi les réflexions menées sur l'introduction d'autres options à l'intérieur du cycle des Ingénieurs Statisticiens Economistes il y a lieu d'en noter principalement deux : l'une concerne l'actuariat l'autre l'analyse et la gestion des projets économiques. La première a une implication directe sur l'augmentation des matières statistiques et l'autre introduit une approche plus économique de certains matières (étude de marchés, analyse de la demande ...)

5 - La décennie 1990

Cette décennie correspond à la période de réforme de l'ensemble de la formation à l'INSEA en général et du cycle des ingénieurs statisticiens économistes en particulier et par conséquent de l'enseignement de la statistique aux statisticiens économistes. Parmi les éléments essentiels de cette

période il y a lieu de noter : l'intervention des différents départements en particulier de la statistique de l'INSEA dans l'élaboration des programmes d'enseignement aux ISE, la réorganisation du cycle ISE et le rôle de la recherche scientifique dans les nouvelles structures d'enseignement.

Certes, l'organisation des départements d'enseignement a été discutée au sein de l'INSEA depuis les années 1970 mais c'est en 1990 qu'ils furent institués officiellement et mis en place effectivement en 1991. La recherche d'un meilleur enseignement de la statistique aux statisticiens économistes est donc une tâche majeure du département de statistique INSEA.

Les différentes matières de statistiques peuvent être distinguées en trois grands groupes : Introduction générale à la statistique, matières de formation de base (probabilités, statistique mathématique) et enfin enseignement d'option voire de spécialisation de statistique avancée, éventuellement, pour chercheurs en statistique et économie appliquée. La dynamisation de la recherche scientifique étant un des objectifs majeurs de la nouvelle réforme il y a lieu d'organiser à côté des enseignements classiques de statistique des séminaires, ateliers voire des laboratoires de recherche dans les domaines très vastes de la statistique (suivi des différents indicateurs économiques et sociaux ...). Le support de publication la revue de l'INSEA existe déjà depuis 1977, [8].

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Résumé

Dans l'étude de l'enseignement de la statistique aux statisticiens économistes ISE de l'INSEA, Rabat, MAROC quatre périodes décennales ont été distinguées : 1960 période de création et de structuration de l'INSEA. 1970 période de passage de la formation de techniciens à celle d'analystes statisticiens économistes. 1980 période de consolidation et de maturation du cycle ISE.1990 période de réforme de l'INSEA pour former les statisticiens économistes pour l'après l'an 2000 ouverts à la recherche scientifique.

Mots clés

Enseignement de Statistique, Formation de Statisticiens, Ingénieur Statisticien Economiste, INSEA RABAT, Recherche.

Summary

In the study of teaching statistics for economic statisticians ISE of the INSEA, Rabat, Morocco four decennal periods are distingued : 1960 period of creation and struration of the INSEA. 1970 period of the passage from trainaing technicians to theaching analyst economist statisticians. 1980 period of consolidation and maturation of the cycle of ISE. 1990 period of reform of the INSEA for teaching economist statusticians for after the year 2000 open for the sceintific research.

SUR L'ENSEIGNEMENT DE L'ECONOMETRIE: PROBLEMES ET PERSPECTIVES

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L'économétrie est une science empirique dans le sens où les concepts qu'elle emploie ont des répercussions observables. Dés lors, l'identification du PGD (processus générateur de données) économique est le but de la modélisation. C'est une tâche difficile surtout lorsqu'on essaie de concilier une théorie a priori et les données de l'observation.

Ces dernières années ont vu apparaître sur la scène un débat sur l'enseignement de l'économétrie: faut-il enseigner les méthodes économétriques ou la méthodologie ? C'est à la suite des récents développements dans les statistiques mathématiques et l'informatique que plusieurs méthodologies se sont développées. Les plus connues sont celles de HENDRY,SIMS,LEAMER et SARGENT. Ces différentes méthodologies se distinguent les unes des autres en fonction de plusieurs critères notamment la référence aux données statistiques et à la théorie économique.

Le propos de cette note est de (i) mettre l'accent sur la pratique économétrique traditionnelle tout en montrant que les difficultés qui émergent sont dues essentiellement à des caractéristiques intrinsèques de la statistique d'une part et de la théorie économique d'autre part (ii) présenter, discuter et comparer quatre méthodologies économétriques en fonction de deux ensembles de critères (statistiques et économiques) et finalement (iii) monter de quelle façon l'enseignement des méthodes économétriques peut être combiné avec celui de la méthodologie (économétrique) de manière à surmonter les inconvénients de la pratique économétrique actuelle. Cela permettra aux étudiants de mieux jauger et apprécier les mérites et les inconvénients de différents points de vue et tirer les conclusions nécessaires de ce genre de débats. Les étudiants seront plus aptes à doser le degré de subjectivité dans ce genre de pratique. Aussi seront-ils conscients du rôle des hypothèses instrumentales (de travail) quand ils confrontent une théorie aux données de l'observation... Bref, nous plaidons pour l'enseignement des principes de l'économétrie aux étudiants, en partie, d'un point de vue d'un spécialiste de la méthodologie.

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Recent Developments in the Statistics Curriculum at the Budapest University of Economic Sciences (Abstract)

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Statistics has been traditionally a compulsory two-semester subject at our university. It has to be taken up by our students in the second year of their studies upon completing a one-semester calculus and a one-semester linear algebra course. Probability theory is offered for them just when they begin studying statistics.

We are offering this course in order to provide our students with a thorough understanding of the basic statistical concepts and principles, but also with the skills enabling them to perform simpler analyses alone and to interpret the results of some more complicated analyses correctly.

To achieve these objectives, in our new curriculum we lay more stress than usual on the statistical mapping of the real world and also on the various means of data acquisition. Index numbers and some other useful methods of comparison over time or space get also more importance in our teaching than in other curricula. Finally, besides making the students familiar with the most frequently used other statistical techniques we also devote an entire chapter to the description of the information system of official statistics and to some ethical issues of statistical activity.

In the paper I will give some more detailed information on the content and structure of our new curriculum and also on the ways of teaching it.

THE EUROSTAT PROJECT "TRAINING STATISTICIANS FROM THE REPUBLICS OF THE FORMER SOVIET UNION"

by Alex ZIVODER and Rudolf TEEKENS

SUMMARY

The end of the last decade saw the start of a generalised transformation process of all Eastern European countries and, among them, of the (then called) Soviet Union. The Commission of the European Communities helps to contribute to the on-going restructuring in the Republics of the former Soviet Union (FSU) through sectoral programmes of co-operation monitored by its Directorate General I responsible for foreign relations. Statistical information systems form one of these sectors and are dealt with by two parallel and interrelated programmes: a technical assistance programme on the one hand, a (formal) professional training programme on the other. Both programmes are run under the supervision of Eurostat (Statistical Office of the European Communities), the training side being under the technical responsibility of the "Training of European Statisticians" (TES) project.

The paper presented at the conference will focus on the main characteristics featuring in the TES training programmes, namely their objectives, target groups, programme of courses, etc. Two specific aspects for FSU Republics will, however, be introduced in more detail: the FSU statistical offices environment and the training approach.

1. The economic and political changes which are taking place in FSU Republics have several destabilising effects on their statistical systems which all need to be dealt with in the short time and under difficult conditions. New fields need to be observed by the public statistician, new actors enter economic life, new statistical tools and techniques need to be mastered. One of the first tasks when setting-up the TES-FSU training programme was to have clear indications on the statistical fields in which training was felt as the highest priority. Special attention will be given in the paper to this issue.

2. One of the distinguishing features of FSU statistical systems lies in their organisation and size. A programme which aims only at training operational staff would fail because of the large gap between training supply on the one hand and training demand on the other. This is why this first approach which is developed in a (sub) programme of short-term courses (max. 3 weeks) dealing with practical statistical issues is combined with a (sub) programme of medium-term courses (max. 1.5 months) whose objective is to "train the future trainers" in priority statistical fields. In both (sub) programmes, training methods are adult oriented.

This paper will also provide a first evaluation of the courses run within the current programme.

STATISTICAL TRAINING FOR EMPLOYEES OF NATIONAL STATISTICAL OFFICES IN DEVELOPING COUNTRIES : PROBLEMS AND ISSUES

United Nations Statistical Division (UNSTAT)[1]

I. Introduction

There are three basic activities of a national statistical office: (a) extracting statistics from administrative records such as production of international trade statistics, vital statistics, health statistics and so on; (b) organising and conducting national censuses for producing statistics on population, households, housing, agriculture, economic activity etc.; and (c) organising and conducting sample surveys for producing statistics related to labour force, income and expenditure, industry, fertility, mortality and so on. Production of national accounts and some other statistics depends on several sources.

The national statistical offices require technically qualified staff for a successful implementation of their work programmes. Both current and proposed work programmes determine the specific skills that are needed. But two features are salient in the needs: first, the work is basically quantitative and thus the

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[1] Document prepared by UNSTAT to be presented by Anis K. Maitra, Interregional Adviser in Statistical Training and Demographic Statistics (UNSTAT).

staff involved in statistical work should have the aptitude of dealing with numerical data; and secondly, since the national statistical offices produce the official statistics in an interdisciplinary manner, the inputs must be available from a variety of fields of knowledge, such as statistical methods, demography, economics, sociology, cartography, computer processing and related areas.

While it is true that the staff of the national statistical offices acquire valuable experience over the years working with statistical data, it is recognized by all concerned that a basic statistical course covering a wide range of fields enables a staff member to grasp the underlying multidisciplinary nature of the work of the office. Experience in many developing countries has shown that this course is best conducted through in-service training preferably organised in the national statistical office. It not only helps to improve the efficiency of the people working in the national statistical office without any prior formal training in statistics, but also benefits enormously the staff in other offices by increasing their capability in handling quantitative data when they are allowed to participate in such a course. In addition, the basic training course is sometimes useful as a refresher course for those who have undergone such training long ago. It is also useful for those who are working in a specialized branch of statistics and have been trained earlier only in the specialized topic of that branch, for example, in cartography for censuses and surveys, or in data processing etc. A basic training course may also help in identifying eligible staff members who may qualify for higher

training, for which resources are always scarce in developing countries. The in-service training course thus enables the national authorities to utilize the available training funds/fellowships more efficiently.

It follows from the above that the in-service training course assists the national statistical offices in developing countries to deal with the problem of consistent attrition of trained staff who are often lured away by more attractive service conditions in other sectors. The problem of staff turn-over is persistent especially in statistically less developed countries. The training at the grassroot level identifies a core of personnel that may be available for further training within the country or abroad.

II. Problems and issues in training of the staff of a national statistical office

One of the major technical cooperation activities of the United Nations Statistical Division has been in the field of statistical training. For almost forty years now, this office has been advising developing countries on course programmes at basic, intermediate and advance levels. The regional economic commissions and some specialised agencies of the United Nations system too have been contributing extensively in the development of statistical training in individual countries and in the region as a whole. However, the process manifested a number of problems and gave rise to several issues that need to be addressed carefully in any new efforts. Some of these are substantive and some others are organisational.

(a) Substantive problems and issues :

First, it must be remembered that the staff working in a national statistical office do not usually come from a common educational background. Some of them are from science stream, some others from arts or commerce. Some may hold just high-school diploma while some others may have attended college level courses and may be even university graduates. It is also common that participation in the in-service training does not in general depend on passing an entrance test as a qualifying examination. The capacity to assimilate a certain course lecture therefore varies greatly among the staff who may be admitted to the in-service training. It is recognized by teachers of statistics that in many cases various levels of teaching are possible under a given topic title. The problem in front of the teacher in the in-service course is to select a level that will not make a topic incomprehensible to a group of participants nor will it be unchallenging to the other group. Two solutions have been attempted, but not without giving rise to other problems. One solution is to devise two course programmes - one at the basic level and the other at an intermediate, that is, a slightly more advanced level. However, to run two different level courses may be difficult because of non-availability of teachers, classrooms and other resources required. The other solution is to use the advanced students as teaching assistants in the practical work classes. But this would certainly result in a loss of their own training time.

Secondly, for teaching a statistics course even at the basic level some elementary mathematics

including arithmetical and algebraic notations and calculations, but not calculus, must be taught at the beginning, because not all participants will come prepared with this knowledge. The trainees who are already conversant with these topics may skip these lessons. However, for participants who are working in a national statistical office, but do not have the general aptitude for learning mathematics, the lessons may not be easy. This aptitude must be built in at a young age. This fact has been discussed especially in the context of developing women statisticians, in several meetings of the Directors of statistical training centres associated with the Statistical Training Programme for Africa, a UNDP-funded project executed by the UN Economic Commission for Africa. One possible solution seems to be to organise a short preparatory course on elementary mathematics for those who would need it before the basic statistics course starts for the whole group of participants. The other solution is to exclude a mathematically weak trainee, but this would defeat the purpose of organising the basic statistics course for the benefit of a national statistical office where all staff except the purely administrative ones should be trained in at least basic statistics.

Thirdly, taking into account the nature of activities in the national statistical office of a developing country, it is understood that a practice-oriented course is more appropriate for training. Every concept and every definition should be explained clearly with numerical examples, preferably drawn from the data generated from statistical activities of the country itself or in the neighbouring countries and in

the region as a whole. However, this does not mean that the theoretical aspects should be totally discarded. It is important to include as much theory as possible that can be assimilated by almost all participants. Simple theories of probability science should be explained and then these should be clarified using numerical examples. The theory behind the construction of different types of price index numbers should be explained in simple terms and their relative advantages and disadvantages should be elaborated with the help of practical exercises. In short, the theoretical definitions and operational aspects should go side by side, remembering always the limitations of teaching a very heterogeneous group of trainees. A solution to this seems to be holding practical classes every study day as well as assigning practical work as much as possible to be completed outside the scheduled class hours.

Fourthly, one will note that national statistical offices are not academic institutions, and therefore, unless special agreements are reached, the diplomas or certificates issued by the national statistical office to successful trainees may not be acceptable for promotion or other purposes. This situation has been corrected in several countries by either involving an academic institution to collaborate with the national statistical office in the organisation and conduct of an in-service training course or seeking formal recognition at the academic level regarding the course curricula, the criteria for the selection of trainees, the periodic and final examinations etc. Governments are now formally accepting certificates awarded upon successful completion of in-service training courses.

(b) Organisational problems and issues :

First, one must remember that the in-service training is generally organized for a large group of trainees. The number of participants should be between 20 and 25 in order to be cost-effective and at the same time manageable in one lecture/laboratory room. It is generally recognized that if the number of students exceeds 25, it becomes difficult for the teacher to pay personal attention to each one. For a subject like statistics, this attention is necessary to be able to respond to questions meaningfully. The problem is that no office can afford to allow 20 to 25 staff members to be away from their desks every day of the course duration. The staff members must perform their daily routine work for a part of every day. That is why the organisers of the in-service training course plan for about four hours of teaching each working day, including the practical work. Another way of conducting the course is to hold it every other day of the week. The duration of the course depends on the available time each week.

Secondly, secretarial services for administrative work must be made available to the organisers. These are needed among other things especially for typing and duplicating the course materials, including the practical exercises to be completed in classrooms and at home. Attendance registers must be maintained and their importance must be realized by the participants.

Thirdly, for the teachers of the theoretical topics and practical exercises as well as for the administrative persons and the secretaries, working for the in-service training course will be additional to their regular work. This extra work must be

compensated for in some form, preferably through overtime remuneration payments. In addition, stationery and other items for teaching must also be purchased. Unless typewriters/word processing machines and duplicators are easily accessible, these must be bought too. All this will need some funds, and it is sometimes extremely hard for the national statistical office to secure this funding. For some countries, this must be included well in advance in the current year's budget of the government. Therefore, the programming of such an in-service training course must start much earlier than when this course is expected to start. For several developing countries, locating some external sources of funding helped in initiating the in-service training course. However, it is understood that after the initial years, the government must take over the financial obligations.

If the in-service training course admits also the participants who are not currently employed in the national statistical office or in similar offices, the issue of trained unemployed people may be disturbing. This particular problem must be dealt with case by case.

III. Conclusions :

The benefits of an in-service training course cannot be disputed. Some of these have been listed earlier in this paper. One would only hope that the countries which still do not have such a training system, will make every effort to establish one, even if it is programmed for a period of five years initially.

Teaching Statistics for Employees of a Statistical Office in Africa

By

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I. Introduction

1. It should be stated that most of the National Statistical Systems (NSS) in Africa are centralised with the National Statistical Office (NSO) responsible for the production of all types of statistical data. The NSO is generally part of the civil service and comes under the supervision of the ministry responsible for planning. In some countries the statistical service is autonomous and is out of the civil service but remains in the public sector e.g. Ethiopia and Ghana. In some of the countries e.g. Malawi and Nigeria, the head of the statistical service is of the rank of head of a ministry, which shows the importance countries attach to statistics as part of the planning process.

2. The subject coverage of most statistical offices include two broad categories: economic statistics and demographic and social statistics. Economic statistics include: agricultural, industrial, construction, distribution, price, external trade, employment and wage and national accounts statistics. Demographic and social statistics include population (fertility, mortality, migration), housing and nutrition, health and education. In addition to the above two broad groups, statistical offices include compilation of statistics on income, consumption and expenditure in their work programmes. The informal sector statistics have began to receive special attention recently in some of the statistical offices of African countries such as Central African Republic, Mali, United Republic of Tanzania and Zambia.

3. In a statistical office, there are two broad categories of staff responsible for the production of statistics: statistical personnel and computer science personnel. The statistical personnel include professional statisticians, middle level statisticians and statistical clerks/enumerators. The computer science personnel include computer specialists and others (programmers, key punchers, etc.). The non statistical staff include administrative, accounting and in very few countries printing staff. With the above staffing situation of a statistical office, any teaching of statistics for the employees in the statistical category should take into account needs at the three working levels: professional, middle and clerk/enumerator. In

addition employees should be taught computer science which is very essential for the processing and dissemination of statistics.

4. The paper discusses efforts which have been made in Africa with regard to the improvement of the teaching of statistics. Teaching statistics to employees of a statistical office and teaching statistics to those expected to be employed by the statistical office. It is believed that the requirements for teaching statistics for the two groups are different.

II. Teaching Statistics for employees of a Statistical Office

(a) Introduction

5. It should be recalled that during the 1960s and the 1970s, the majority of statistical offices in Africa faced a number of problems including shortage of staff and high turnover of their qualified staff. These problems were discussed extensively for the first time at the second session of the conference of African statisticians in June/July 1961. The conference initiated an intensive training programme aimed at overcoming the above problems with an initial emphasis on middle level statistical training and gradual development of professional facilities.

6. The staffing of statistical offices was further discussed at the ninth session of the conference of African statisticians in Lome, Togo in 1975. A recommendation that a working group to consider African statistical training needs be convened was made at this meeting. Such a working group was convened in Munich, Germany in August 1977. The working group gave special attention to the improvement of existing training centres and their effective utilisation, the practical orientation of their teaching programmes, reduction of the loss of qualified staff at NSO and financial resources required including the coordination of statistical training activities in and outside Africa. At the tenth session of the conference of African statisticians in October 1977, it was noted that the staffing situation of countries of the region was still unsatisfactory. The conference therefore adopted a comprehensive programme

entitled "Statistical Training programme for Africa (STPA) which was formally instituted by resolution 9 ECO (XVIII) of the Economic Commission for Africa (ECA) Executive Committee at its 18th session held in Khartoum (Republic of Sudan) in 1978.

(b) The Statistical Training Programme for Africa

7. The STPA has been the main instrument for promoting the teaching of statistics for employees of a statistical office in Africa. We shall describe below selected aspects of the STPA covering: objectives, institutional framework, preparation of teaching syllabuses, training of trainers and provision of short-term visiting lecturers.

(i) Objectives

8. The main objective of the STPA was to ensure that the African region has a permanent supply of qualified statistical staff for the NSS and other organizations in the public sector as well as the private sector. STPA was originally conceived as a ten year programme aiming at ensuring Africa's self sufficiency by: increasing the number of trained statisticians and improving and maintaining the quality of the serving statistical staff. This programme was aimed at teaching those already employed by the statistical offices and those expected to be employed by the statistical offices.

(ii) Institutional Framework

9. It was initially proposed that STPA should serve as a framework for the coordination of the establishment, improvement and if need be, the expansion of training facilities in Africa. It was decided that STPA should concentrate in the following training areas: Professional; Post-graduate and Specialised studies; and middle level. The institutional arrangements of STPA included: Establishment of a regional mechanism (regional component of STPA) to provide operational support to the improvement and expansion of the STPA at ECA through a project; Selection of existing training centres to participate in the programme; Selection of STPA associate centres generally outside Africa to supplement basic training

activities to be undertaken by STPA centres; strengthening NSS which were expected to supply trainees and employ those trained at the STPA centres; and collaborative arrangement with multilateral and bilateral agencies such as the European Union, the Commonwealth Secretariat, the Canadian International Development Agency (CIDA), the Swedish International development Agency (SIDA), Germany, United Kingdom (U.K) and other bilateral agencies which expressed interest to participate in the programme.

10. Over the years, sixteen STPA centres have been selected on the basis of their inter-regional or regional character of their services and the practical orientation of their teaching programmes. A total of eight associate STPA centres were selected over the years. The list of STPA centres and associate STPA centres is included as appendix I.

(iii) Preparation of Teaching Syllabuses

11. Recognizing that training institutions had teaching programmes which were initially theoretical in nature with very little if any practical training, the regional component of the STPA located at ECA initiated the preparation of guide syllabuses whose objective was to assist in the maintenance of curricula and qualifications and also in the review and reorientation of course programmes at teaching centres. The guide syllabuses were prepared at three levels: professional, middle and in-service training and in three language groups: English, French and Portuguese. This was necessary because of the differences in the education systems existing in the three language groups.

12. The guide syllabuses which were prepared are: Guide syllabus for middle level personnel in statistics (1982) (English); "Programme-type pour la formation statistique de niveau moyen" (1982); Guide syllabus for in-service statistical training (1983) (English and translated into French); Guide syllabus for in-service statistical training (1984) (Portuguese); Guide syllabus for professional level statistical training (1986) (English); and

"Programme-type pour la formation statistique de niveau superieur" (1986). The guide syllabuses were prepared with as much practical orientation as possible.

(iv) Training of Trainers

13. In order to strengthen the teaching of statistics at STPA centres, the regional component of STPA provided fellowships with project funds made available by the United Nations Development Programme (UNDP). Thirty nine fellowships were awarded between 1978 and 1993. The training of trainers had two main objectives: To ensure that STPA centres had qualified staff to teach statistics or related fields of specialisation; and to enable trainers to conduct research in their fields of specialisation. It should be mentioned that multilateral and bilateral donors also provided fellowships for the training of trainers at STPA and other training institutions.

14. The fellowships offered by the regional component of STPA for the training of trainers were mainly in the following broad range of subjects: Statistical Methods, Computer Science, Sample Surveys, Applied Statistics, Experimental Design, Theoretical Statistics, Economics, Operations Research, Development Planning and Social Statistics.

(v) Provision of Short-term Visiting Lecturers

15. These were fielded to STPA centres with the objective of filling the teaching gap of a trainer who had been awarded an STPA fellowship or to provide teaching in a specialised subject field. Sixty five (65) visiting lecturer were fielded during 15 years of STPA. The regional component of STPA financed the visiting lecturers.

16. It should be mentioned that due to expertise in applied statistics which is available in the ECA Statistics Division, professional staff were at times requested to undertake teaching missions to STPA centres, NSO in-service training programmes and middle level training centres at national level. The teaching subjects included mainly National accounts, Industrial

statistics, Household surveys, Agricultural statistics, Demographic statistics, Price statistics and Transport statistics.

(vi) Teaching Statistics for those Currently Employed by a Statistical Office

17. Within the framework of STPA, it was considered important to promote or strengthen teaching programmes which would improve the technical capability of statistical personnel in the statistical offices. The programmes included: In-service statistical training programmes at national level; Middle level statistical training programmes at national level; Post-graduate and Specialised training; Workshops and Seminars; and On-the-job training.

III. Conclusion

18. The efforts made under the STPA have indeed been commendable not only with respect to the promotion of teaching statistics for employees of a statistical office but also in the coordination and standardization of statistical teaching programmes in Africa. The equivalences of qualifications offered at training institutions can now be easily determined.

19. It should be stated that efforts in teaching statistics in the Portuguese-speaking African countries are far from satisfactory when compared to those of the English- and French-speaking African countries. There is dire need to establish in-service statistical training programmes or middle level statistical training programmes at national level for the training of their middle level statistical staff. The professional training centre which was recently established in Lisbon, Portugal will assist in the training of nationals of these countries provided adequate fellowships are available.

20. In the 1990s efforts in the teaching of statistics for employees of a statistical office will have to be revitalised within a new framework for the overall statistical development in the African region which has been adopted under the umbrella of the "Addis Ababa Plan of Action for Statistical Development in Africa in the 1990s" and the associated strategy for its

implementation together with the setting up of the Coordinating Committee on African Statistical Development (CASD). Under the CASD, a sub-committee on training has been established and any further development of the STPA will have to be seen within this new framework.

ABSTRACT

A review of the organizational set-up of a national statistical office, its staffing levels and subjects covered has been described. Two groups of employees of a statistical office have been considered with respect to the teaching of statistics viz those already in employment and those expected to be employed by a statistical office. The Statistical Training Programme for Africa (STPA), under which was undertaken, improvement or strengthening of statistical training programmes for employees of a statistical office, has been described including selected aspects of the programme. Teaching programmes for those currently in employment with the objective of improving their work performance have also been mentioned. In conclusion a new framework for revitalisation of teaching of statistics in Africa in the 1990s has been mentioned.

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List of STPA Centres

Appendix I

French-speaking Centres: 1. Institut national de statistique et d'économie appliquée (INSEA), Rabat, Morocco; 2. Institut national de la planification et de la statistique (INPS), Algiers, Algeria; 3. Centre européen de formation des statisticiens - économistes des pays en développement (CESD), Malakoff, France; 4. Institut sous-régional de statistique et d'économie appliquée (ISSEA), Yaoundé, Cameroon; 5. Institut de Formation et de Recherche démographiques (IFORD), Yaoundé, Cameroon; 6. Institut africain et mauricien de statistique et d'économie appliquée (IAMSEA), Kigali, Rwanda; 7. Collège statistique de Dakar (CS), Ecole Nationale d'économie appliquée, Dakar, Senegal; 8. Ecole National Supérieure de Statistique et d'Economie Appliquée (ENSEA), (Abidjan, Côte d'Ivoire).

English-speaking Centres: 1. Institute of Statistics and Applied Economics (ISAE), Makerere University, Kampala, Uganda; 2. Department of Statistics, University of Ibadan, Ibadan, Nigeria; 3. Eastern Africa Statistical Training Centre (EASTC), Dar-es-Salaam, United Republic of Tanzania; 4. Department of Statistics, University College of Botswana, Gaborone, Botswana; 5. Department of Statistics, National University of Lesotho, Maseru, Lesotho; 6. Department of Statistics, University of Ghana, Legon, Ghana; 7. Regional Institute for Population Studies (RIPS), Legon, Ghana.

Portuguese-speaking Centre 1. European Centre of Statistics for developing countries (CESD - Lisbon), Higher Institute of Statistics and Information Management, Lisbon, Portugal.

List of Associate STPA Centres

1. The Munich Centre for Advanced Training in Applied Statistics for Developing Countries, Munchen, Germany; 2. The Institute of Development Studies (IDS), University of Sussex, Brighton, U.K.; 3. The Applied Statistics Research Unit (ASRU), University of Kent, Canterbury, U.K.; 4. The International Statistical Programs Center (ISPC), Bureau of the Census, Washington, U.S.A.; 5. The Institute of Social Studies (ISS), The Hague, the Netherlands; 6. The Department of Statistics, University of Newcastle upon Tyne, U.K.; 7. The Department of Probability and Statistics, University of Sheffield, U.K.; 8. The Indian Agricultural Statistics Research Institute (IASRI), New Delhi, India.

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Session 13 - Statistics for employees of a statistical office

Abstract for a contributed paper

The UK government statistician trainee scheme

The UK Government Statistical Service Trainee Statistician Scheme is a six month conversion course designed to give graduates with a good honours degree who have little or no formal statistical training the practical skills and knowledge to become a government statistician. The trainees follow two intensive eight week taught blocks at university separated by a period of similar length in a government department where they work on a project under the direction of their line managers. This paper describes the approach taken at the University of Greenwich in teaching the college based component of the training during 1993/4.

Flavia Jolliffe
University of Greenwich

Italian National Statistical System: Training strategies

(Cristiana Conti, ISTAT via Gaeta 4, Roma-Italy)

The Law 322/89, which estabilished in Italy the National Statistical System (SISTAN), made a radical change of the statistical activities in the Country. Each organism of the public Administration has had the charge to create a statistical office of its own. All these offices have become a part of a coordinated and complex system with the aim of rationalizing the production and the diffusion of statistical information.

The Central Secretariat of SISTAN -that's a part of Italian National Statistical Institute- must coordinate the different organisms of the system and must give training and qualification to people working for the system itself.

The wade and complex system has imposed such a way of operating in training: trainees have been divided into different typologies, depending on the role they develop in the system, and for each of these typologies has been foreseen a general "training itinerary" which achieves the diffusion of a same statistical culture and sets up, at a time, the specific charges to be accomplished by the system. The training programme is four-monthly. It is reexaminable at the end of each of the three sections in order to allow the inserction, for the next four months, of training events judged as necessary. Teachers come both from professional and academic areas, to assure a balance of practical and theoretical procedures.

STATISTISKA CENTRALBYRÅN

THERE IS MORE TO THE COURSE!
Experiences from a survey course in the Baltic countries

by Ulf JORNER, Statistics Sweden, Thomas POLFELDT, Statistics Sweden and Imbi TRAAT, University of Tartu, Estonia.

Summary

The STAC (Statistics in action) course (described at the ICOTS-3 conference) covers the full survey process, in a learning-by-doing approach, demonstrating survey techniques and the interaction of the phases of a survey. In the Baltic countries, where sample surveys were rare, this course also offered an excellent opportunity to display and teach a statistical perspective in a wider sense - the inherent variation, the possibilities that errors occur, the interdependence of the steps in a statistical production process, and the possibilities to control this variability, with a view to reaching usable final results.

The STAC approach, with its emphasis on group work and free discussion of possible solutions, was found to be very suitable in this context, as one of the objectives is to stress the need to work with alternatives and choose among several plausible solutions to each problem. The realistic time pressure incorporated in the course is also very productive.

From a pedagogical point of view, the course has many further features that are unusual in the Baltic countries, and that were much appreciated: for instance, the informal atmosphere, the detailed time-table that was scrupolously followed, the necessary improvisations, the frequent use of summary material produced by the teachers after a day's work.

Among further important consequences of teaching the course in the Baltic states, there was an increased confidence in using English, enhanced contacts between the Central Statistical Offices and university departments, extra opportunities for the course participants to meet their own highest leaders, and a certain training in management and co-operation.

A TEN-YEAR UPDATE OF THE 1984 IOWA WORKSHOP ON STATISTICAL EDUCATION FOR ENGINEERS

Robert V. Hogg
University of Iowa

The statistics course outlined in 1984 contained too much material for one semester. While all of that material (which is reviewed) is important, a more realistic course is considered. This includes some discussion of capability indices and Taguchi methods and their shortcomings. In addition, there are remarks about how Total Quality Management can be used to improve presentations in the classroom. Much of the latter depends upon improving the feedback between the students and instructors: minute papers, quality teams, punctuated lectures, instant replay of tests, time plots, etc. However, improving communication skills, preparing carefully, using computers, and doing projects are also important.

STOCHASTICS IN ENGINEERING CURRICULA

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Abstract

Two wellknown reports on Mathematics in Engineering Education, one issued by UNESCO in 1966, the other by SEFI, the European Society for Engineering Education, published in 1992, treat in considerable detail what should be taught to engineering students. The importance of probability and statistics for the engineering sciences has been recognized by both reports.

We will examine the evolution of stochastics for science in general in the quarter century between the two reports, what has been achieved and in which respects the actual situation still falls behind the stated demands. An attempt to analyse the reasons for the shortcomings will be made.

The problem has been internationalized in order to find solutions that are not only nationally binding. In this the three previous ICOTS conferences (the first was held in 1982 in Sheffield) had a catalystic effect.

But we will report on other, mainly European, endeavours, which could be helpful in pointing to possible solutions in other places. While there is already a considerable literature on the subject, the textbooks have - with some notable exceptions - not caught up with what is now an accepted syllabus for the subject, teaching stochastics to engineering students.

Le génie statistique perspectives et réalités

Aziz Lazraq ENIM/RABAT/MAROC

Après une présentation de l'enseignement de la statistique à l'Ecole Nationale de l'Industrie Minérale de Rabat, j'explique comment, des efforts et des méthodes d'enseignement utilisés, ont pu faire aimer la statistique à nos élèves ingénieurs.

Dans la seconde partie de l'exposé, je m'inspire de certaines appelations qui ont pu s'ériger en véritables disciplines autonomes (comme le génie logiciel par exemple) pour donner à mon sens une signification et puis, définir la méthode et la discipline génie statistique. Je terminerais par expliquer comment, à mon avis, peut on mettre en place une spécialité de formation en génie statistique dans des établissements de formation d'ingénieurs.

Teaching and Assessing Critical Thinking in Engineering Statistics

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April 12, 1994

Abstract

It has been recognised that students to manipulate formulas only plays a minor role in introductory statistics courses, and instructors in statistics are becoming more and more aware that critical thinking ought to be taught in the classroom. This can be accomplished by using laboratory-oriented techniques and project-based methods. Although the approach is highly computational, few computing skills are required from the students. Only basic reasoning skills are required, and higher-level mathematical concepts (e.g., calculs) are not used. I focus on how to teach and evaluate critical thinking by using simple word problems, short projects, written and oral tests. Teaching and assessing critical thinkings are exemplified with our first course in Applied Statistics at Worcester Polytechnic Institute (WPI) that I taught seven times in the traditional style over the past five years and recently once as a pilot course.

Key Words : Word problems, Experiments, Labs, Oral and Written tests, Projects.

1. Introduction

Slowly we are beginning to recognise that the usual lecture courses frequently discourage our students and do not really engage them. Active learning by students is the key to making them think critically about statistical concepts and analyses. This is consistent with Hogg (1991) and Gnanadesikan (1993) who are among many authors advocating changes in the pedagogy of statistics to getting students actively involved in the learning process. I share their concern.

The teaching of critical thinking involves getting students to (a) ask the right questions about how given data were generated (b) consider different strategies for generating data as a step in solving a problem (c) use various data analytic tools to view data from different perspectives (d) try various approaches to make sense of data (e) critically assess measurement variability, sources of that variability, and the regularity and pattern found in that variability (f) learn about theoretical and empirical modeling and their role in the scientific method and (g) understand the limitations of statistical methods. In addition, students should be able to think through the implications of their analyses and how sensible their results are as compared with the expectations in the particular discipline. In our approach students are expected to discover new knowledge for themselves, a real intellectual creative process.

Since I arrived at Worcester Polytechnic Institute (WPI) Fall 1989, one of the courses I taught each year is MA2611, Applied Statistics I. It has always been given in the lecture mode with four lectures and one lab per week, each lasting fifty minutes. Otherwise, each instructor used her/his own method to teach the course. Among the innovations I added to the course are (a) the practical exam on the computer, (b) asking students to analyse small data sets reporting results in layman's language, (c) short weekly quisses on course materials, (d) one large term project with an oral presentation and one written report, (e) asking deep questions on the critical understanding of the easiest concepts in the course, and (f) to bridge the gap between statistics and other disciplines.

The current activities in restructuring our basic statistic course is based on a grant we received from the National Science Foundation (NSF) in the United States. The proposed work is described in Petruccelli and Nandram (1993). This talk represents, in part, the contribution of the project team led by Joseph Petruccelli, and includes the efforts of myself, Ming-Hui Chen, and many others. I will like to report on the manner in which the course was taught in Term B 1993 at WPI, and how teaching and assessment of critical thinking were incorporated into it. In Section 2 we describe the course materials, and in section 3 the methodology. In Section 4 there are recommendations, and in Section 5 there are conclusions. Some illustrative materials are given in the appendix.

2. Course Description

MA2611 is a first course in elementary statistics at WPI, a small college of engineering, science and management in Worcester, Massachusetts. The course is run on a term basis (i.e., seven weeks) and we meet for five fifty minute periods per week. Over the past five years we have been teaching this course using the traditional approach (i.e., lecture setting). We started with very small innovations gradually introducing computer work, project work, presentations. Currently, this traditional course is run with four lectures and one lab per week, each lasting fifty minutes. Depending on the instructor there is also a term project. The students who take the course are mostly not mathematics (statistics) majors; most of them are from management and biology with a few from various engineering disciplines (electrical, chemical, etc.) and other

sciences. The decision on the textbook used is made by the statistics faculty, and the books we used in the past are comparable to Moore and McCabe (1993) which was used for the past three years excluding the current year.

Currently, the pilot course, MA2611P, is run in parallel with the traditional course. This is a project- and laboratory-based approach to teach elementary statistics. The methods of teaching differ from instructor to instructor, but all involve cooperative learning to some extent. The course is modular, and six one-week modules are done over the term. There are no text books for this course but there is a set of modules written by the project team, and these are given out to the students at the beginning of each week. There are an oral presentation and a written report on the mini-project.

Each module consists of a set of reading materials, one or more laboratory activities, homework questions, discussion questions, and a mini-project. The modules are organised according to knowledge and skills and the work is divided up roughly into five days. The objectives of each module and what is to be accomplished each day are clearly written at the beginning of each module. For example, Module 1 is an "Introduction to Data Analysis." At the end of this module the students must have a knowledge of (a) a stable process and (b) sources of variability in a simple stable process. The skills that they should acquire at the end of the module are (a) the use of the DECstation computing environment (b) the use of the SAS Statistical Software System, including entering, editing, manipulating and graphing data, and performance of simple data analyses (c) use of an Ishikawa diagram to identify potential sources of variability in a stable process and (d) use of stratified plots to identify sources of variability in a stable process.

The statistical software used is the user-friendly portion of SAS, SAS/Insight and SAS/Assist with the students running macros, written by the project team accessible from SAS/EIS. For data entry, the students can use the SAS/Editor or any of the editors available. Since engineers work with computers most of the time, the students find it convenient to use the computers as a tool to learn statistics. (Only a few of our students might not have prior use of a computer.)

The course is run in two rooms. The first is a computer room equipped with 23 DEC workstations, and two printers. There are two long tables with seats on both sides of the table with the workstations on them. As the approach is cooperative, this arrangement is attractive as it encourages discussion among the group members. The second is just a lecture room equipped with a very long white board. Occasionally short lectures of ten/fifteen minutes' duration are given in this second room.

3. Methodology

Here a description of my experience in the pilot course in Term B 1994 is presented.

As our approach was cooperative, the first task was to form the groups. This was difficult at first because for many students this approach was not acceptable. It was (and still is) not the standard pedagogy on campus. At day 1 there were sixteen students who were officially registered, and we started with four groups. By the end of the second week, seven students dropped from the course. These students either went to the parallel section of MA2611 as the traditional course requires much less work. The remaining nine students were formed into two groups, one of size four and the other of size five. (These two groups remained throughout the rest of the term.) All laboratory, project activities and discussion were done within each group. Each group sat around the same part of the table, and each member of the group had access to

her/his own computer.

Among the expected tasks of management and administration of the course, I (a)gave short lectures of about ten to fifteen minutes' duration for about two/three times per week; (b) gave general remarks about difficult materials to the class in lecture settings as the course progressed; (c) with individual students within their groups during class time, I would assist the students to read and understand SAS outputs on the screens of the workstations; (e) asked the students in each group key statistical questions during class time, and helped students with questions on the discussion set; (f) prepared two preparatory and two class tests; and (g) graded written tests and the project report, and ran oral tests and oral presentations.

The first written test evaluated the materials on the first three modules which are on data analysis, stable processes and modeling. The preparatory test contained questions based on the materials of the written test, and these questions were of the same nature as the written test. This exam was given a week before it was discussed, and the students were expected to solve these problems by that day. This exam was discussed with the entire class the day before the written test was taken. Students volunteered to solve the problems on the white board in the computer room, and they were asked to explain their solutions to the entire class. This activity was rewarding as it formed a method to remedy some of the deficiencies.

The exams were graded the same day they were given, they were graded the same day, and each student was required to do an oral examination the next day in my room. All the students took the oral exam, and they were asked about materials they misunderstood and did incorrectly in the written examination. This was an extremely good idea as it not only helped the students to increase their scores at the written exam, but they also learned the materials better. Of course, students, who did really well in the written examination, had very little to do in the oral. Students, who did poorly on the written exam, had a good chance to improve their scores.

The second test was based on the last three modules that include relationships between two variables, regression and the bootstrap method, and an elective of which one group chose to do a module on statistical process control and the other a module on probability theory. The discussion and test proceeded in a similar manner.

The students were actively participating in the learning process as they worked on labs and mini-projects, homework assignments, and preparation for examinations. Basically, the laboratory activities started in the computer room and the students were guided by the TA and me. Most of the labs were to be written up individually by the students. They were allowed to work within their groups, but the tendancy was for them to work individually because they had to turn in their own report on each lab. The TA graded the lab reports, all deficiencies were communicated to me, and finally I discussed these deficiencies with the entire class.

The students were required to turn in a proposal for each project. One of my jobs was to look through the proposal to ensure that the project was reasonable, to focus the project so as to enable the students to use the materials of the module, to ensure that the project reinforced their understanding of the statistical concepts, and to make them think more critically by suggesting other questions which could be answered in the same experimental settings.

In my office hours, four times per week, and sometimes outside these hours the students would interact with me about their activities in the project. The students were expected to

work cooperatively on the projects and to share the work evenly.

The project culminated in an oral presentation. In the presentation, they were required to stand up in front of the class, and each student would present an equitable portion of the project in a coherent manner. This activity went extremely well. During the presentations I would point out the deficiencies of their work, particularly to enhance the understanding of the statistical concepts. The project was given two grades, one for the oral presentation and one for the written report. The grade for the oral was obtained as a combined score based on the TA's score and scores from the students in the other project group together with my score. The grade on the report was my responsibility. Homework assignments were given on each module. The students had to do these individually. The TA graded these, all deficiencies were reported to me, and I clarified them with the students in class.

An example of a mini-project is given in Appendix 1 and an example of a lab is given in Appendix 2. (As the directions on the labs are usually two or three pages long, in the interest of space a summary is presented.) A lab can be a simulation exercise on such topics as the central limit theorem or confidence interval estimation. It can also involve the analysis of data obtained from a physical experiment the students just performed or a data set available on the computer. In the mini-project the students are required to come up with "two further questions" and this is useful as it makes the students think more. Examples of questions on homework, discussion, preparatory test and examination are given in the appendices. There are also questions in which the students must use SAS. Note the critical thinking that is required from the students to understand these word problems.

4. Recommendations

After I taught the pilot course in Term B, and after looking through the completed student evaluation forms, I came up with the following recommendations which I strongly believe can improve the quality of the course, and make the students think critically about the materials.

- **Cooperative Learning:** This is a good idea as students interact more in smaller groups, and it is a natural setting for students to learn from one another, and to speed up the learning process. It is useful for the instructor to interact with these smaller groups as students tend to talk more in such groups. This gives the instructor an opportunity to diagnose misconceptions and then remedy them. Each student within a group can serve as a student-teacher in turn in her/his own group. The discussion questions should be used to stimulate more discussions among group members.

- **Problems:** We should ask students to do things in which their current knowledge is used to find out new information. Word problems should be used more often as they stimulate more thinking. Mechanical problems such as we normally see in standard text books should be de-emphasised.

- **Interdisciplinary:** Ask students to think more about real practical situations where a particular concept under discussion is used. Students should be motivated to do statistics. An easy way to do this is to choose examples in the students' area of concentration. This can improve their thinking skills.

- **Lectures:** I am confident that, while an activity-based curriculum is beneficial and highly influential in the learning process, lectures must be given to students. I, myself, like to be

talked to after I read the materials. This builds confidence in the students. A neighboring class room should be set aside for lectures so that the students can be moved back and forth easily. I suggest giving lectures, say the first ten/fifteen minutes, each day.

- **Group Sizes:** Since group sizes are very unstable at first, I recommend starting with group sizes of about five or six students. With luck after attrition groups reach a size of four, an ideal number. If a group is too large, some group members might not want to think or do much.

- **Number of Projects:** A weekly project is a distraction to the learning process. Too much work makes the students rebel, and little can be done in such situations. (Critical thinking is then not in statistics!) One or two larger projects might be more useful with ideas being pooled from a number of modules to do each project.

- **Project Grading:** It is a good idea for everyone, excluding members of the group presenting, to grade the presentation. This is helpful in two ways. First, it is difficult to grade projects. The scores given by other people will help the instructor to grade not only the oral presentation but also the written reports. Second, this creates another learning environment for the students, who are not presenting, because it makes them focus their attention on the presentation, and think about the materials that are presented. Students, who are not presenting, do not pay attention to the presentation. We need to get all the students engaged.

- **Oral Presentation:** Each student within a group should contribute an equitable portion of the presentation to the class, and the presentation as a whole should be cohesive and coherent. This is also a part of the thinking process.

- **Oral Tests:** The oral test, which is given after an exam, helps to serve as a remedial process as students understand more material better in this setting. Such tests should be given more often if possible.

- **Module Quizzes:** It is a good idea to give a quis at the end of each module. In this way the students are forced to understand the current materials before going on to new ones.

5. Conclusion

Students must be held responsible for their own learning. By using cooperative learning a class becomes more manageable, and the instructor can really assist each individual student to think critically through interaction. This is also attained through office hours and oral examinations.

It is difficult to compare the performance of the students on the traditional and the pilot course. The pilot course had only nine students, and it was difficult to test the same questions on both examinations. However, one point that I can make is that in the traditional course my ratings on the student evaluations for each of the times I taught MA2611 at WPI range 60% to 75% but for the pilot course the students rated me 90%.

While teaching and assessment of critical thinking are difficult to evaluate, they can be attained through a activity-based curriculum. Labs, projects, tests and the interactions they provide are good instruments to make students think critically.

In an activity-based curriculum, the time spent by the instructor, the TA and the students is of great concern. I spent an average of 22 hours per week teaching this course. This is about 10 hours more per week that I normally spend teaching any course. A lot of the time went into the preparation of questions, grading projects and exams, and running oral examinations. The work was just enough for the TA. (Our TA's are asked to spend up to 20 hours per week on a course.) With a larger number of students (with say 25 groups of four students) the time spent for grading projects, tests and running oral examinations will be inflated, and the job is impossible with one instructor and one TA. In future we must study ways to make the course more economical.

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Appendix

Appendix 1. Module 5 Mini-Project

How Good a Shot Are You? Your task in this project is to use regression methods to investigate the relationship between the distance a person stands from a target placed on the floor, and the accuracy with which a thrown coin lands in the target.

Your group should think of an experiment which will answer the above question. In addition, you should design your experiment to answer at least one other question about this relationship. You are free to decide all design issues of the experiment including what will be measured, what the target looks like, and how the experiment will be conducted. Before conducting the experiment, submit a short one paragraph proposal for your instructor's approval. The proposal should state what data will be collected, exactly how you intend to collect it, and what kind of relationship you expect to find. Your instructor will discuss the proposal with your group, and may suggest modifications.

After your group's proposal has been approved, proceed to collect the data and use any of the techniques discussed in this module that are appropriate to analyse the relationship between the two variables. Write a short report summarising your findings. Be sure to state whether the data confirmed the kind of relationship you predicted in your initial proposal. Also include two further questions suggested (but not answered) by your data and tell what you could do to get answers to these questions.

Appendix 2. First Lab in Module 2

All washered up! You are a production worker in a factory that manufactures washers.

Your group can take one of the large bags. Each large bag contains twenty smaller bags each having five 7/8-inch washers. You should also take a set of calipers to measure the outer diameter and thickness of each washer. You should then enter the bag number, the outer diameter and the thickness as one record to form a SAS data set. Complete the measurements for the five washers in the bag. Now repeat these measurements for four bags. You do not have to do all 100 washers as the data can be obtained by accessing the SAS data files, SASDATA.WASHERi, where i=1-4 indicates the number of the large bag of washers you are working on.

Finally, analyse the data and write a short lab report (one page or less, graphs excepted) detailing and justifying your analysis, and drawing conclusions. In particular answer the following, and any other questions that occur to you:

i. What is the overall distribution of all the data?

ii. Is this distribution the same for all bags? If not in what way does the distribution differ from bag to bag?

iii. Suppose the washers in a given bag are taken from production all at one time, but those in different bags are taken at different times. Suppose also that the bags are numbered in time order. What do the data tell you about changes over time?

iv. Is the process that generated the data stable?

[Note: This is a summary of a three page step by step handout.]

Appendix 3. Examples of Questions

- **Homework:** In 1000 flips of a supposedly fair coin, heads came up 560 times and tails 440 times. Are these results consistent with a fair coin?
- **Discussion:** (a) What is a resistant measure? Why and when would you want to use a resistant measure? Why and when might you use a non-resistant measure? (b) What is a k-times trimmed mean? Where have you seen it used?
- **Preparatory Test:** The tensile strengths (psi) of 10 bars of metal are 78, 102, 101, 81, 82, 99, 100, 80, 79, 98. What summary statistics will you use? How can you explain the variability? (No calculation is required.)
- **Examination:** The weight of widgets produced by Brown Company follows a normal distribution with mean 10 lbs. and standard deviation 0.2 lb.. The heaviest 2.5% of the widgets produced are rejected as overweight. What weight, in pounds, determines the overweight classification? Give your arguments.

TEACHING DATA ANALYSIS AT TECHNICAL UNIVERSITIES

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Data Analysis courses for undergraduates (introduction), graduates (advanced) and doctoral students (specific parts) represent new subjects at some technical universities nowadays. Curriculum of typical one semester course is specified below. Exercises are organized in computer room in form of interactive work on IBM PC. Theoretical part is demonstrated on representative technical problems. Student is guided to learn a active application of packages for statistical data analysis e.g. ADSTAT and SYSTAT and packages for data presentation e.g. SLIDEWRITE PLUS and QUATTRO PRO:

(1) Graphical and Spreadsheet Tools in Data Treatment: editing and calculus in spreadsheet, diagrams, histograms, 2D- and 3D-plots, various types of plots.

(2) Errors and Law of Errors Propagation: types of errors, precision and accuracy, Taylor series estimation, Monte Carlo simulation in error propagation.

(3) Exploratory Data Analysis: sampling, sorting, ranking, EDA diagnostic plots for continuous and discrete samples, types of nonlinear data transformation.

(4) Statistical Analysis of Univariate Data: confirmatory data analysis, summary statistics, averages, classical and robust statistics of location-spread-shape, code-book.

(5) Statistical Hypothesis Testing: one-sample and two-sample analysis, tests for randomness and location.

(6) Analysis of Variance: one-way ANOVA, two-way ANOVA.

(7) Regression Model Building and Testing: linear and nonlinear models, regression diagnostics in model building and testing, analysis of data-model-method triplet.

(8) Multivariate Data Analysis: correlation analysis, cluster and discriminant analysis, method of principal component,factor analysis, classification analysis.

The practical experiences with realization of these curricula will be discussed and computer assisted teaching of data analysis wiil be demonstrated on some case studies.

R e f e r e n c e s :

1.M.Meloun, J.Militky and M.Forina: Chemometrics in Instrumental Analysis, Part 1. Interactive Data Analysis, Part 2. Interactive Model Building and Testing, Horwood, Chichester, 1994

Questions to Ask a Statistical Consultant

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Much has been written about the role of a statistical consultant. In this paper we attempt to view the consultancy process through the eyes of the client, a person carrying out a piece of research. Questions which may interest such a person are the type of service provided, its possible cost and the qualifications of the statistical consultant. We also discuss how the researcher should prepare for the consultancy session, which questions to ask and which to avoid. Some differences will be noted between ongoing consultancy and one-off sessions. Suggestions will be made on the provision of quality consulting and the teaching of applied statistics to future researchers and statistical consultants.

1. Introduction.

Perhaps the first question which should be asked is whether it is appropriate to talk about consultancy in a session dedicated to the social sciences? We believe it is appropriate and important to do so. It has been said that the best way to get to know a subject is to teach it but it could be argued that to know statistics you should not only teach it but you should also be a consultant in it.

The consultancy referred to in this paper is based in a university setting where the majority of clients are staff or graduate students who have knowledge about their subject area but may have little knowledge about the theory or practice of statistics. Other clients are statistically aware but want more detailed guidance in particular techniques or understanding the output from a particular computer program.

The consultancy session provides a very different platform than a lecture or series of lectures. A lecturer is able to be proactive and prepare in advance the topic, the approach and the amount of information to be provided but a consultant's role is mainly reactive in response to the to the perceived needs of the client. Furthermore, the expectation of a student in a lecture situation is likely to be very different from that of a client While flexibility is a virtue in consulting, it may be distracting and disturbing in a lecture situation. Practicality of advice is imperative in consulting whereas the theoretical underpinning should be more evident in a lecture. Consultancy may give rise to different views on various topics in statistics which could then feedback into one's teaching.

It seems to this author that whereas some years ago statisticians had to argue somewhat defensively for the wider use of statistics, the situation has changed as the importance of its use is now generally accepted and the widespread availability of user friendly powerful computer packages has provided access to statistical analysis for most clients. The need for statistical advice, fortunately for our profession, has not diminished. The American Statistician, for example, publishes about one article a year on some aspect of consulting and has done so for the last 30 years.

2. Setting the Ground Rules

From experience, we are aware that clients may be hesitant to seek advice from statisticians ("I was never any good at mathematics") or, on the other hand, may be overly dependent on a statistician and seek help at every step. Others are assertive and insensitive, expecting consultants to give help on demand ("I have a simple question which will be obvious to you").

For our consulting service, we have designed a one page flyer which raises questions which may be in the mind of a client and responds to these issues.

How is the consultant paid?

In a university setting, clients may be quite ignorant of the way consultants are paid for their services and it seems useful to clarify this point from the start. Are they paid in hard cash? This is not often the case unless the client works for an agency outside of the university. Interdepartmental transfers of money would be helpful but professors may try to restrict funding outside of their own section. Staff could be released from other duties to provide consultation, but this still puts pressure on all staff within the department providing the service. It is not often the case but it may be of more widespread benefit for the service to be paid for by the university. In large grant proposals, there should be room for money to be set aside for statistical assistance and in our university many researchers are building this into their proposals.

What is the cost?

In our system, the first session of up to 30 minutes is free but after that the theory is that the client should pay. If payment is to be made, what is a reasonable price to ask? Academics tend to underestimate cost although guidelines are made available taking into account a number of the other costs such as holiday pay, superannuation, various insurances, office overheads and so on.

We should keep in mind that the higher the cost the higher the degree of professionalism needed.

What are your areas of interest?

Statisticians do have hobby horses or hangups on the latest techniques. Hand and Everitt (1987) coined the term *problem stealer* for an academic on the look out for interesting projects for students. They also listed some nine other types of consultants which clients should be wary of.

We operate a system of referrals to experts in particular areas depending on the degree of technicality that is required.

What are your qualifications?

Clients are often very trusting and it may not be easy for them to question the consultant's ability to provide high quality advice but they should be encouraged to do so.

What qualifications are required of a statistical consultant? Academic qualifications in statistics and/or social science cannot be overlooked but other skills would be a help or indeed essential for an effective interaction. Listening skills are not usually taught in statistics classes but are very important or a lot of time will be wasted in talking around the problem without getting to the nub of the problem.

What assurance will I have that the advice given will be of a high standard?

There is an ongoing discussion in the American Statistical Association as to whether statisticians should be certified while the Royal Statistical Society has introduced the title of Chartered Statistician. These are starting points as they recognise that statisticians have appropriate qualifications and are aware of codes of ethics. Quality cannot be absolutely guaranteed so that the consultant may need liability insurance.

3. What services do you provide?

One-off sessions or ongoing?

One-off sessions are the norm in our consultancy service which is directed mainly at the university community. This is not ideal but it reflects, in part, the academic situation and perhaps the paucity of funding. It could be noted that Deming(1966) was very reluctant to consider consultancy other than of an ongoing nature.

What do statisticians do well?

Scientific endeavour comes in many shapes and sizes. Many studies involve a number of steps from the initial conception of the study, formalising of goals and research design through to data collection, analysis, conclusions and finally a review of the validity of the whole process. Are statisticians trained to be equally conversant with the subtleties of each of these steps? Converted mathematicians would, no doubt, be interested in the analysis section while applied statisticians may be interested in the logic of research.

What do statisticians not do as well?

Social scientists may be more conscious of, and concerned about some conceptual considerations of the design of the study and matters of measurement and other aspects such as privacy, confidentiality and situational matters which may impinge on the validity of the study. Some statisticians are well versed in these matters but a quick study of research design texts written by statisticians will show that the more philosophical questions are downplayed.

4. Preparation for a consulting session

How should I prepare?

The consulting session is typically short so that it is essential that the client marshal information which can assist the consultant to understand the problems and the situation from which they arise. To this end, we have developed a Consultancy Request Form following a suggestion of Watts(1970). The first question on this form relates to the purpose of the study, namely whether the study is a thesis or a paper to be published. A second question relates to the description of the study as an exploratory study, experiment, sample survey, modelling, simulation or observational study. The type of query is to be identified and a brief statement of the problem given in the client's own words. Part of the actual data should be attached to the form as this provides important clues about the type of measurement, the structure of the data and how well organised the client is.

Checklists have been suggested (Jeffers, J N R, 1978, 1979 and 1980) as a way for clients to gather their thoughts and to appreciate some aspects of the logic of research methods. These have connotations of cookbook methods which some teachers may abhor but consultants would find useful.

5. The consultancy session: approaching the problem

Who asks the questions?

The consultant will usually take control of the session as there is only a short time to take in the information, process it at different levels and avoid the dual mistakes of not listening carefully enough to what the client is asking, on the one hand, and, on the other, assuming that the client knows the true nature of the problem and how it is to be approached. Clients often feel that there must be a complicated procedure which would solve all their problems but they may be surprised that the consultant will usually seek the simplest method possible.

Will the consultant be critical of my research and data?

Graduate students may have heard horror stories of statisticians who are overly critical of the data collected by fellow students and may be hesitant about approaching such consultants for help. Good advice for statisticians is for them to be positive and supportive. If there are real problems with the study, search for damage control strategies.

Will the consultant stop me from doing what I want to do?

Professional conduct comes into play here. If the client wants to have a paper published in a particular journal which mistakenly tends to refuse papers with no statistically significant results, should the consultant condone a fishing expedition to find such results. What if the sample is not random or if the sample size is not appropriate for the technique which was used? Should the advice depend on the nature of the study and whether it was carried out as course work in a degree, for a thesis, a paper for publication or a report for a commercial company? There are grey areas. Deming (1966) has set out useful codes of professional conduct which are appropriate for ongoing consultancy but are they appropriate in an academic setting?

Do I need to become a statistician?

No. Nor should the consultant expect to become an expert in every technical area. The shared problem may give rise to a synergism in which both parties gain a deeper insight into their own area of expertise. This may not happen often but it is exciting when it does and may lead to ongoing collaboration.

6. Consultancy - a different educational experience.

Do statisticians do things differently?

We believe that statisticians do have a different viewpoint on such things as variation and the possibilities of errors so that they may be more conservative in their view of the validity of certain results or the robustness of methods than are the clients.

A consultancy service provides a platform to get across statistical ideas to those who are ready and eager to learn. The timing and motivation is right as the clients have specific problems and they need help in solving them.

This educational role of consulting is important but often it must be approached in a different way to that of formal statistical education.

In this talk, we will consider a number of examples. Sample size is a common concern for researchers. It is approached by some authors by the application of a formula but as Williams(1978) noted, it involves approximation and guesswork so that it may be better to approach the topic from a different standpoint. Smith(1993) pointed out the importance of the target population and how this affects the conclusions of a study. The basic concept of statistical significance and its relationship to sample size and sampling, or experimental, units is a difficult problem to explain in a series of lectures. Is it possible to explain these concepts and difficulties in a short session and perhaps in a different way?

What problems should I try to avoid?

Clients who want to come to grips quickly with the difficulties of statistical ideas and practice could benefit from checklists, as mentioned earlier. Examples of bad practice could be useful and some of these will be discussed in this talk.

7. Wrapping it up: Some nice touches

Acknowledge the statistician

This could be a two edged sword for the statistician could be misquoted. The Consultancy Request Form mentioned earlier has a space for the consultant to write a summary of his suggestions using the correct terminology which the client could use in a report or paper. Ideally consultants should see the completed paper before agreeing to have their name attached to it.

Include the statistician in publications

Joint publications are a useful and traditional way of recognising the input of the consultant. The amount of input by each author sometimes raises problems and so does the quality of the paper.

Ongoing consultancy

This is the nicest touch of all and shows that the original consultancy was successful for all parties. With ongoing collaboration, new methods can be tried as all participants become experienced in specific statistical methods and the area to which they are applied.

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Strategies for Teaching Social Statistics to Graduates from the Workplace

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1. Introduction

During the past decade statistical knowledge has become increasingly important to many professionals from non-mathematical backgrounds such as psychologists, sociologists, and people trained in education, business, politics, biological and health sciences. Also researchers from a large number of fields often need to substantiate their results with statistical evidence, or at least understand journal articles which use statistical methods and language. Furthermore, the trend towards increased monitoring of workplace performance, and the use of quality assurance programs, has led to the need for more people to be involved in writing reports which often involve the use of statistical techniques.

To help meet the wider statistical needs of the community, both in higher education and in the workplace, a number of organisations and tertiary institutions offer programs in statistics for these students. At Swinburne University of Technology two main approaches have been used by the Department of Mathematics to assist this group. Firstly, a short course program has been established to help meet the immediate, short term statistical needs of people in the workplace, see Phillips (in press). Secondly, part-time post graduate programs in statistics have been developed for graduates who are currently working in areas in

which they use statistics, but for which they have had inadequate training. An outline of the original social statistics program is given in Garnham, Jones and Phillips (1991). This part-time program has proved to be very successful and in the past few years the two year Graduate Diploma has been extended to include a one year Graduate Certificate and a coursework Masters degree. Also, to better meet the statistical needs of workers in the health and medical professions, post graduate programs in Health Statistics are now offered.

2. Course objectives and outlines

The *Graduate Certificate* concentrates on practical skills and enables participants to broaden their theoretical and practical knowledge of the basic areas of social statistics. It consists of a one year part time program made up of units on statistical computing, introduction to data analysis, survey research methods and elementary statistical modelling.

The *Graduate Diploma* is for people with similar backgrounds to those undertaking the Certificate, but who want to progress further and cover a wider range of topics at a greater depth. It consists of a two year part time program made up of the units from the Certificate plus units on demography, multivariate statistics, survey sampling and further work on statistical computing.

The *Masters* degree by coursework is for people who have been very successful in the Graduate Diploma, but who want to develop research skills and make an in depth study involving knowledge and skills developed earlier in the course. It consists of further work on statistical modelling and multivariate statistics and involves a significant amount of research work.

3. The students

To date around 80 students have completed or are continuing graduate studies in the course. A number of others have taken single units in the program. The students fall into five broad groups:

- those working in market and social research, often with five to ten years experience in their fields, but needing to improve their statistical skills in their current positions or requiring further qualifications to gain promotions.
- those trained in areas remote from data collection and analysis but who have become involved in research in their respective fields.
- teachers wanting to broaden or update their knowledge.
- recent graduates wanting to improve their employment prospects.
- those wanting total career change or wanting to re-enter the workforce at a later stage in life who have an interest in statistics.

Of past and present students in the workforce (at least 80 percent), approximately equal proportions are drawn from the private sector (mainly research agencies); government departments and organisations; and educational institutions where they are involved in research work. A growing proportion of students are employed in the health sector.

4. The staff

The course is run in the Department of Mathematics and is mainly taught by people who were originally trained in mathematics and/or mathematical statistics, most who have teacher training. The Department has a wealth of experience of teaching statistics to students who do not have mathematical backgrounds. As the numbers doing the courses have grown, and with the expansion of the program to Masters level and to health statistics, specialists from other areas have been used in the regular teaching program. These include psychologists, demographers, sociologists and epidemiologists. Other specialist lecturers have been used on a one off basis, especially to give case studies or lectures on specialist topics. From time to time, present or previous students from the program are invited to give talks or workshops on an area in which they have practical experience.

5. Methods used

The approaches most suited to teaching adult learners with practical experience can differ from those used with undergraduate students. The Swinburne

Social Statistics students differ from many other graduate students studying statistics, for example as described in Brewer (1991) and Belli (in press), since they are enrolled in a course devoted to statistics, rather than merely studying statistics as a service subject to other fields.

A non-mathematical approach, in which statistical theory is kept to a minimum, is generally used in these courses. For example a data analysis approach similar to that used in Moore & McCabe (1993) is used in the introductory courses along with the associated videos with great success with these students. Students are taught about the various statistical methods and their assumptions. They initially use pencil and paper methods, assisted by the calculator and simple datasets, to develop the basic concepts. Then they use statistical packages to do more realistic problems. Minitab is used in the introductory statistics courses since it is quick to learn and is a very good teaching tool, particularly with its ability to do simulations. SPSS is also used because of its widespread application in this area. Spreadsheets and data entry packages are introduced to provide students with practical experience in preparing data for analysis. Computer intensive methods are also being introduced to help with the understanding of inference and with modelling, (Jones, Lipson & Phillips, 1993). Special care is made to try to integrate the statistics and computer work. This is being made easier as students gain classroom use of laptop computers as an aid to learning and have them available when needed in a manner similar to the way in which calculators are used.

Since most students are currently working in areas in which they have to use statistical thinking and techniques, attempts are made to capitalise on this knowledge and experience. They are encouraged to bring their work based questions and examples to class to make the learning more relevant and realistic, not only to themselves but also to other class members.

At the introductory level students are encouraged to study data which they can obtain readily from sources such as the daily press and journal articles. They are also encouraged to look for misuses of statistics and report them in class presentations. At the next level students are set assignments which often include finding and discussing journal articles which make substantial use of specific

techniques, and where possible, reproducing the results given. The major part of the assignments in many of the units involve the analysis of real life datasets.

Since the practical experience with statistics of these adult part time learners ranges from virtually none to a daily exposure of collecting and analysing data, the activities which students find worthwhile vary. New graduates, who usually have not had data collection experience, are encouraged to carry out assignments in the design and data collection area. Those who have had this type of experience do assignments which concentrate on the use of more advanced analytical skills. Students with previous experience with the computer packages taught in the course are expected to extend their knowledge to some of the more advanced features of the packages.

Assessment varies from unit to unit. These include tests, usually open book, assignments, essays and 'hands-on' computer tests. Students are required to give presentations as part of their assessment. For example in the statistical computing units students present reports on packages or procedures not covered in class. These include cases where students prepare a lesson then teach it to the class in a practical session. These sessions have been most successful. As Taffe (1991) points out "The person giving an explanation is the one who learns a great deal from it". Many students, while initially hesitant and nervous, find the experience of presenting in front of their peers greatly improves their confidence and understanding. Some students clearly have extensive experience in making presentations to clients and others in the workplace and those with little experience can learn a lot from hearing others speak.

In the classes early in the course, students are encouraged to work in groups on assignments and projects. Although this is sometimes met with resistance by students who prefer to work alone, in the long term students find that group-work gives them the opportunity to benefit from each other's knowledge so they end up getting a lot more from the experience than the mark gained. Working in groups is also seen as good training for the workplace.

At the graduate level, where employment is relevant to their studies, students are likely to have as much to learn from each other as they do from the lecturers. In this course special efforts are made to establish interaction among students and staff

from the outset. Each year begins with a welcoming session over drinks to informally introduce new and continuing students and staff to each other. Past students and present students are invited to special functions such as seminars or workshops and class dinners, which are well attended by students of from all intakes. Their opinions are sought when major changes are being made to the course, and these continued contacts have led to a number of consulting jobs and student projects. Beyond the formally organised functions, it is interesting to note that many past students still have regular contact with their peers, both on a professional and social level, several years after completing the course.

6. Student evaluation

Student feedback on the courses has been very positive, both in terms of the level of enjoyment derived from the courses and the relevance of the material taught. The strong positive reactions to the course were gauged both formally by regular student panel discussions and by means of a questionnaire sent to all past and present students, and informally through the networks which have naturally evolved among each intake.

Most students noted at least one aspect of the course they really enjoyed. These varied a lot between students but many reported that they most enjoyed the statistical or computing aspects. Others enjoyed learning about survey research methods. Apart from the formal side of the course, a number of students also commented that they particularly enjoyed the professional and social friendships they established.

Few students commented that there was any aspect of the program they did not enjoy. If anything, the worst aspect was finding the time to complete assignments or to practice what they had learnt. This is in line with Belli (in press) who found that the main problems facing her adult learners, were not so much concerned with factors such as the instructor, the course difficulty or their own failings in the area, rather " ... the common denominator of being older and already involved in a full time job (often a long term career), with many responsibilities beyond schooling, overrides any differences that might otherwise prevail."

The topics students found most useful often coincided with their work needs. Many felt that the knowledge they gained about either SPSS/PC+ or SAS (depending on their work) was the most useful aspect. While one of the early objectives of the course was to give students exposure to both these packages, because of their wide application, there is a clear preference from students to learn to use either, but not both, packages. Others felt that the multivariate statistics they learnt were the most useful - some students felt that even more multivariate statistics should be taught. It is notable that students tended to separate their computer training from their statistical training when asked which aspects of the course were the most/least useful, particularly as a conscious effort is made to integrate the computer and statistical training.

Many past students commented that overall the course was very useful to them as they felt their knowledge and confidence in working with statistics had greatly improved. The techniques most often applied in the workplace were survey research methods such as questionnaire design and survey sampling. While multivariate techniques were only of use in the workplace to a small number of people, a number reported it was very useful to know about these techniques.

At least one quarter of past and present students have changed jobs since starting their studies in social statistics. Most of these students felt that these studies had influenced the change. For some, a post-graduate qualification was essential for the position, particularly where people were seeking a promotion. For others, the employer was seeking a person with a knowledge of statistics and research methods. Nearly all students who have changed employment are working in areas where a statistical knowledge is likely to be useful at some stage.

Overall students seem very satisfied with the courses, although some students would like to learn about techniques which specifically relate to their work, such as conjoint analysis in market research or the use of logistic regression in medical research. While every effort is made to continually improve the Graduate Diploma course to meet students' needs, the Masters course offers a key opportunity for talented students to develop their own expertise in specialised areas.

7. Summing up

The Swinburne program provides graduates from a wide variety of backgrounds, often non-mathematical, with a complete course in statistics tailed to their abilities and practical needs. The strategies of involving the students in practical activities as much as possible, drawing on their own experiences, developing student networks and varying the requirements to meet students' individual needs, has proved to be a successful way of teaching students attracted to these courses The need for continued development and improvement of these courses is seen as important in the general statistical education of users of statistics, particularly for those who do not have a traditional background in the area.

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The Importance Of Context In Statistical Education For The Social Sciences

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At Victoria university in New Zealand the first year statistics course for those majoring in social sciences is one in which female students consistently perform well. This is in contrast to other first year statistics and mathematics courses.The course has been examined for factors that may contribute to this outcome.

Males and females mostly attempt the same questions in the final examination. Theoretical questions are unpopular and performance is poor in them. The most frequently attempted questions are those involving people and the environment. These are the questions in which the students do particularly well. In the weekly assignments the emphasis is on 'people' problems in contrast to the alternative course which still makes heavy use of urns and dice questions and contexts from manufacturing and industry. Given a choice of contexts the students have very definite preferences: no matter how relevant a problem on environmental issues, if this problem is in competition with one involving people then the people problem is preferred, and a standard, recognisable problem is preferred over a non-standard problem however interesting it may be. The preference for 'people' problems is more marked in female social science students than males and they are more likely to choose a second option if the first is not "female-friendly". In this course females do significantly better than males in both the traditional timed examination and in the internally assessed work but they do 'more better' in the latter investigational, openended setting.

Given problems couched in terms of people and everyday reality,social science students appear to achieve better and be more comfortable than when attempting the same material couched in the abstract or in terms traditionally associated with industry and manufacturing.

Teaching the Statistics of Inequality through Case Studies

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Students tend to be really motivated by things they themselves relate to and find interesting. This paper focuses on case studies which reflect on the state of Britain in the 1990s. Poverty has gone up, racial tensions have risen and unemployment has increased. The Population Census 1991 provides a good opportunity to analyse an accessible, large data set which can be used to address those issues. It enables students to obtain hands on experience of the type of analysis which local authority statisticians or sociologists do. It also enables them to use multivariate data analysis in a practical context. This paper will give examples of such case studies.

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Using a group assignment for assessing students in an elementary statistics course

Group assignments are useful to give students the experience and benefits of working with others (C.W. Anderson & R.M. Loynes, 1987) and useful to academic staff who have to assess large numbers of students (G.Gibbs, 1992).

The assignment was given to 200 (mostly psychology) students. One report was produced by each group of 5 students. Preliminary information as suggested by Gibbs, 1992 was provided and an example of a report (V.Barnett & S.Hilditch, 1993) given. Two questions were set using data from: Ryan, Joiner & Ryan, pp.318-321, 1986 and OPCS, p.98, 1988. The same grade was given for each member of a group. Written feedback was given for each group and one written critique given for all the students.

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The Characteristics of Statistics in the Social Sciences

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Abstract

In this paper we explore the notion that students in the social sciences have little chance of comprehending the holistic role of statistics if it is taught in a manner which is abstract and independent of measurement paradigms of the social sciences. Making statistics relevant to students is not achieved by using isolated examples of statistical tests from the social sciences. These will be meaningless unless students have considered such fundamental questions as 'why is it necessary to measure things?', 'what is going to be measured?', 'should different classes of individuals be measured in order to establish whether there is a difference?' and 'how are the measurements going to influence management?'

It is possible to bring students to recognition of the need for statistics by including the usefulness of measurement and quantitative research methods. Without this approach, some students will still pass tertiary statistics subjects, even with distinction, because they may have the mathematical ability, have excellent recall or just work hard. However, without appropriate understanding some students will develop an anxiety and alienation towards statistics which may be long lasting. It is the responsibility of the statistics lecturer to be fluent in the role of statistics within the social sciences and not just in the application of statistical testing.

This paper focuses on sciences which study living populations and develop measurements, analysis and conclusions which are of relevance to planning. The four population sciences considered are demography, biodiversity, epidemiology and market research. There is discussion of the need for students to understand background theory, be it social science or management, and the underlying measurement paradigms. The roles of computers and logic are re-evaluated.

INTRODUCTION

Firstly, what do we mean by the social sciences?
The Macquarie dictionary defines social science as

> **"a broad group of subjects, as economics, social history, esp. as taught in schools, sociology, etc., relating to man's (sic) function as a social being" (Butler 1982).**

In this paper, we are referring to the teaching of statistics to such disciplines as business, economics, education, geography, health science, humanities, management, planners, psychology, sociology.

Historically, statistics in our community has been firmly aligned to the approaches of Sir Ronald Fisher, who was an eminent geneticist and statistician. The statistical outcomes of his work were in many cases a reaction to problems in experimental design and analysis in agriculture and biology.

Although experimental design is largely ignored, the influence of Fisher's work in inferential statistics is obvious when examining the content of undergraduate introduction to statistics text books. Most devote the majority of the text to techniques of confidence interval and hypothesis testing. These are pursued through questions like

- what is the range of values for the proportion?
- are the proportions the same?
- what is the range of values for the mean?
- are the means equal?
- is there a relationship?

Often the only difference between a statistics text book for students in agriculture and that for students in business is that the examples have settings purporting to relate to the particular discipline. Such translation implies the existence of a universal toolkit of statistical techniques, which just need a change of example to make them relevant to students of a different discipline.

PERSPECTIVE

We question whether these traditional statistics courses provide students in social science with the ability to change the understanding of their world through experiencing a course in statistics (Ramsden 1992). If they are not able to do this, then statistics just becomes another of those subjects imposed upon students in the quest for credentials.

Our awareness of the credibility gap has come from several sources

- discussions with mature aged students from the work force, whose comments about the lack of relevance of these traditional statistical approaches to the situations they encounter, give cause for concern
- course co-ordinators who, in our university, are taking the opportunity to re-organise, associated with mergers in the tertiary sector. This has led to hardnosed negotiations over the development of statistics courses
- reading of the professional literature for the particular discipline. This can provide substantial information about the types of questions being asked and the way that they have been answered
- industry input from people who are involved in planning and decision making
- our own experience in the non-academic work force as market researchers, consultants, public servants, investors.

ASPECTS TO BE CONSIDERED

The information that we have received has led us to propose that statistics teaching in social science needs to reflect the following

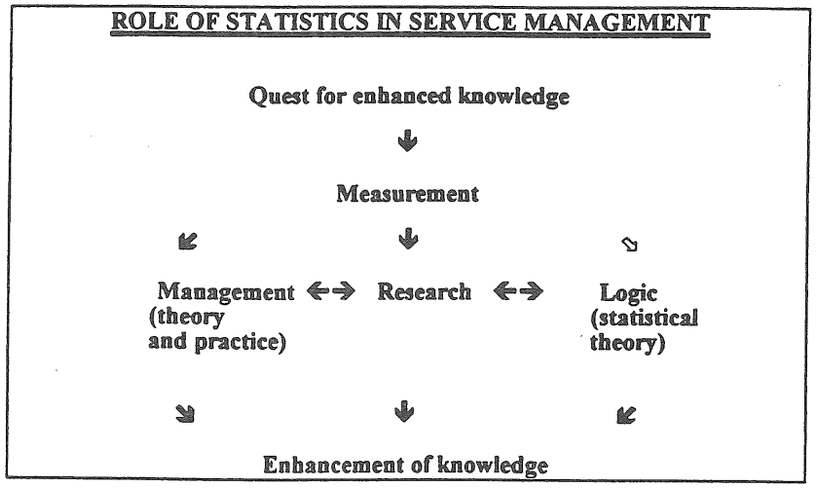
- the current debate on what research is, particularly with regard to qualitative versus quantitative research and action versus classical detached research
- experimentation is less likely than in agriculture
- variables to be measured are less obvious (Maher and Burke 1991). Issues and decisions are not as clearly dimensionalised as they are in agricultural statistics or in physics and mathematics.
- instruments for measuring may not exist or may not be reliable. In agricultural experiments concern often relates to calibration accuracy for the measuring instrument. Social scientists may have to create a measuring instrument which may only be relevant in a local context
- variables may not be as controllable or transferable as they are in agricultural experimentation.
- setting of hypotheses may not be important.

MODELLING THE ROLE OF STATISTICS

Whilst we recognise that social science is broader than service provision and management, we have tended to focus our efforts on where social science contributes to programme development or delivery and the running of service organisations. Here the following questions need to be addressed.

- How does an organisation run its processes better?
- How does an organisation satisfy the customer or client better?
- How does an organisation decide what business it is in?

We believe that the time and statistical effort expended on each of these questions will depend on the nature of the discipline. Agricultural experimentation fits primarily into product development which is a subset of the second question. Social science generally has a wider application and statistics will contribute to answering all three questions. Therefore the following model is proposed for the role of statistics in service management.



WHAT IS MEASUREMENT?

Measurement assigns quantity and meaning to experience (Maher and Burke 1991). Measurement is the conceptual means by which two different entities can be compared in numeric terms. Once established, this means provides a unit in terms of which a numerical coefficient can be assigned to every member of the class to which the measure is applicable. This implies that some abstract property is recognised as being common to all members of the class (Crump 1990).

Measurement is something that people from a scientific background often take for granted. However, there are clear differences between cultures and over time within cultures in the understanding and use of forms of measurement (Crump 1990). Just as a chemistry student is expected to learn how to use the measurement tools associated with the discipline, a student studying statistics in the social sciences needs to know how to use the basic measurement tools. We should not take for granted that students can use the tools without instruction

Measurement has characteristics of dimension, utility, standard unit, measurement instrument, validity, reliability and statistical significance (Crump 1990). Of these characteristics, dimension and utility will be discussed in detail.

Dimension is the primary characteristic. It is the underlying quality that the measurer is trying to measure or that we may subsequently try to measure. It is dependent on social science and management models, and their underpinning theories. Without the ability to dimensionalise, a student has no chance of making sense of statistical analysis since steps in the iterative process, given below, are missing

theory -> dimension -> instrument -> measure -> comparison ->

statistical analysis -> interpreting -> reporting -> (theory)

Another primary characteristic is utility. It is the usefulness of the measure to theory development and management. Students need to be taught how to reference theory and consult with management to specify attitudes to utility

The other characteristics follow fairly logically once these two are established

MEASUREMENT TAXONOMY

In agriculture, yields and concentrations are commonly used measures. Having recognised this, we then asked whether there was a finite set of measures which recurred in social science?

We have attempted to develop a taxonomy of measurement for the four population social sciences of demography, biodiversity, epidemiology and market research in social science.

Summary of Measures in Four Population Sciences.

	Demog-raphy	Biodiv-ersity	Epidem-iology	Market Resrch
MEASURES				
Abundance	Yes	Yes	Yes	Yes
Prevalence	Yes	Yes	Yes	Yes
Incidence	Yes	Yes	Yes	(Yes)
Diversity		Yes		
Fertility	Yes	Yes	Yes	Yes
Morbidity	Yes	(Yes)	Yes	Yes
Mortality	Yes	Yes	Yes	(Yes)
Consumption	(Yes)	Yes	Yes	Yes
Resource use		Yes	Yes	(Yes)
Behaviour	Yes	Yes	Yes	Yes
Communication			Yes	Yes
Environment	Yes	Yes	Yes	Yes
Habitat	Yes	Yes	Yes	Yes
Determinants	Yes	Yes	Yes	Yes
Risk factors	Yes	Yes	Yes	Yes

We recognise that there are severe limitations in teaching a taxonomy of measures. Students may overlook the potential for a dynamic taxonomy. Nevertheless we believe that there is value in introducing a set of basic measures.

MANAGEMENT

A number of management models have been developed over the 20th century. Each model has its own set of underpinning theories and perceptions of management. Several of these models have been substantially influenced by developments in the social sciences. Each model has its own approach to measurement. Consequently some organisations use only financial measurement while others use a range of measures in decision making. Similar statements could be made about each of the social science disciplines. Students need to be made aware of these models, theories and measurement approaches.

Management and measurement are linked together. If management does not appreciate the dimensional approach to decision making then no amount of sophisticated statistics will alter the decision making process.

STATISTICAL TECHNIQUES

If more time is to be spent on the characteristics of measurement when teaching social science students, there will be less time to spend on the toolkit of tests that are the staple diet for many undergraduate statistics courses. Some people would claim that there are three basic statistical techniques covered in such courses. These are chisquare, ANOVA and regression tests. Rather than making the course a rushed cookbook of statistical techniques, students should be instructed on a good example of design and then taught how to investigate the statistical techniques available. There are books available which are good resources for the investigator in the social science, providing commonly used research designs (Isaac and Michael 1981). This book gives a summary of 8 basic research designs for social scientists.

In the past, statistical courses devoted much time to the formulae of statistics because there were primitive, if any, calculation aids. Computers have revolutionised statistics in the late 20th century by changing the competency needs. No longer is there need to spend a lot of time on hand calculations, but instead large databases of material can be accessed and manipulated easily. Freedom from the drudge of calculations allows time for creating new social science measures. Statistics courses should reflect this change in direction

LOGIC

Mathematical logic is the basis on which the techniques of statistics are built. It can also become a refined art form, wherein the beauty of the mathematics is to be enjoyed. Within many courses for the training of statisticians a great deal of emphasis is placed on the algebraic and inferential calculus theory underpinning the statistics used. There is some justification for such courses having this type of training. However in the social sciences, study of the logic basis for a statistical technique will build greater knowledge of the logic but will not necessarily enhance the students' understanding of how statistics contributes to knowledge in the social sciences. In teaching statistics to social science students we believe that there should be a limited amount, if any, of mathematical logic.

CONCLUSION

We conclude that there is a need for all teaching of statistics to refer to much wider issues than appear to be currently addressed. In particular, unless we demonstrate the overall role of statistics in the social sciences, and emphasise practical measurement, statistics will not be perceived as relevant by students.

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Activity based learning within a traditional lecture-tutorial structure

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Abstract

A course in basic statistical inference which had traditionally been taught in a lecture-tutorial format was adapted to incorporate activity-based learning. A compulsory practical class each week involved students collecting and investigating data in a group situation. These practical classes preceded and motivated the presentation of the theory in the lectures. The emphasis upon examples involving common shared experiences led to increased enthusiasm and interest in the course.

The traditional model for the teaching of tertiary units to large groups of students in many universities around the world has been one of lectures and tutorials, with practical classes where necessary. This implied behaviourist model of learning suggests that knowledge is transmitted from the lecturer to the student and is constructed in a framework quite separate from the learner. Current thinking, however, suggests that learning takes place in the context of the whole of the students' lives, and is not limited to what happens in the lecture theatre.

In Australia, most lecturers have not been trained to teach. Since tertiary education has broadened its intake and the needs and backgrounds of students have become more varied, the issue of teaching in universities has received greater attention.

Consideration must be given to what students need to know, and to the most effective means of teaching it. Students in service statistics courses, particularly in the social sciences, often lack the perceived necessary skills. Since many of them have a mathematical history of poor performance, poor motivation, and anxiety, it has been suggested that courses should capitalise on students' common experiences and use

these as motivation. (Burton 1987). Studies have shown (Adler & Rodman 1988) that where students are expected to take a passive role in learning it is highly probable that most are not taking part at all. Howsen(1988) suggested that for service courses in mathematics, good physical illustrations may be more enlightening for students than logical proofs. Caulcutt (1987) indicated that we ought to concentrate on real problems in our teaching of statistics and to emphasise statistical techniques rather than theory.

It is also helpful to consider the natural learning process in the everyday lives of students. Rogers (1986) identified the main characteristics of self-directed learning activities for adults. He found that learning activities were usually episodic and aimed at the solution of specific and immediate concrete problems, that knowledge from many sources was brought to bear on any problem, and that material was applied as soon as it was mastered..

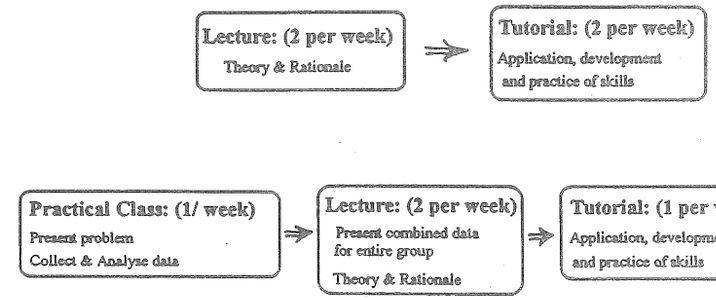
The lecture-tutorial method seems to be the least effective means of transferring knowledge, but it is the method forced upon most of us by large student numbers and inadequate resources. Our challenge was to develop a way of introducing applications of immediate practical interest to the students, and to encourage deep learning through activity based investigations, while still maintaining the lecture-tutorial structure.

Working with an established syllabus, we replaced one of the weekly tutorials with an activity based practical session. Because these practical classes were compulsory, all students had a shared context for their learning. The activities were chosen to introduce concepts which were then discussed fully in the following lectures. Hence the theory could be related to a common experience. The final tutorial for the week was devoted to the usual tasks of solving set examples and answering particular student problems.

Many of the activities had been developed for use in a classroom situation over the previous four or five years. The adaptations required to fit a lecture-tutorial format were mainly organisational. Worksheets, overheads for data consolidation and instructions to tutors had to be well prepared in advance. Regular meetings of tutors were essential, and the cooperation of the timetabler was needed to schedule all of the practical classes prior to the two lectures of the week.

All of the tutors involved in the program were enthusiastic about both the underlying philosophy and the implementation of the practical classes. While the classes involved more than the usual amount of preparation, they were able to be run successfully regardless of whether or not the tutors were trained teachers. We anticipate that the level of preparation will not be as great in future years.

The following diagram provides a schematic representation of the traditional arrangement, and the changes made in 1993.



Most practical sessions involved the students collecting their own data. For example to introduce hypothesis tests for the mean, each student measured their height and the length of their right foot. An overhead transparency was provided to enter the data in a table showing foot length, height and sex (0=Female, 1=Male). Two questions were posed:

Is the average foot a foot long (1 foot = 32.5cm)?
Are people today taller on average than they were in 1935?

Data on the average height for males and females from a medical almanac of 1935 were provided.

Each student entered the data for their tutorial class into Minitab. Instructions were given to calculate means and standard errors for foot length for the class as a whole, and for height by sex. Questions on the worksheet lead the students though the philosophy behind the hypothesis test by asking how many standard errors away from the given mean were their values. They were asked to speculate on the probability of obtaining such a result by chance.

The follow up lecture discussed the theory of *t*-tests and related it to the data obtained in the practical classes. In the case of the height question, some interesting differences could be pointed out between the results for a single tutorial group ($n \approx 15$) and for the entire class ($n=140$). This lead later into a discussion of sample size and power.

Other practical classes involved activities such as counting loose change in pockets, comparing pulse rates after different activities, investigating the colour distribution in packets of M&M's, and a chocolate chip cookie taste test. Each activity was designed to introduce the statistical theory for that week. By the end of each week, all students

had access to the combined data sets from each of the tutorial classes, and were encouraged to review it in their own time.

The experiment was reviewed in two ways, through examination results and through a course evaluation questionnaire.

The course evaluation questionnaire was handed out in both 1992 and 1993. In 1992 the course was taught in the traditional way, with two lectures and two tutorials per week. In six of the tutorials the students completed a worksheet-based Minitab activity, where data was provided in a computer file, and the activity followed the presentation of the theory in lectures. The differences in 1993 were threefold:

- there was a practical session each week;
- the students collected their own data;
- the activities *preceded* rather than followed the theory.

Student responses to questions on the value of the computer worksheets in 1992 were compared with those on the practical classes in 1993. An increased percentage of students gave a positive response to the questionnaire statement "*computer work-sheets/practical classes were interesting*" (70% in 1993 against 55% in 1992). Their response patterns to other items on the questionnaire were fairly similar.

In both years students were asked to rank in order from 1 to 7 the things they saw as most important in their learning for this course. Choices included lectures, tutorials, computer worksheets/practical classes, set tutorial problems, revision problems, text-book, and discussion with friends. The practical classes were seen to be more important in 1993 than the worksheets were in 1992. This can be seen in the table below which summarises the students' rankings of the worksheets (1992) and the 1993 practical classes in importance for their learning.

Table 1: Percentage of respondents ranking worksheets or practical classes in importance for learning:

	Ranking		
	First	In first two	In first three
1992 Worksheets	1	11	25
1993 Practicals	11	27	40

Most written comments from the students were positive. Several stated that the practical sessions were of considerable benefit to their understanding. However, there were many requests for more problem solving and skills development in the tutorials.

Attendance at lectures seemed better in 1993 than 1992, although no accurate records were kept. Anecdotal evidence suggests that students were keen to find out more about the problems they had been investigating in the practical classes, and came to lectures, even though these were scheduled at a less convenient time in 1993.

The practical sessions were designed to improve motivation and provide a better foundation for understanding the theory. They did not necessarily improve the type of skills assessed in a traditional examination. The assessment of the unit in 1993 was deliberately kept similar to that for 1992. Unfortunately the pass rate dropped, from 75% in 1992 to 67% in 1993. This may not have been due to the change in teaching methods, as there was a general perception in the university that due to changes in the State secondary education system, this year's intake was weaker than that of previous years. This was borne out by a corresponding drop in pass rates in two other introductory statistics units taught at the University, from 89% to 61%, and from 86% to 78%.

One of our objectives was to increase the understanding of concepts so that when students need to apply their statistics in the later years of their social science, or of any other course, they would have the necessary skills. Whether or not this occurs to a greater degree than was previously the case remains to be seen.

Conclusion

Whilst examination pass rates were not improved, almost half of the students rated the practical classes high on their list of things they considered important for their learning. The classes added a level of interest and enthusiasm for both students and tutors that was not available in the traditional structure. This program has demonstrated that it is possible to incorporate activity-based learning at a tertiary level with large classes.

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MANIPULATING THE TEACHING-LEARNING ENVIRONMENT IN A FIRST YEAR STATISTICS COURSE

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The present paper reports a cooperative research between the Department of Data-analysis of the University of Gent and the Open University of the Netherlands. The OTIC research program of the Open University developed a prototype of an interactive learning environment, consisting of learning materials and support devices. This prototype was tested at Gent University (period December 93-March 94). The group of students enrolled at the initial statistics course at the department of psychology and educational sciences at the University in gent, is heteregeneous in relation to prior knowledge of mathematics and statistics and to attitudes towards scientific research and use of computers. The initial statistics course is one of the hardest courses in the curriculum. The research design consists of 5 groups : 4 experimental ones and 1 control group. The teaching-learning environments in the 4 experimental groups are based on 2 factors :

A Computer-based or pen-and-paper based materials

B Overt or covert didactic components

The teaching-learning environment in the control group is a traditional one : lecture with pen-and-paper exercices. In this setting, interactions between lector and students and between students are possible. The students in the 4 experimental groups get a self-study package in a controlled setting without human interactions. The study takes into account some variables related to the three broad categories of individual difference constructs :

a) intellectul abilities : - academic ability and prior knowledge
- reading ability

b) personality characteristics : attittude towards computers and scientific research

c) cognitive style : use of support devices

The effects of the different treatments on the results of a statistics test, related to the teaching materials, are analysed taking into account the above mentioned co-variables.

The specific analysis approach to analysis of variance

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The present paper is concerned with what we call the *specific analysis approach* to analysis of variance. Roughly speaking, a specific analysis for a particular effect consists in handling only data that are relevant for it. This approach is contrasted with the conventional one of a general model. Thanks to this approach, the analysis of variance can be reconsidered as a direct extension of the basic procedures used in descriptive statistics (means, standard deviations) and inferential statistics (comparison of means by Students *t* test): see Lecoutre (1988), Lecoutre and Poitevineau (1992). This leads to decisive methodological improvements. In particular, the exact validity assumptions for each inference are made explicit and comprehensible. Furthermore inferential procedures allowing to draw conclusions about the *magnitude* ("scientific significance") and not only the *existence* ("statistical significance") of the tested effect become easy to use. For complex (especially repeated measures) designs, the advantages of the specific analysis approach appear overwhelming (Rouanet and Lecoutre, 1983).

This conception brings a simple way for teaching the analysis of variance (including MANOVA) to non statisticians. This point is illustrated from a numerical example.

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THE CHALLENGES OF TEACHING A UNIVERSITY-WIDE POSTGRADUATE SERVICE COURSE IN STATISTICS: A NIGERIAN EXPERIENCE.

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ABSTRACT

In 1986, the Senate of the University of Lagos mandated the Department of mathematics to mount a University-wide post graduate service course in Statistics. The course is entitled "Quantitative Research Methods" but is more popularly known on campus as " MAT 840 ". It is designed to serve the needs of non-statistics-based Departments whose students often require some exposure to statistical and other quantitative techniques in their postgraduate programmes. Prior to the Senate decision, postgraduate courses in statistics for non-statistics-based Departments were taught outside of the control of the Department of Mathematics.

This article highlights basic features of the MAT 840; furthermore it discusses experiences of the teaching crew and pinpoints major constraints inherent in teaching statistics to non-statistics majors and in an environment where modern teaching aids, for example computers, are hard to come by.

PROBABILITIES AND STATISTICS IN PERFORMANCE EVALUATION OF COMPUTER SYSTEMS AND COMPUTER NETWORKS

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ABSTRACT

This paper intends to show the knowledge in probabilities and statistics needed by the engineers working in the field for correctly evaluating the performance of computer systems and computer networks. It shows the main techniques used and their statistical and probabilistic basis that includes classical as well as new developments.

1. INTRODUCTION

Performance evaluation of computer systems and computer networks is a discipline of computer and communication science and engineering devoted to measure and predict the behaviour of such systems.

To evaluate the performance of such systems two basic techniques can be used: measuring and modelling, depending on whether the system to be evaluated exists or not. On the other way, depending on the level at which we are looking the system the modelling and measuring tools to be used will also vary.

In consequence, the goal of this paper is to present the different tools used in the different steps of the life-cycle of such systems and the probabilistic statistical needs that they have in order to give a basis for discussing how and when these topics are to be taught in the formation of the computer scientists and engineers.

To attain this goal, section 2 will be devoted to general considerations about the problems that appear in measuring and modelling such kind of systems. In real world it is very difficult to separate computer system from computer networks; actually there are computers in a networks and the applications running on computer systems have very frequently need of some kind of communication network; so for divide and conquer reasons the probabilistic and statistical needs of the performance evaluation of computer systems and computer networks are reviewed in two different sections. So,. section 3 will be dedicated to analyse the particular needs for evaluating the performance of the computer systems at their different levels: hardware, software and application and section 4 will be devoted to analyse the needs for evaluating the performance of networks systems. Finally in section 5 some conclusions will be extracted from the general needs to evaluate the performance of computer systems and computer networks.

2. GENERAL CONSIDERATIONS

Before to analyse in particular the needs in probabilistic and statistical knowledge, let introduce some general aspects of the performance evaluation of both computer systems and computer networks.

2.1. Measuring

The main characteristic of this kind of systems is their impossibility to repeat a measurement when they are running under real environments. For instance, let assume a computer system running to serve a set of interactive terminals; if a repetition of a work session is intended with people using the terminals, it is easy to restart the system at its initial situation and it is possible to ask the user to repeat their work. However it is very probable that, first of all, the users do different typing mistakes and, in consequence, provide different request sequences to the system, and secondly, a work learning effect in the users implies a reduction of the thinking times, and in consequence putting the system in different work conditions.

These facts avoid to, strictly speaking, measure the system behaviour because we cannot repeat a measurement in order to reduce the measurement errors. If we wish to do so, it is possible to place the system in a fully controlled environment in such a way that we can place the system in the same situation as many times than we need. So, we can:

- monitor the system behaviour in order to know what is happening in the system, when it is running in a real environment
- measure the system performance when the system is running in a fully controlled environment in order to have the possibility to compare the performance of the system along its life (the configuration of the system may vary) or to compare different systems submitted to the same workload.

2.2. Modelling

Modelling the performance of a computer system or a computer network is to create a mathematical model that represents the system behaviour in order to estimate the performance variables when the system is running under pre-established conditions. That means that it is not necessary to model all the system components that are not active in the considered environment; otherwise the model obtained can be extremely costly to run. For instance, if it is considered a system running in steady state conditions, it is not necessary to represent in the model the crash and error recovery procedures.

Also it is necessary to remind that modelling a system is to create a representation as simple and precise as necessary. This assertion has two consequences:

- a system has not a unique model, depending on its accuracy and on the modelling technique used.
- the models of the system components can have different accuracy degrees depending on their critical influence on the system behaviour.

Normally to represent the behaviour of the system, it is necessary to show the sources of delays. This sources are mainly of two types:

- synchronisation (of any kind) of two or more processes.
- conflict of several users or processes in the use of some resource.

Techniques used to represent these sources of delay are:

- Markov chains [ALLE90, TRIV82].
- queueing theory [KLEI75, LEUN88] and queueing networks (open, closed or mixed) [CONW89, FDID89, KOBA78, LAVE83, LAZO84, PUJO89], in fact a particular case of Markov chains, better suited for representing the conflict in the use of some resource by different users or processes. Advanced topics of this technique can also be found in [TAKA91, TAKA93A, TAKA93B].

- timed Petri nets [AJMO86], in fact a particular case of Markov chains, better suited for representing the synchronisation of different processes.

and the methods to run models built by these techniques are:

- analytical methods in which by means of some kind of closed formula it is possible to compute the performance variables; these methods are applied to queueing networks and can be:
  * exact, able to be used with some specific set of queueing networks, known as product form networks or BCMP networks [JACK62, BASK75]; main algorithms to solve this kind of queueing networks are:
    . convolution [BRUE80] for open, closed and mixed queueing networks.
    . mean value analysis [REIS80] for closed queueing networks; faster and more accurate than the previous one for these networks.
  * approximate[AGRA85], able to be used to a larger set of queueing networks and that can be classified in three families:
    . diffusion [KOBA74, GELE81] based on the study of the discrete queue length distribution as it was continuous, by means of the diffusion equation, and then its discretisation.
    . decomposition-aggregation [COUR77, GELE81, JAIN91]by application of the Norton's theorem or the decomposition of the space state, that can also be applied to the finite size Markov chains.
    . iteration [CHAN75, MARI77] based on the iterative computation according with some reasonable conjuncture and from some initial situation.

  The application of these methods requires the matching of different statistical conditions mainly about the service time distributions, the arrival processes, the routing mechanisms across the network and the types of servers.
- numerical methods [ALLE90, TRIV82] in which the behaviour of the system is represented by means of its transition matrix and to evaluate the performance variables it is necessary to compute the eigenvector associated to the eigenvalue 1.
- simulation methods in which by means of some of computer program the timing behaviour of the system is represented and to compute the performance variables, statistics of the model running are taken [FISH78, KOBA78, LAVE83, MACD87, MITR82, SAUE83]. The main topics to be known from the user view point are:
  * to know the quality of the results obtained by means of their confidence intervals [FISH78] together with the ways to organise the simulation: iterative, batch means, regenerative, spectral.
  * to choose the appropriate distributions for the input variables defined in this way and also the hypothesis tests to justify the closeness of these distributions to the experimental values if this is the case [ALLE90, TRIV82].
  * eventually to generate random numbers uniformly distributed and/or distributed according any other statistical distribution [KNUT81, LAVE83] and to test their randomness.

From the computing time view point, the fastest methods are the analytical ones; however, they have the mentioned constraints on service time distributions, arrival processes, routing mechanisms and types of servers. Simulation methods have no theoretical constraint from the modelling view point; however they are much harder to debug and have longer

(depending on the desired accuracy of the results) computing times. Numerical methods are not so restrictive from the modelling view point than the analytical ones but their computing times are close to those of the simulation ones and have numerical accuracy problems for big models.

3. COMPUTER SYSTEMS

In a computer system, it is possible to distinguish three different components that have influence in its performance:

- hardware.
- basic software (operating system, data base management system) that interfaces hardware with applications.
- application software (set of programs that manipulate specific data) that interfaces the basic software with the users.

Obviously, as each level needs the previous for running, the corresponding models implies those of the inner levels.

3.1. Hardware level

3.1.1. Measuring. Measuring tools are normally hardware monitors and electronic probes that allow the hardware designer or user to get information on what is happening in the system hardware [FERR83, JAIN91].

The general needs are those of any measuring experience: the number of measurements necessary to get a pre-established measurement accuracy.

3.1.2. Modelling. The necessary knowledge for correctly modelling the hardware behaviour depends on the type of work done: design or use.

The designer needs to build sophisticated and accurate models (markovian, queueing or Petri nets) of the hardware itself and to use as inputs to these models information concerning the behaviour of programs with respect to the hardware, as traces and internal parallelism. This information can be directly collected from real cases or extended from the collected one by means of any kind of statistical distribution [AJMO86]. The actual main problems considered are those related to the memory organisation (hierarchical organisation, distribution among several processors, etc.) and to the load balancing of multiprocessors. In this kind of problems, very frequently *ad hoc* models using the above mentioned techniques are frequently necessary to predict the behaviour of the system in development.

The user are much more concerned with the application level and frequently is satisfied with simpler and more standard models of the hardware behaviour than those needed by the designer.

3.2. Software level

In this section just the basic software (operating systems, data base management systems, etc.) is considered. The application software is considered in section 3.3.

3.2.1. Measuring. Measuring tools are normally software monitors, software probes and accounting systems that allow the software designer or user to get information on what is happening in the system software [FERR83, JAIN91]. The main inconvenient of these tools is overhead, and in consequence the perturbation, introduced in the measurements. However they (specially software monitors) normally give the measurement of the resources consumed to the tool itself.

The general needs are those of any measuring experience: the number of measurements necessary to get a pre-established measurement accuracy.

3.2.2. Modelling. As in hardware modelling, the necessary knowledge for correctly modelling the software behaviour running on a specified hardware depends on the type of work done: design or use.

The designer needs to build sophisticated and accurate models (markovian, queueing or Petri nets) of the hardware itself and to use as inputs to these models information concerning the behaviour of programs with respect to the software and the behaviour of both levels of software (basic and application) with respect to the hardware. This information can be directly collected from real cases or extended from the collected one by means of any kind of statistical distribution. The main problems considered are those related to the resource management algorithms of the operating system and to the data access policies of the data base manager. In this kind of problems, very frequently *ad hoc* models using the above mentioned techniques are frequently necessary to predict the behaviour of the system in development.

The user are much more concerned with the application level and frequently is satisfied with simpler and more standard models of the hardware behaviour than those needed by the designer. The accuracy of the user models should be lower because he has normally a lower knowledge of the internal behaviour of both hardware and basic software.

3.3. Application level

Models at this level are just concerned by users of computer systems. They can be either system responsibles or application designers. The first one is mainly concerned by the system tuning and the second one by the performance constraints meeting.

3.3.1. Measuring. Measuring tools are normally hardware and software monitors, software probes and accounting systems that allow the system responsible or the application designer to get information on what is happening in the system [FERR83, JAIN91]. The main inconvenient of the software tools is the overhead and of the hardware ones its incapacity to access to software related information. Also it is frequently necessary to build workload models by means of data analysis techniques (factor analysis, clustering, etc.) in order to prepare benchmarks to study the evolution of the system performance versus configuration or to get a comparison basis for different system proposals [CALZ93]. To estimate future workloads classical statistical techniques (regression, correlation, analysis of variance, etc.) are used [ALLE90, TRIV82].

3.3.2. Modelling. Models are built mainly by means of queueing networks in order to predict the performance of a computer system running under a specified load. In this environment normally there are not need of *ad hoc* models, but standard queueing network models to be solved by means of analytic or simulation techniques [FDID89, LAVE83, LAZO84, MACD87, MACN85, MOLL89, PUJO89]. There are standard tools (QNAP2, BEST-1, RESQ, etc.) that allow the user to describe the system and its environment by means of some language and to solve the model using someone of the above mentioned techniques. The main difficulty in building such models is not the description of the system components in terms of queues but to describe the behaviour of the basic software with enough accuracy with respect to the rest of the components and to get enough accurate data of the resource consumption of the workload components to run the model to obtain the desired estimation of the performance variables..

When these techniques are used to predict the performance of an existing system under future workload, to describe the system workload, techniques similar to those used in benchmark preparation can be used but, instead of giving groups of programs, statistical distributions describing the program classes have to be provided. When these techniques are used to predict the performance of some system (normally a real-time one) in development, to get good estimations of data of the resource consumption, statistics of similar software components running on similar hardware are to be taken and organised in such a way that their reuse be simple.

4 NETWORK SYSTEMS

The variety of structures existing in the computer networks is larger than the one of the computer systems. In consequence, it is much more difficult to get standard procedures to study its performance and very frequently it is necessary to use specific techniques for each kind of computer communication network.

4.1. Measuring

Measuring tools are normally specifically designed for each kind of network (LAN, MAN, WAN, etc.) in order to allow the network designer or user to get information on what is happening in the computer network.

The general needs are those of any measuring experience: the number of measurements necessary to get a pre-established measurement accuracy [ALLE90, TRIV82]. The difficulty, as it has been said, is to place the computer network in some steady state in order to obtain valid measurements; in consequence, the use of the tools is more a monitoring use than, strictly speaking, a measuring use. However form this monitoring it is possible to get very useful information to understand the network behaviour and to have resource consumption data to be used in descriptive or predictive performance models.

4.2. Modelling

Performance models are built by means of queueing networks and Markov chains and protocol models by means of Petri nets. The large variety of network structures obliges to specific models for each one of them [AKIM93, FDID89, HAMM86, HAYE84, KLEI75, KLEI93, PUJO89, SAUE83, SCHW87, TAKA86]. There are standard queueing network tools (QNAP2, BEST-1, RESQ, etc.) or network specific tools that allow the user to describe the network and its environment by means of some language and to solve the model using some analytic, numeric or simulation technique. The main difficulty in building such models is not the description of the network components in terms of queues but to describe the network workload with enough accuracy, specially in future networks like ATM ones, and to get enough accurate data of the resource consumption of the workload components to run the model to obtain the desired estimation of the performance variables..

When these techniques are used to predict the performance of an existing network under future workload, to describe the network workload, techniques similar to those used in benchmark preparation can be used but, instead of giving classes of messages, statistical distributions describing the message classes have to be provided. When these techniques are used to predict the performance of some network in development (at present ATM to implement broadband ISDN networks, DQDB, etc.), to get good representations of the burstiness of the input information flow new statistical distributions like MMPP (Markov Modulated Poisson Process), IPP (Interrupted Poisson Process), IBP (Interrupted Bernouilli Process) are to be used. Also, as one of the performance measures of the broadband ISDN systems is the loss ratio and the required levels are of 10^{-6} to 10^{-12} the use of simulation can be very time consuming and requires special techniques in order to reduce the running time to some reasonably short one.

5. CONCLUSIONS

This paper has reviewed the probabilistic and statistical basis necessary to the computer and communication professionals working in this field to measure and predict the performance of such systems. Most of this knowledge is acquired at university graduated studies but must be updated to incorporate the new needs introduced by the new developments in both computer and network systems.

Some of the techniques used are classical and well known, like statistical distributions, hypothesis tests, regression, correlation, analysis of variance, queueing theory and Markov chains. Others, like Petri nets and queueing networks, have become a stable discipline.

However, the new developments in computer and communication systems oblige to expand some of these topics, like the statistical distributions to describe the workload of the broadband ISDN communication systems or to reduce the simulation time of systems with very rare events. Other developments oblige to adapt well known techniques like queueing theory and Markov chains to new problems generated by the need of predicting the behaviour new developments of computer and communication systems.

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Computer software is used extensively throughout the workshops, as described in Section 3. Graphical methods of analysis are emphasized, and formal statistical techniques and mathematical formulas are de-emphasized, as in Hahn, Gemesderfer and Olsson (1987).

2. USE OF IN-CLASS EXPERIMENTS.

Training must be used to be effective -- and used quickly! One way to accomplish this is to have participants conduct a number of experiments as the workshop progresses. In-class experiments, in particular, tend to be fun! They give variety to the day and keep interest up. The students also remember these experiments long after the workshop is over, and they are able to draw on their experiences to help them to conduct better experiments in the future.

The experiments can be used to emphasize the importance of brainstorming and teamwork (for formulating objectives, developing a strategy, or choosing factors or levels), for teaching the basic principle of design (randomization, replication and blocking), for introducing factorial and fractional factorial designs, for illustrating sequential experimentation, and for addressing measurement problems. The importance of randomization can be stressed (by actually doing it!) and practical difficulties associated with randomization can be addressed (for example, what are the consequences of not randomizing the run order -- or of doing some form of restricted randomization?).

Hunter (1977), Rogers (1986), Schmidt and Launsby (1989) and Bisgaard (1991) are good sources for in-class experiments. I particularly like the paper helicopter, which has been used by Rogers, Bisgaard, Box, Montgomery and Spagon, among others. It can be used to teach simple

comparative experiments, as well as factorial and fractional factorial designs. I have also used it to teach response surface methodology.

Another excellent teaching tool is the catapult, which was initially developed by L. Truma of Texas Instruments (see also, Schmidt and Launsby, 1989). Again it can be used to teach factorial and fractional factorial designs.

For conducting simple factorial experiments, I have sometimes used experiments involving illusions. For example, a number of factors can be varied in the Poggendorff illusion (Tolansky, 1964), such as the distance between the two parallel lines, or the angle of intersection of the third line. Although such an experiment does not have an industrial flavour it can be used to generate data quickly, and it can lead to discussions of measurement and transformations. Students also tend to be interested in illusions.

3. USE OF THE COMPUTER.

It is essential that computer software be used and that participants have access to it during and after the training. Ideally, during the workshop there should be two people per computer, which actually works better than one person per machine.

I have used *Design-Ease®* in these four-day workshops and *Design-Expert®* in subsequent workshops on response surface methodology, although there are a number of other possibilities for design software. *Design-Ease®* is menu-driven, easy to use, and very good for designing and analyzing 2^k and 2^{k-p} designs, although it is not an all-purpose experimental design package.

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Training users of statistics

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1. Introduction

In Australia, as in many other countries, universities are now expected to have a broader role than merely teaching undergraduates and doing research, as was often the case in the past. The situation in tertiary education which existed in Australia till the late 1980's is changing as Kenway et al (1993) reports:

> "Education is currently being thought of in market terms and markets of various forms are guiding priorities and funding. ... Knowledge is to be regarded as an investment which pays off for individuals in a job, for industry for a better trained labour force and for the nation in economic growth. ... with regard to short, money spinning fee-based courses, they are to identify and serve the student /consumer/ clients/users' needs."

Some of the extra activities which universities are now involved in include consulting, running fee for service graduate courses and providing continuing education for the general population. This continuing education includes giving lectures to the general public and running a variety of short courses. Some of these short courses are designed for the general interest and education of the public. For example, at The University of Melbourne, an

annual summer school is held in which every department is expected to run courses which may be of general interest to the wider public, or may be directed at a particular group such as students and/or staff in senior secondary schools. Other short courses are aimed at industry groups and are often run on an *ad hoc* basis.

To help meet the wider statistical needs of the community, both in higher education and in the workplace, a number of organisations offer programs in statistics for students with limited statistical or mathematical knowledge who wish to acquire a range of statistical skills in a short time period. The short programs in statistics run by the Inter-university Consortium for Political and Social Research, ICPSR at Ann Arbor, USA, the Essex Summer School in Social Science Data Analysis in the UK, and the Australian Consortium for Political and Social Research Inc., ACSPRI, all offer a wide range of topics from introductory statistics to advanced courses in statistical modelling. Most students attending these courses are not seeking credit since they already have a degree, and often a higher degree, but need to advance their statistical knowledge.

For more than ten years the Department of Mathematics at Swinburne University of Technology in Australia, has used a number of approaches to help meet the need for continuing statistical education for people currently working in areas in which they use statistics but for which they are inadequately prepared. Firstly, post graduate programs in statistics have been developed for graduates in humanities, social and health sciences who are currently working in areas in which they use statistics but for which they have inadequate training, see Phillips and Bartley (in Press).

The Department also provides statistics short courses for industry. Many of these are run on campus, but a number of 'in house' courses have been given. People who attend the courses come from a variety of areas including market research, public administration, social welfare, criminology, education, banking, insurance, politics and health. Some have a reasonable training in the statistics, but many find that they lack technical skills both in understanding the procedures and in the practical aspects of using the latest technology.

Staff volunteer to develop and teach the courses since they are not part of their normal load. Most have qualifications in mathematics and/or mathematical statistics and are trained

teachers. On occasions, lecturers from outside the Department have been used either to bring an industrial perspective to a course or to assist with specialist topics.

2. Reasons for running short courses

There are many reasons why university departments run short courses, some of which are outlined below.

(a) Service to industry. Many workers find they need to regularly upgrade their skills. Those in business and industry often have to keep up with greater statistical demands from groups such as their customers or from funding bodies. In research environments, either at the post graduate level or in industry, workers are finding that they need an increased statistical knowledge both to appreciate the literature and also to substantiate their results for publication. Many do not have the time or interest to pursue a formal course in statistics, but rather prefer a short course to meet their immediate needs. A university department is in an ideal position to provide this service due to the expertise of the staff both in the subject matter and also as experienced teachers. It also has the facilities required such as classrooms, computer laboratories and catering facilities.

(b) Needs of industry. Participants on short courses usually have a specific problem they wish to solve or technique they need to learn. When they attend a short course they are invited to bring their problems with them. These are either discussed during the program if they are of general interest, otherwise individually. If the problem proves too large to be dealt with within the confines of the course, the participant may enter into a consulting arrangement with the staff member. In this way the staff are kept in close contact with the needs of industry in the area and obtain a source of examples and case studies which can often be used in regular classes.

(c) Links with industry. As Kenway (1993) reports " .. all educational institutions are being persuaded (by financial stringency as much as anything else) to develop links and form partnerships with and to seek sponsors from industry." Short courses for industry help establish these links.

(d) Source of funds. In these days when finances are becoming an increasing problem for most university departments, methods of obtaining funds other than from traditional sources need to be considered. Running short courses for industry is one way of obtaining some extra funds. At Swinburne, expenses such as advertising, catering, printing and any charges such as hiring of resources come from course fees. Fees are paid to the central funds of the University and the Department receives a percentage of the gross income. Any remaining profit is available to the staff who gave the course for uses such as special equipment, books, software, workshop and conference attendance or as additional income.

(e) Department's profile. Each university department is competing in the market place to attract students and any means by which it can increase its profile is considered worthwhile. To make contact with potential participants of short courses it is necessary to advertise widely in the press, society bulletins, through posters and mailouts. This exposure puts the Department in the eyes of potential customers not only for short courses, but also for regular students and for possible consulting activities.

(f) Interest in the job. Participation in short courses helps staff retain interest and motivation in the job. This can occur because the lecturer is not restrained by factors such as an imposed curriculum, is not bogged down with the features of a normal credit course such as assessment and has the opportunity of teaching people who are there because they want to learn rather than because it is part of their course.

(g) Training Guarantee Act. In Australia, the Training Guarantee Act encourages companies to spend money on training. Hence attendance at these short courses not only provides valuable training to employees, it also helps industry to comply with this Act.

3. Statistical short courses offered

Over the past few years the Department has been involved in running courses in a range of statistical topics as outlined below.

Basic Statistics, Data Analysis using SPSS, Data Analysis using SAS, Questionnaire Design and Analysis, Research Designs in the Health Sciences, Multivariate Methods, Scaling and Dimensional Analysis, Microtab for CADE, CATI and CAPI.

Many of these have been run on campus, but a number have been custom made for a particular company. In many of these latter cases problems and data from the company have been used to illustrate the techniques.

The courses are designed to be as practical as possible. Some participants have particular problems which they need to address such as how to develop a questionnaire, how to understand a specific technique and when to use it or how to use a particular computer package. Others do not have such a specific agenda, but rather use these programs to get a general feel for the topic. Others may study a package to get a feel for using computers for data analysis or to compare the package with another they are already using. Very few are interested in the theoretical basis of the subject.

Introductory courses attract far more participants than more advanced courses, especially in the area of computer packages. This is often because they are suddenly confronted with using a package and find working from manuals rather daunting, especially if they have had little previous experience with computers. They see a course running for several days as time well spent rather than spending weeks trying to come to grips with a package. Furthermore, people who teach themselves packages usually confine their learning to a very restricted section to cope with their immediate needs. This often means that they take a long time, if ever, to become proficient or even aware of, the capacities of the package. However, after taking a short course on the basics of the package, they seem to have sufficient confidence to learn the more advanced features by themselves whenever they need to.

Courses such as basic statistics attract people who need to use descriptive statistics and tables in reports. Also people who need to understand the statistics content of reports and articles are attracted to courses of this nature. A course run over three to five days often only has the effect of making participants aware of some of the issues, but is usually insufficient for any 'in depth' statistical work. Packages are incorporated into the statistics classes with the use of laptop computers. They have proved to be very effective as a teaching aid, are not intrusive and do not detract from the statistics being taught as is often the case when separate computer rooms are used.

More advanced courses attract people who are familiar with basic statistics, but find that they need to use more advanced procedures such as multivariate analysis often because these techniques have been requested by their customers or supervisors. Unfortunately some try to make the progression from basic statistics to the higher levels too quickly and do not gain much from the experience.

4. Some problems

Running short courses, like any other extra work, does not come about without a number of problems. The main ones encountered at Swinburne are outlined below.

(a) Lack of time for maturation . Although short courses of three to five days are an ideal way to learn some specific tasks, such as a computer package, they are not always so good when concepts need to be developed. For example most students taking a course on multivariate analysis for the first time need time for notions to be developed through exercises and assignments. This is usually not possible during a short course, especially when it is run on consecutive days. When take home exercises are set they are rarely attempted due to the participants other commitments and because there is no assessment threat. Those who gain most from advanced statistical programs are those who already have had some introduction to the topic as they can focus on understanding and implementation.

(b) 'In house' distractions. Courses run at the participant's workplace have the obvious advantages of working on their own equipment, easier access to the venue and having a group with common tasks to concentrate on. However, it is far too easy for these participants to be distracted with work duties. This causes many of them to be late for sessions, to miss sections of the course, to be called to the phone or to leave early. These problems are far less frequent when they have to get away from the office and are not available for work while the course is on.

(c) Hard to judge the effectiveness of the course. Since there is no formal assessment it is hard to judge the effectiveness of the learning. This can be partially overcome by setting

exercises to be done throughout the program, but, since they usually have to be short and quick to do, there is little chance for experience with a problem of the extent they are likely to meet at work.

(d) Lecturers' schedules. The short courses are not part of the lecturers' regular program so time has to be found when they are available to give them. Additional time has also to be allowed for preparation and marketing of the courses.

(e) University's timetable. Since the programs are usually held at the University they normally have to be programmed in non-teaching times so that facilities such as classrooms and laboratories are available. Problems also occur with courses being run in study vacation and exam times when staff need to be available to regular students. This is partially overcome by having at least two lecturers involved in each course.

(f) Extra load. Short courses create an extra burden on an already heavily loaded staff, both academic and administrative. Not surprisingly, the hardest working staff are often the ones who get involved in short courses.

(g) Competition with private business. Groups such as market research companies sometimes see universities as unfair competitors in the market place. Gary Morgan (1993) was reported in the Australian Market Research Society's newsletter "I'm horrified at the amount of government research which is generated at taxpayers' expense and is not correctly costed." However an alternative view in the same article pointed out that it is reasonable for universities to carry out these activities since it helps them keep up to date with industry practices, and gives staff and students the opportunity to gain invaluable practical experience. In any case they are often costed at higher rates than private industry. Although the discussion was centred on consulting activities, a similar argument could well be directed at the running of short courses.

7. Summing up

There is an increasing need for continuing statistical education for people in the workplace. University departments in which statistics is taught have the expertise to help provide this knowledge and can gain much from running the courses. These include gaining closer links with industry and a welcome source of extra income. Attendance at short courses sometimes leads to consulting jobs and participants enrolling in more extensive studies such as graduate diplomas. It is important that these short courses are run at competitive rates to comparative courses run by industry so that the work done is not undervalued, and they do not have to be propped up by the university infra-structure. Participants in short courses are unlikely to develop expertise in the topics covered, but can gain sufficient knowledge to know when to apply a technique and become more aware of when they should consult a statistician.

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LEARNING TO LEARN: THE CONTINUOUS DEVELOPMENT OF A PROFESSIONAL STATISTICIAN

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ABSTRACT

Learning can be defined as a process in which individuals can change their attitude to adopt a continuous development of basic knowledge and skills in pursuit of total professionalism.

The essential feature of an effective learning process is constant updating and continual feedback. Thus the effective learning process in an organisation should be focused around the quality of feedback provided by the organisation. Effective action must be organised around a range of systems and procedures to accomplish the goal.

Learning to learn involves the continuous development of various strategies and skills that support the process of learning in many different contexts.

The basic requirement of any effective learning process is, therefore, the desire to learn the skills, to implement them and to practise them in an appropriate context. However continuous learning requires a sustained interest in learning over time and relates to the improvement in learning ability which is independent of the content being learned.

In this paper the authors will be discussing the goal, strategy, various learning processes, advantages and disadvantages of the continuous development of a professional statistician.

CONTINUOUS LEARNING

There is a common misconception that learning in relation to working life at the professional level ceases when full-time education comes to an end. This may be at the first degree, masters or doctoral levels. The reality could not be further removed from this.

There are a variety of learning approaches but the major ones include:

(i) studying for examinations for professional membership
e.g. actuarial, accountancy, engineering, statistics

(ii) part-time study for masters and doctoral degrees by study and research
e.g. M.Sc. Applied Statistics, M.B.A., M.Phil. and Ph.D.

(iii) learning at work.

It is this last approach that is the focus of attention in this paper. It does not mean that these three ways of learning are mutually exclusive but the desire is to explore approaches to training and coaching in the workplace. Training in the workplace can follow many patterns: it can be ad hoc and uncoordinated with much of the responsibility put on the individual or it can be planned with some assessment of efficacy. This paper looks at one learning model.

COMMON LEARNING

It is commonly assumed that learning is strongly associated with the teaching process when information is given by a teacher. The application of the assimilated information is then applied to appropriate tasks. This is not now thought to be the case. Most 'real' learning is achieved via experience. This is 'on-the-job' experience. There is a common learning cycle (see Figure 1):

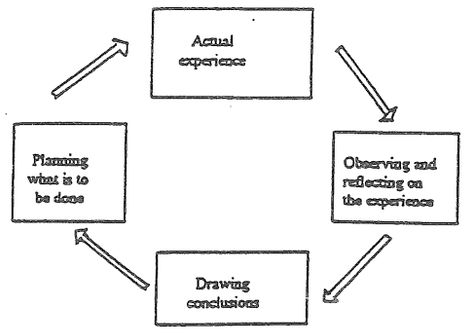


Figure 1: Common Learning Cycle

The essential feature is that of feedback; action is taken, the effect is noted and appropriate modification of behaviour follows.

If real learning is to be achieved then all stages of this cycle must be experienced.

The establishing of this learning cycle as a model of good practice for effective learning is the focus of this paper. There are many issues relating to the facilitation/enabling of this learning cycle to be established in an organisation but we must first look at how a start may be made.

EFFECTIVE LEARNING

There is an obvious need to ensure effective learning. If learning is not treated seriously then there will be adverse repercussions for the organisations concerned. An effective learning strategy is likely to encompass the following:

(i) understand how and why people learn
(ii) promote a healthy learning environment
(iii) identify individual's learning needs
(iv) prepare a learning plan with agreed objectives
(v) promote learning opportunities
(vi) evaluate learning outcomes.

QUALITY LEARNING

We've talked a little about how adults learn through the 'learning cycle'. If people are to really learn then each stage of the cycle must be travelled. There are many other factors involved in this process (some of which we'll see later). What we need to do is to place this learning cycle clearly within the organisation.

Within an organisation there may be many equivalent cycles for areas of development. Here each cycle needs to be complete and unbroken for effective development to be possible. Take, for instance, the continuous quality learning process which includes all organisational activity.

The Continuous Quality Learning Cycle or Continuous Improvement Cycle (Deming) (see Figure 2) which helps to improve the quality of the organisation can be described as follows:

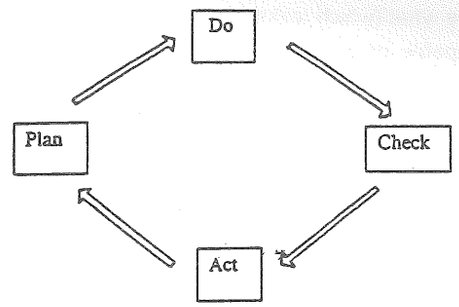


Figure 2: Continuous Improvement Cycle (P - D - C - A) (Deming)

In general, quality learning is a continuous process that can be broken anywhere in the learning systems of supply and customer service.

Here in the Deming Cycle 'plan' defines the learning process which ensures documentation and sets measurable objectives against it. The 'do' executes the process and collects the information and knowledge required. The 'check' analyses the information in a suitable format. The 'act' obtains corrective action using quality learning techniques and methods and assesses future plans. At the end of each cycle the process is either standardised or learning targets are adjusted based on the analysis, and the cycle continues.

The Continuous Improvement Cycle and the Learning Cycle can be superimposed i.e. a planned, quality-improving strategy. Before we go on to look at some examples via a case study we need to consider the learner and how his/her needs should be considered and also look at the preparation of a learning plan.

LEARNING PLAN

Before a plan can realistically be drawn up both the learning needs of an individual and the desired learning outcomes for an individual need to be considered.

To identify the learning needs of an individual firstly the knowledge, skills and attitude required for a particular task or function to be performed successfully must be established. Against this list should be considered the knowledge, skills and attitude already possessed by the individual. This second list will probably be achieved by consideration of career history and known work record. The difference between these two lists is the learning need (or learning gap). Part of the process of the identification of learning needs should be open discussion, with and the agreement of the individual concerned. We'll see an example later on.

Learning outcomes define what (which tasks) an individual will be able to perform and how well they will be capable of performing these tasks as a result of the learning process. There should be a list of required outcomes in terms of behaviour and performance. The standard required should also be established so that the effectiveness and the amount of learning can be measured. There should also be a time horizon for this learning process.

The learning plan is thus, clearly, a bringing together of learning needs and learning outcomes. This plan, which is best formalised in writing, should be jointly agreed by both individual and trainer/supervisor. The plan should follow the learning cycle and so will consist of a list of desired outcomes together with a list of activities necessary for the desired outcomes to be achieved. There may well be resource and specific training needs identified at this stage. This can be viewed as the planning stage of the cycle. Once the learning experience has been completed then some reflection/assessment should follow. Hopefully there will have been appropriate consideration of the measurement of the desired outcomes. The final essential stage of the learning cycle is that conclusions based on reflection and/or assessment are fed into reformulating and refining the next planning stage of the learning cycle. The process goes on and on and on ..... continuing and continuous learning.

That may be the ideal but what about the practice? Let's look at experience at Sheffield Hallam University.

CASE STUDIES AT SHEFFIELD HALLAM UNIVERSITY

The Professional Development Scheme

The Management Sciences Programme is a thick Sandwich Programme leading to two separate degrees, namely B.Sc. Applied Statistics and B.Sc. Systems Modelling. The B.Sc. in Applied Statistics has been running since 1974 and the B.Sc. in Systems Modelling since 1980. Between 1980 and 1984 changes to both degrees were made to make the first year essentially common, a second year comprising some common subjects, a third year being a year's placement (the 'thick' sandwich) and a separate final year. This then is the Programme in Management Sciences. The placement is an integral part of the course where students can relate their studies to the work environment. The placement helps the student to:

- relate academic theory to real applications
- practise skills and techniques acquired on the course and learn new ones
- develop personal and professional skills
- gain knowledge of how organisations function

- make better informed career choices

It is important that students do not merely 'experience' work but are also encouraged to observe, enquire, analyse and evaluate what happens around them. This is very much the place for ensuring that the learning cycle works smoothly; and this is the reason for the Professional Development Scheme within the placement year. Personal skills and qualities are recognised as being very important and students are expected to be aware of their own strengths and weaknesses and to work to develop their personal skills.

The Personal and Professional Development Portfolio is a folder of pre-prepared documents aimed at encouraging the student to record their experiences on the course. There are two main aspects:

- to help students develop an awareness of him/herself. Strengths can then be built upon and weaknesses addressed.
- to help students obtain feedback from lecturers and personal tutors concerning their progress and identify mechanisms for self-improvement.

The students are encouraged to take responsibility for their own learning and to become much more involved in the learning process.

The extension of the PDS into the sandwich experience placement year

The aims of the Professional Development Scheme in relation to the placement year are:

- to create an effective awareness in students and to encourage them to record their strengths and weaknesses.
- to improve the monitoring of student performance via supervisor feedback
- to ensure that students are effectively incorporating the objectives of their placement employer into their work
- to enhance Sheffield Hallam University's evaluation of student placements
- to provide students with documentation of their placement achievements.

The vehicle for the extension of the Professional Development Scheme into the placement year is a Logbook which is 'owned' by the student. The student must keep it up to date. The Logbook consists of three components:

- The Placement Plan
- The Monthly Activity Reviews
- The Placement Performance Reviews

The Placement Plan

At the start of the year the supervisor, in agreement with the student, should complete the Placement Plan form. The plan is the start of the logbook and helps to clarify what the student's role is and what learning opportunities are likely to be available during the year. The plan is also a useful basis for discussion when the University tutor visits. The tutor may ask the student to send a copy of the plan prior to the first visit. It does not matter if the plan changes during the year (this is often the case). Modifications should be written on the original plan or alternatively a new plan may be drawn up if the student's role changes significantly.

The Monthly Activity Reviews

These meetings will monitor progress on a monthly basis by identifying work and training events, problems, personal development milestones and proposed actions. Part A of the appropriate form should be completed by the student prior to each monthly meeting. This is a record of activities. In this regard, it is recommended that the student keeps a diary of working notes on which to draw information.

During the meeting the supervisor will make comments on part A and/or proposals outlining potential action with regards to further training, giving further on-the-job experience, any identified problems or follow up to a previous performance preview. Part B of the form is used for this purpose.

The Placement Performance Reviews

These meetings will assess the student's level of achievement within specific categories at three points during the placement; the timings of these meetings are left to the joint discretion of supervisor and student. It may or may not be appropriate to have these meetings immediately following a monthly activity review meeting.

Prior to the meeting the student will complete Part A of the appropriate form by entering a perceived rating of his/her level of competence, along with supporting examples/comments, in the various skill areas given.

During the meeting the supervisor will agree and amend, where appropriate, the details submitted in Part A by the student. Additionally, at this meeting, the student will complete Part B of the form in agreement with the supervisor. The supervisor will agree or revise the original ratings and add comments as appropriate.

The PDS and the Learning Cycle

This logbook is an attempt to facilitate the learning (feedback) cycle and also acts as a documental record.

There is a Placement Plan which forms the Plan of Action for the year. This is likely to change with additions during the year.

The actual experience is monitored in two ways: via the Monthly Activity Review and via the Performance Review. These two meetings which focus on agreed work planning, the need for extra resource/training where appropriate and agreed performance, enable the learning cycle to be traversed completely. The components of the cycle are addressed viz:

- learning modes are identified) in relation to
- desirable learning outcomes are agreed) tasks/role
- a timescale is agreed
- a learning plan is drafted
- activities that will lead to particular desired outcomes are listed (Monthly Activity Reviews)
- students are encouraged to reflect on activities via the Activity Review form, which identifies skills used and allows comments on achievements etc.
- assessment (via Performance Reviews) that learning has taken place.

An assessment of this adult learning model as expounded here, is being carried out by a panel of employing organisations. The results of this survey will be discussed at the time of the presentation of this paper. There will also be an attempt to compare and contrast the PDS used at Sheffield Hallam University with some schemes already in use by employing organisations.

CONCLUSION

The continuous development of a professional statistician has been placed within the framework of a continuous improvement learning cycle. The implementation and monitoring of this learning model has been evaluated with the cooperation of a panel of employing organisations in the context of the professional experience year of the Applied Statistics Honours Degree at Sheffield Hallam University.

The results of this evaluation will be discussed during the presentation of this paper.

COMPUTER-INTEGRATED METHODS IN THE TEACHING OF STATISTICS AND PROBABILITY

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ABSTRACT

We discuss the importance of teaching integrated methodology in statistics and probability. That includes a major emphasis on problem solving, with the inclusion of numerical computation, computer experimentation and the graphical display of results. Some specific examples are discussed.

A Changed Environment

Undergraduate courses in probability and statistics serve two purposes. They introduce the student to the basic ideas of quantified uncertainty, an essential feature of the scientific method, maybe of all human knowledge. They also prepare, or should prepare, the student for the implementation of statistical ideas in the modern work place. In recent decades that environment has profoundly changed. For education in our disciplines to remain true to its mission, it is essential that we take cognizance of these changes and adapt our teaching methods accordingly.

Based on my long experience of teaching in departments of mathematics, statistics, and systems and industrial engineering and on discussions with colleagues worldwide, I find that most of our undergraduates take two basic courses. One introduces them to sample spaces, combinatorics, and the discrete and continuous distributions. It concludes with the central limit theorem or the usual estimators and tests of hypotheses for normal data. The second course deals with basic stochastic models such as renewal processes and Markov chains. There is little variation in the contents of these courses. Engineering students may learn a little about second order processes or simulation; students in the social sciences hear about such subjects as ordinal data or factor analysis, but that is already uncommon.

Substantial statistical methodology and probability theory is taught at the graduate

level. Because of the required mathematical background, that is probably their appropriate place in the curriculum. In this discussion, I leave aside formal measure theoretical treatments of probability, statistical theory and stochastic processes that are pillars of the education of the potential research student.

I shall deal with the educational needs of those who have to use probability and statistics in their jobs, but who will not be statistical professionals. From follow-up questionnaires to graduates with at least five years work experience, it was learned that many found courses in probability and statistics among the most valuable they had taken. That held equally well for mathematics as for engineering graduates. In the work environment, our graduates will use software packages for statistical analyses of data and for simulation studies. They will be expected to do so competently and with insight. Good software packages eliminate nearly all the computational drudgery associated with the statistical practice of a bygone era, but if anything, the level of technical understanding required for their competent use is increasing. That level is far beyond the contents of standard undergraduate courses.

It is a worthwhile, but sobering experience for those of us who have only taught in the classical style, as exemplified by available text books, to spend some time in exploring the capabilities of some major statistical software packages. A similar experience awaits those who teach the calculational skills which are still such a large part of learning calculus and differential equations. Standard mathematical software now formally integrates functions and solves differential equations of a complexity far beyond those seen in standard courses. What software cannot do is formulate the integrals or differential equations appropriate to the problem at hand. It also does not interpret what the solutions tell us about the model. That is what we can and ought to teach our students.

The Educational Challenge

An educated person requires the knowledge and understanding to hold a responsible position in society. The level and the nature of that knowledge changes as society evolves. Therein lies a basic challenge to education. For instance, not so long ago the ability to do complex or merely lengthy calculations was a prized skill. Many were gainfully and honorably employed in clerical, statistical or engineering jobs, mainly to use that skill. Without much exaggeration we can say that, for most, a traditional education in statistics and engineering prepared for a career of careful, organized technical calculation. Those who also gained deeper understanding of "what is really going on" were the very best, maybe the exceptional students. In the computer age, jobs for human "calculators" have mostly disappeared.

From perusing many text books, I am amazed to find, if anything, an increased emphasis on formal manipulations often at the expense of understanding. The reason

for this is social. For many years now, a vocal segment of the student population has objected to "word problems" in which equations for a model must first be formulated and then solved. Merely manipulating a simple equation is much easier than thinking through the specifics of a problem stated in words. What bothers me is not the reluctance of some students to more difficult work but the extent to which these have been given what they asked for! Most students are eager to learn interesting subjects. If we present situations involving probability or statistics which they really want to understand, they see the technical work that needs to be done as a means to that understanding. Too much emphasis on the calculations bores the gifted and leaves only the others with an illusion that they now know these subjects.

The Importance of Good Problems: I am thoroughly convinced that probabilistic thinking is learned by solving and understanding many good, interesting problems. The enduring attraction of William Feller's classical book [1] lies, I believe, much more in its superb set of problems than in the treatment of the theory. It is now rarely used as an undergraduate text because it requires too much "difficult" combinatorics and too advanced calculus. My own, minor reservation to its continued use as a text book is that it relies solely on methods of analysis. It is an excellent, possibly the best probability book of the pre-computer era.

A good problem is one that captures the interest and requires several steps of insightful logic. Little is learned from direct applications of results in the preceding section. A student derives satisfaction from solving a good problem and it often raises new questions. Problems based on interesting models are usually complex; their complete solution may involve several ideas and understanding the result often requires some numerical work. The computer can be nicely integrated in teaching through the solution and exploration of probability models.

Interesting probability models also has nice structural properties. The main message should not be that, with computer software, we can handle messier problems than by simple calculus. Structural thinking is essential to probability. The student must learn see just where an assumed independence of random variables or the structure of a Markov chain enter into the modelling process. To teach that is particularly important as a prelude to simulation. I find that quite a few persons view simulation is a cheap, easy alternative to a thorough analysis. Of course, nothing is farther from the truth. The most belabored simulation of an incorrectly structured model is worthless and deceptive. Nonetheless, even in courses on simulation, little attention is given to the proper design of simulation experiments and to the interpretation of empirical results.

To summarize my proposal for an integrated teaching methodology in basic probability and statistics courses focused on problem solving, the following are desirable features of the problems we should ask the student to solve:

a. Structural properties should be clearly identified, not hidden under heavy calculations.

b. A significant number of problems should have complex, though elementary modelling features which require several steps of logic.

c. The student should be asked to interpret what is learned about the model, both from the analysis and from numerical computations.

d. Methodology should be integrated in a stimulating combination of formal mathematics, algorithmic thinking and, where appropriate, simulation and visualization.

By an elaborate example, I illustrated some of these ideas in a communication at ICOTS 3, Neuts [2]. Over many years, I have also formulated and tested many exercises with these features. These have now be collected in a volume which is awaiting publication, Neuts [3]. As further illustrations, let me discuss a few problems in that collection. That should better serve our purpose than do general considerations.

Example 1: A Choice of Coins: This is an idealization of a problem in clinical trials or in quality engineering. A total of N independent Bernoulli trials will be performed by one of two procedures. We think of these as tosses of coins. Coin i has success probability $p(i)$, $i = 1, 2$. In general, $p(1)$ and $p(2)$ are unknown. We obviously want to use the coin with the higher probability as often as possible. One experimental protocol is as follows: An integer m with $0 \le m \le N/2$, is specified and each coin is tossed m times. The resulting numbers of successes are $M(1)$ and $M(2)$. If $M(1) > M(2)$, we use Coin 1 for the remaining $N - 2m$ tosses. If $M(1) = M(2)$, one of the two coins is randomly chosen for the remaining tosses. Otherwise we use Coin 2.

A first problem is to develop an algorithm to find the value of m for which the *expected number* $S[m;N, p(1), p(2)]$ of successes in the N trials is maximum. The student is told that values of N between 100 and 300 are of primary interest. A computer code to handle N up to 300 should ultimately be written. In a second question, a value of N, say, $N = 250$, is specified. For the optimal m, the student is asked to compute the density $\{P(k)\}$ of the total number K of successes scored. Further questions deal with the sensitivity of m and other items to the values of $p(1)$ and $p(2)$.

Discussion: For this problem, we can give explicit formulas for $S[m;N, p(1), p(2)]$ and for $\{P(k)\}$, the density of K. These formulas are elementary but rather messy. They involve the joint density of $M(1)$ and $M(2)$. In an algorithmic solution, we note that the problem consists of simpler modules. For a given m, we first compute the joint density of $M(1)$ and $M(2)$, which readily yields the probabilities of using coins 1 or 2 for the remaining trials. From these, it is easy to compute $S[m;N, p(1), p(2)]$.

By an efficient search, we then find the optimal m. For each m, the density of K can be evaluated by a recursive scheme that starts from the joint density of $M(1)$ and $M(2)$.

In the process, the computation of negligibly small probabilities can be avoided. That saves much processing time. That turns out to be much easier than a direct implementation of the explicit formulas.

This problem also illustrates the solution of implicit equations. These are common in applications. It is often difficult, if not impossible, to write explicit equations for the quantities of interest. In many cases, of which this is one, that is not necessary. We construct a formal recursive structure for use in the computational modules. We use these to search for the maximizing m. The function to be maximized is implicit in the algorithm. It is never needed explicitly.

Example 2: Cheating in a Gambling Device: In a game of chance, the gambler wins the Grand Prize upon scoring five successes in a row. The game is announced to operate according to independent Bernoulli trials with probability 0.45 of success. Assuming that this is true, compute the probability that the gambler wins the Grand Prize if he does at most 100 trials.

The operator of the game has also computed that probability but finds it too large to his taste. Being far from honest, he tampers with the chance mechanism as follows: Once three consecutive successes have occurred, the success probability at subsequent trials drops to $p < 0.45$. As soon as a failure occurs the mechanism returns to the advertized probability 0.45. The operator wants to set p such that the probability of winning the Grand Prize in at most 100 trials is one tenth of its value under Bernoulli trials with probability 0.45. Find that value of p.

Discussion: We leave aside the moral aspects of this problem. The first question is standard. There is a simple recurrence relation for the probability $P(n)$ that the gambler scores 5 consecutive successes in n trials. It suffices to calculate $P(100)$. With the tampering, the corresponding probability $P_1(100,p)$ is an absorption probability in a Markov chain with 6 states. It equals $P_1(100,p) = 1 - (1,0,0,0,0)T^{100}(1,1,1,1,1)^T$, where T is the matrix

$$T = \begin{vmatrix} 0.55 & 0.45 & 0. & 0. & 0. \\ 0.55 & 0. & 0.45 & 0. & 0. \\ 0.55 & 0. & 0. & 0.45 & 0. \\ 1-p & 0. & 0. & 0. & p \\ 1-p & 0. & 0. & 0. & 0. \end{vmatrix}$$

We must find the value of p for which $p_1(100,p) = 0.1P(100)$. We have an explicit matrix equation, but each function evaluation requires the 100-th power of a 5×5 matrix T. The student should know that, for efficiency, this can be done with 8 matrix multiplications only and also that a bisection search for p in (0, 0.45) should be used.

These two examples, chosen for simplicity of discussion, illustrate elementary uses of integrated methodology and some of the structural thinking essential to algorithmic solutions. In the book, a significant number of the problems call for some experimentation and visualization. The next example offers an opportunity to explore properties of spacings. It is also an accessible illustration of highly dependent random variables.

Example 3: Fragmentation Processes: Suppose that a unit of something, mathematically the interval (0,1), is broken into m pieces according to one of several procedures. We describe four such methods. In the most thoroughly studied *random partitioning*, $m - 1$ points are chosen at random in the interval (0,1). They determine m intervals, called *uniform spacings*. In a second method, we pick a first point at random, next we choose a point at random in the longest of the two intervals. We continue that way, each time breaking the longest piece randomly in two until we have m pieces. In a third method, we again break (0,1) at random, but next we choose one of the two pieces with equal probability and break that one at random. Again, we continue in this manner, each time selecting one of the fragments at random and breaking it at a random point.

In the first two methods, the probability that an interval is broken up depends on its length; in the third method it does not. The fourth method is a compromise. Starting with an initial random point in (0,1), when we have $2 \le k < m$ current intervals, we choose the next with equal probability from among those intervals that are longer than $1/k$. There are infinitely many such fragmentation methods, but we limit attention to these four. You are given the set of m fragments, either as they appear in place or perhaps all scrambled up. Mathematically, you see the actual spacings $Y_1, \cdots, Y_m$ or only their ordered values $Y_1^* < \cdots < Y_m^*$. The problem is to identify statistically which of the four procedures was used.

Discussion: The problem is, of course, a test of hypotheses. Nature or the computer chooses the procedure. The statistician sees the results and must guess as best he can which was used. The art is to choose a good test statistic, that is a function of the data, here $Y_1, \cdots, Y_m$ or $Y_1^* < \cdots < Y_m^*$ which takes very different typical values for each procedure. For this problem, there is no obvious choice of a good statistic.

For the first method, we know the properties of a few statistics, but little is known about the others. In addition, the statistics that are easiest to investigate analytically may not discriminate well between the four methods. It is therefore natural to investigate many promising statistics by simulation. We assess their quality by the success probabilities in the statistical game that I have described. What is so interesting and stimulating is the variety of ideas to be explored. Along the way, we saw some empirical results that suggest theorems and we have already been able to prove some. That is intellectually satisfying. However, what I have found astonishing is how well some unconventional test statistics perform in the thousands of replications of the game we ask the computer to play. That is genuine computer experimentation. It is unlikely

that anyone will be able to prove (near-)optimality properties of these statistics, but there is also persuasive evidence in experiments that others can repeat and check.

This problem was particularly successful with a group of advanced students. It sent them to the literature on spacings, on Kakutani's conjecture and on limit distributions for random partitions. It was presented as a computer game. The person to propose the identification procedure with the highest (empirical) probabilities of correct identification was the winner. The students' enthusiasm carried over into the summer vacation and some are still working on this problem.

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STATISTICS IN CONTINUING ENGINEERING EDUCATION — A FLEXIBLE AND DISTANCE LEARNING APPROACH —

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I DEDICATE THIS PAPER TO THE MEMORY OF W. EDWARDS DEMING

ABSTRACT

The main purpose of this paper is to call the attention of the statistical community to the potentialities of the continuing engineering education (CEE), as well as to its difficulties. CEE is a big concern in the world at the present. Due to its ambitious objectives it will require a significant investment of resources, as well as, the leadership and personal attention of top executives in industry and governmental institutions and of top professors in academia. It is the author's opinion that top statisticians should share this concern and work together with the other professionals, to help finding efficient and effective answers to the huge and complex questions posed by CEE. That also presents the opportunity and the challenge of extending the scope of statistics postgraduate instruction. To miss this opportunity can be highly disastrous for the appreciation of statistics in the future.

1. INTRODUCTION

We academics have been, in the last decades, tying each other up through: publications, conferences, seminars, visiting positions, and so on. More recently also through, fax, e-mail, and in the near future more and more through computer - teleconferencing and satellite - teleconferencing.

Furthermore, for some people the work vision of the 21st Century seems to be in terms of "cooperative world wide teams", where the raw materials used will be the individual and collective knowledge; communicating with one

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another through telecommunications, satellites and high speed networks of interlinked, local area computer networks spanning continents and oceans.

How well are we preparing our students to be active participants in this world of cooperative work?

Should universities be decentralised, ultra-flexible, highly interconnected and networked, using satellites and computer networks to link students and teachers?

Should we start establishing now some kind of ethical principles to avoid too much wildness and suffering in this highly increasing competitive academic world?

My proposal would be let us, for the time being, try this cooperative approach in the CEE environment, where students are more mature people and let us also learn from that.

Therefore, the CEE adventure might also be useful as a way to learn about the changes that will need to take place in the traditional teaching at undergraduate and postgraduate levels.

In this paper, section-2 attempts to show the importance of the CEE concept using material from the 2nd European Forum for CEE; section-3 deals with statistics in CEE, where some of the difficulties around the "transfer of current research work to industry" as well as around "statistical methods targeted to industrial needs" are listed; section-4 presents a short discussion on flexible and distance learning and lists some institutions in US and Europe which are using distance learning in engineering education; section 5 briefly refers to the need of continuing education for applied mathematicians; as a conclusion it is stressed the importance of the interplay between continuing education (interdisciplinary approach) and "knowledge creation/use of knowledge", supported by telematics.

2. THE IMPORTANCE OF CEE

It is recognised that, with the current rapid changes in political, economic, industrial and social conditions in the world, higher education faces greater challenges than ever, and has an even more constructive role to play in society.

This has led central and local governments, as well as higher education institutions and industry, to force themselves to search for joint solutions to the serious problems of unemployment, business competition, limited available financial resources, among others, which will affect all of them, and to which continuing education and training can be a partial solution.

Moreover, the current studies on work and training indicate that a person will typically have several different careers and, more than ever, will need to be able to adapt to the changing technological environment. That, of course, might also be true for statisticians. Bearing in mind all these factors, we have to conclude that also a new attitude towards undergraduate degrees should be developed - undergraduate courses should leave the student with the foundation for lifelong retraining, i.e. for continuing education.

In what follows, I shall concentrate on CEE.

The average effective professional life of engineers in many fields, is steadily decreasing with the increasing pace of technological innovation: for electronics and computers it is estimated as has shrunk to about one third of their working life.

On the other hand, public opinion, increasingly demands that the engineer/manager accepts broader human responsibility for our environment, our natural resources, and people's feelings and reactions towards technology and management. Engineers/Managers must be ready to participate in the development of new visions of society. That means that they have to be acquainted with more subjects than traditionally covered in their curriculum; those relating to technology management, environmental methodology, cultural relations, negotiation methodology, ethics, law and languages, to name but a few.

Furthermore, industry recognises that technology transfer does not take place mainly through research and development contracts but rather through the intellectual equipment of new graduates coupled with advanced continuing education for established employees.

However, the specific issue of linking higher education and industry for the purpose of educating and retraining the existing professional workforce is a hard task. So far, most of what has been written on this topic has been heavily influenced by experience with joint research projects and/or the employment of university graduates. Moreover, in the past, a serious

disparity of opinion between higher education and industry has virtually led to a lack of significant communication and cooperation in the field of CEE.

Since, in a time of change, we should take control of our own destinies, it has been recognised that European educators (providers of education and training), engineering employers and individual employees, need to liaise with European Union officials, governments and engineering trade unions, on a regular basis, every three or four years, to share experiences, to learn about new developments in CEE, to discuss current issues in training and professional development, and to define future strategies and new directions.

The European Forum for CEE

In 1988, the Europeans launched the First European Forum for CEE in Stuttgart on the topic "Continuing Education of Engineers - Investment into the Future".

The Second European Forum for CEE on the topic "International Cooperation between Industry and Academia", took place in April, 1992, in Lisbon.

Its opening address, "Academic Industrial Collaboration and European Success", was delivered by Sir Robert Telford. There were three Panels, two on Human Resources Development Strategies and one on Environment and Related Ethics Issues; two Round Tables, entitled Improving Educational Productivity and European Flexible and Distance Education; four invited sessions on Quality Control and Technology Management (discussions of which were very much on the line of TQM), Research and Development, Networks and Information Channels for CEE, and Accreditation and Credit Transfer. At the closing session, the Forum was presented with conclusions and recommendations summarised in seven points. These seven points are printed in the inside front and back covers of the Forum's proceedings. They have also been published nationally and internationally within the industrial and academic communities. See, for instance, the paper in the International Journal of Continuing Engineering Education, IJCEE, Ramalhoto (1993).

Let me quote from Sir Robert's "opening address" (Robert Telford, 1993, pp. 24,26) to better illustrate the importance that it is currently being attached to CEE:

"...by the year 2000, it is estimated that of the order of 60% of the technology that will be used in industry is not yet developed and yet 80% of the people who will be working in industry in the year 2000 are already in place. These figures illustrate in a direct way the magnitude of the continuing education and training programmes that faces us."

Considering that the elements of economic success are: natural resources, technology, human resources, Sir Robert states that *"In Europe we have all three resources and, in particular, we have a rich diversity of peoples, cultures and an educational system capable of rising to the economic challenge. If we can get our act together - if we can foster and speed the developing closer partnership between academy and economic life to raise the educational and skills levels of our people we can raise our industrial competence and competitiveness and ensure the future well-being of Europe and its citizens."*

Let me also quote from the paper by Van Seventer (1993, p. 197), the general secretary of EADTU (European Association of Distance Teaching Universities): *"... conventional educational policies in modern society should be transformed along the lines of a clear distinction between initial, youth--bound teaching with an accent on basics, on core knowledge and especially the capacity to learn on the one hand and "recurrent" (continuing) education, including further training and the development of capabilities, on the other hand. This binary distinction in educational policies should be translated into legislation, into budgetary allocations, into shared responsibility for more government agencies than the ministries for education alone, and into strong cooperation with employers and trade unions."*

Perhaps I should also list here the following six additional recommendations that took shape while I was editing the proceeding (Forum's preface, pp. X, XI):

- to create some kind of local "science and technology clubs", where, among other activities, business, labour and university personnel could be invited, on a regular basis, to come together and determine how

universities could most effectively meet the needs of Industry for CEE in each location.

- to keep in mind that, given the complex nature of Industry today, "tailor--made" courses which have direct relevance to Business and Industry have to be interdisciplinary. Attention has to be paid to the application of appropriate techniques for educating adults in the programmes targeted at Industry.

- to bear in mind that, through telematics, distance learning programmes can bring the benefits of learning at the work-site itself, coupled with direct discussion between students and experts, leading to new applications of knowledge as well as new perspectives on the job.

- to do a better job of conveying the message that Engineering and Science can be fun and rewarding. We, in Academia and Industry, must involve the media in order to improve the image of Science and Technology as a career for young people.

(For medium and small sized enterprises)

- readily available and easily accessible information on educational and training programmes could in itself be a kind of motivation. To provide recognition, in one form or another, to those who have successfully completed formal CEE programmes could prove to be an important incentive

- A national or regional "bureau" to integrate and make public all the available information (including the names of those unemployed who have completed CEE programmes) and to form networks with the already existing centres and databases could help to answer most of the demands.

These "bureaus" could provide business consultancy information, not only concerning the technology relevant to particular products, but also the economic and human resources which would be needed, and the location of those which are available, for more details, see Ramalhoto and Bonfim (1993, pp. 238-240).

That shows the need to set up at a national level a team of the "think tank" type on Continuing Engineering and Management Education (CEME), to address all those above mentioned questions as a whole, to assess the needs

in CEME by sectors and to create mechanisms to respond in an appropriate way to these needs.

Tom Peters says that anytime anything gets done anywhere it is because a "champion". A champion is defined as the person who leads the effort to initiate a project, fights the battles, defends the project, refuses to let the project die, and pilots the project through to a successful completion.

To set up the Forum and to publish its proceedings, one year later, it was not an easy task. However the effort needed to set up a useful "think tank" of the above type, requires champions on both the academy and industry sides, as well as to be blessed by those who know the players, politics and power centers and who can successfully support and manoeuvre the project through the bureaucratic and political arenas. It is a huge project and very rewarding if successful.

I accepted with pleasure to be the President of the second Forum because I believe that CEME activities are going to be as important as the present university regular teaching and research activities and because I am also convinced that due to its importance in science and technology, statistics and operations research, should be part of this continuing education movement.

3. STATISTICS IN CEME

Let me give some reasons why I want, as a statistics professor, to be part of this movement:

- the recognition in modern physics that the physical phenomena are essentially stochastic instead of deterministic, heavily demands a bigger emphasis on stochastic in engineering theoretical education;

- engineering and management systems are almost all subjected to demands of a random character. The process that take place in response to those demands are therefore also random. That poses a heavy demand on stochastics in the engineering and management practices.

- the environmental engineering and management issues, which are going to dominate at least the beginning of the 21st century, will create new demands on stochastics in various areas, namely in manufacturing and service industries where, for instance, the inventory and production

planning have to take into account new types of uncertainties and the same is true for most of the optimisation problems.

As the president of Exxon R&D, Edward David, points out in a report to the National Foundation of the US *"Too few people recognise that the high technology so celebrated today is essentially a mathematical technology"*.

In fact, there are several situations where it is getting increasingly difficult to distinguish between the applied mathematician and the engineer.

It is also getting common to find statisticians in very high decision positions in Industry.

However, the use of statistics in both CEME activities — *"transfer of current research work"* and teaching of *"statistical methods targeted to industrial needs"*, do not come easily. It very often requires a multi-faceted and interdisciplinary approach to be successful.

Let me try to list some of these difficulties.

Transfer of current research work

- Engineers and managers do not have much time to study or use all the latest models that we produce, unless we present these models in a user--friendly and easy — to — understand fashion.
- Usually the first model and its numerical solutions are far from practical implementation. Further steps are very often necessary. What is important for the engineers and managers is to be able to judge the results not the mathematical solution per si.

That means that to prepare statistical research results for a transfer technology CEME activity very often needs a complete different approach from the one used to simply present these results in a research paper.

The partnership with other groups, as software houses and open learning groups specialised on the use of telematics for adult teaching can even be required.

Statistical methods targeted to industrial needs

- The development of complex technical systems in industry and business, ask for an interdisciplinary way of working, combining elements, for instance, from mechanics, electronics, with statistical methods from a lower, to a very high levels.
- The statistical methods modules for these CEME activities have to *teach things right* (efficiency) and also to *teach the right things* (effectiveness).

To prepare material for these modules can be more time consuming than to prepare material for regular university courses.

Also very often the job of the professor supervising CEME activities becomes that of a director, including financial, personnel and other management problems.

Any statistics unit that decides to be seriously and deeply involved in CEME activities has to consider it, on one hand, in equal terms with its traditional duties — academic teaching and research — and on the other, to bare in mind that CEME, it is a new concept which most likely demands a different approach to its teaching, administration and financing. Furthermore, has to become a partner in the adventure of learning how to work in an interdisciplinary environment and, most likely, to use telematics and to network with enterprises and other national and international research groups. Perhaps, it has also to know to interact with the "right people" in industry and governmental institutions.

Will the freedom of research be inhibited by "industrial control"?

In my opinion, the CEME activities will force a new kind of "industrial relationship" that most likely will also provide new ideas upon the teaching and the research at university. However the "industrial control" shouldn't be in more than in the CEME activities. Education only for short-term industry needs is perhaps all right for CEME but out-dated otherwise.

In fact, for obvious reasons, to keep the undergraduate courses and the research activities independent of "industrial control" is even healthier for industry itself.

Some successful examples of interaction between industry and statistics

It is well known that, one of the major successes in the applications of the statistical methodology has been in industry. W. Edwards Deming is, no doubt, one of the most celebrated statisticians among engineers and managers all over the world.

As a recent example of a breakthrough in statistical thinking through industry, let me recall here Taguchi, who is a Japanese engineer and statistician and at the present the executive director of the American Supplier Institute. His work has changed the way of thinking about the role of experimentation in engineering.

According to Grove and Daves (1992) Taguchi has asked the right questions without always supplying the right or at any rate the best answers. But nevertheless has supplied a good answer in deciding what to measure in engineering experiments. They summarise Taguchi's view as follows: *"engineers should measure what the engineering hardware is meant to do, and not yield to the temptation of measuring what it is not meant to do."*.

Taguchi'ideas set off a new round of research into the best ways of using experimentation in industry, of which the work of Georg Box and his co--workers at the university of Wisconsin are to be acknowledge.

Perhaps, some people will agree that there is a big waste in terms of the *"use of knowledge"* in statistics and in mathematics in general. For instance, our research work, when published in the most famous periodicals or otherwise, is usually read only by very few statisticians and operations researchers among those who are directly involved in the same research topic. The transfer of this knowledge to industry, to other scientists or mathematicians or even to other statisticians and operation researchers is extremely limited.

To be involved in CEME might be a way of improving the dissemination of our *"knowledge creation"*.

In conclusion:

- CEME is a huge task where the right methodology for making it successful is still being build up.

- Statistics in CEME although difficult to implement, among other advantages, allow us to expand the scope of statistical postgraduate instruction and to enlarge the dissemination of our *"knowledge creation"*.

To help to facilitate the interaction between the statistical community and the CEME community, a special issue of the IJCEE on Applied Probability Modelling in CEE is in preparation, with contributions from top statisticians and operations researchers from US, England, Sweden, France, Portugal, Spain, Israel, China, Korea , India and Australia.

4. FLEXIBLE DISTANCE LEARNING

Telematics brings together advanced information, telecommunications and audio-visual technology to give easy personal access to a wide range of services from a distance. Therefore, through telematics, distance learning is moving into the new information era of interactive multimedia systems.

Personal interaction between the student and the teacher, and among students themselves, is necessary at a deeper learning level. However through the power of telematics, which is becoming cheaper all the time, that interaction can also take place when the teacher and the student are physically not in the same place. The main issue here is to focus on how to make the process of teaching and learning more productive, efficient and cost effective.

Concerning CEME, the National Technological University (NTU), founded in 1984 in US, uses expertise from most of the major engineering schools in the country to deliver both graduate and continuing education, by electronic means (satellite-teleconferencing, computer-conferencing, video--tele-conferencing, etc.). NTU began regular satellite delivery of advanced technological education on August 1985.

NTU addresses the pressing national problem of the quality, size and the up--to-date training of the engineering and scientific workforce.

The benefits of education at the work-site itself, coupled with direct discussion between students and experts, lead to new applications of knowledge and new perspectives on the job.

In Europe, EuroPACE, initiated in 1988, tried to address similar questions but failed its intents. On December 1993 the EuroPACE 2000 emerged from the ashes of EuroPACE with a new working group and a new face.

Another powerful dimension of telematics (e-mail included) is to open up boundaries and stimulate the exchange of ideas. Either crossing university network departmental levels or linking the university network and its industrial partners nationally and internationally.

We clearly have already entered into the *"information age"*. By making use of this new and increasing technological opportunities we can shortly also enter into the *"knowledge creation/use of knowledge age"* to eliminate most of the today's intellectual waste as well as to potentiate to level up education among the world regions.

The whole subject of efficiently exploiting telematics in CEME is a very important task for universities, industry, public and private service sectors, among others. However, it is still far from being achieved.

To help to facilitate the interaction between the CEE community and the flexible and distance learning community a special issue of the European Journal of Engineering Education is in preparation. It attempts to give an overview, though not exhaustive, of what is going on in the area of flexible and distance learning in engineering education worldwise. There will be contributions from the top executives of flexible and distance learning institutions from US (including the President of NTU), Canada, India, Africa, Australia, France, England, Russia, Spain and from the European Union special programmes.

5. CONTINUOUS EDUCATION FOR APPLIED MATHEMATICIANS

Continuing education as a *"knowledge creation/use of knowledge"* facilitator, as well as continuing education as *"education in an interdisciplinary environment"*, to my mind, are also extremely important concepts to pursue and to implement among the applied mathematicians. To provide updated creative and problem-solving applied mathematicians, wherever they are, teaching at secondary school, polytechnics, university or working at the industry, governmental institutions, etc.

As a first step on the direction of knowledge dissemination, I wonder if the ISI — International Association for Statistical Computing — could be interested in providing a multimedia guide for statistical software with an almost on-line updating. Where ISI members, could found not only the list of the software available, but, for instance, deeper information on the quality of the conceived and documented models involved, reliability, functionality, analytical approach, maintenance, comparative drawbacks and advantages with similar types of software, as well as addresses of specialised software consultants. The same could be asked for, from ORSA/TIMS for operations research and management software, as well as from SIAM and other mathematically oriented institutions. A network of all these multimedia software guides could be organised worldwise.

I guess that would also help our mathematical technology to have a much greater impact on the world.

Most of the OR, applied statistics, numerical analysis and other applied mathematics periodicals, newsletters and so on, review software.

However, as far as I know, there isn't any organised and well structured applied-mathematics-software-network easily available, very reliable and articulating most of the relevant software available.

As a final conclusion, I would like to stress that, to my mind, any statistics unit able:

- to create an efficient and effective continuing education methodology and to make a good practice of it;
- to invest in telematics tools to facilitate the *"use of knowledge"* and to network with the other international research groups;
- to invest in *"knowledge creation"* (research);

is well prepared for the 21st century and is doing a great job to the statistical community as well as to the society.

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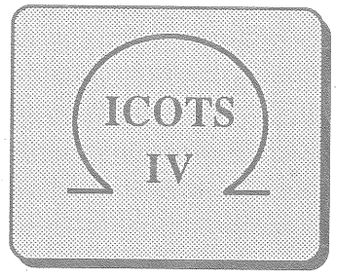
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L'enseignement de la statistique dans le domaine agronomique : quelques idées générales

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Summary

The teaching of statistics in the field of agriculture : some general views

Although a very large number of references are devoted to the teaching of statistics, very few are specifically related to the field of agriculture.

The purpose of this paper is to present some views on this topic. We successively consider the following aspects : the frame of our comments (section 1), the difficulties of teaching statistics to agricultural students (section 2), the qualification of the teaching personnel (section 3), some problems related to the content of the courses (section 4), and the teaching aids (section 5).

All these aspects are considered for the general teaching of statistics to agricultural students, but some comments are also given concerning the continuous education and the teaching given to specialists of statistics in the field of agriculture (section 6).

Some references posterior to the list of Misra et al. [1987] or not included in this list are given.

Most of the comments are probably also relevant to other fields of the experimental sciences.

1. Introduction et résumé

L'enseignement de la statistique est l'objet d'une abondante littérature, comme en témoigne notamment la revue bibliographique de Misra *et al.* [1987], qui comprend plus de 1.600 références. Toutefois, si certains domaines particuliers, tels les sciences commerciales, économiques et de gestion, et les sciences de la santé, possèdent une bibliographie propre relativement importante [Gandhi *et al.*, 1991; Sahai *et al.*, 1990], il n'en est pas de même pour le domaine agronomique. Une exception notable est cependant le travail de Cochran [1945].

L'objectif de cette note est de présenter quelques idées générales en la matière. Après avoir défini de façon plus précise le cadre envisagé, nous traiterons successivement des diffi-

cultés rencontrées (paragraphe 2), des enseignants (paragraphe 3), du contenu des enseignements (paragraphe 4) et des supports pédagogiques (paragraphe 5)[1].

L'enseignement de la statistique dans le domaine agronomique peut être envisagé à trois niveaux différents : les études de base, qui concernent la formation de l'ensemble des diplômés de l'enseignement universitaire ou supérieur agronomique, le recyclage ou la formation continue des chercheurs et techniciens du secteur agronomique, et la formation des spécialistes en statistique ou en biométrie appelés à travailler dans le secteur agronomique.

Nous considérerons essentiellement ici la formation générale des diplômés en agronomie, en donnant toutefois quelques indications également au sujet de la formation des spécialistes de la statistique et de la biométrie et de la formation continue (paragraphe 6), ce dernier aspect étant traité plus particulièrement, au cours de la même réunion, par J. Badia[2][3].

On notera que les réflexions formulées ci-dessous s'appliquent sans doute également, dans une large mesure, aux autres domaines des sciences expérimentales.

2. Les difficultés rencontrées[4]

En abordant le problème de l'enseignement de la statistique dans le domaine agronomique, il nous paraît important d'identifier tout d'abord certaines sources de difficultés.

Une première source de difficultés est l'hétérogénéité du public étudiant. Certains étudiants en agronomie ont en effet, comme principale motivation, leur goût pour tout ce qui a un caractère "naturaliste", sans aucun goût pour le "quantitatif" et les sciences exactes, dont les mathématiques. D'autres, au contraire, abordent plus volontiers ces derniers aspects. Or, un bon apprentissage des méthodes statistiques, appliquées à quelque domaine que ce soit, nous semble exiger à la fois une qualification suffisante dans le secteur du quantitatif et dans le domaine d'application considéré.

(1) Pour les différentes matières envisagées, nous donnerons quelques indications bibliographiques, en nous limitant à des références postérieures à la publication de Misra *et al.* [1987] ou qui ne sont pas citées dans cette publication. En outre, on pourra consulter aussi, d'une manière générale, les comptes rendus de la *Third International Conference on Teaching Statistics* (ICOTS 3) [Vere-Jones, 1991], y compris un article de Hadzivukovic [1991] relatif au secteur agronomique, ainsi que d'autres ouvrages relativement récents, tels ceux d'Anderson et Loynes [1987], de Hawkins [1990] et de Hawkins *et al.* [1992].

(2) Voir aussi, à ce sujet, Badia et de Turckheim [1993].

(3) Pour mieux définir le cadre de cette note, précisons aussi que notre expérience, en matière d'enseignement de la statistique, a été acquise à la Faculté des Sciences agronomiques de Gembloux (Belgique) et, comme professeur-visiteur, dans d'autres institutions de divers pays africains et européens, dont l'Institut agronomique et vétérinaire Hassan II, à Rabat (Maroc). Il s'agit d'études agronomiques postérieures à l'enseignement secondaire et d'une durée de cinq ou six ans. Par comparaison avec le système français, ces études englobent à la fois l'équivalent des classes préparatoires et les études supérieures agronomiques proprement dites. Enfin, on notera également que, sous le vocable "études agronomiques", sont pris en considération, non seulement les secteurs classiques des productions végétales (grandes cultures) et animales, mais aussi l'horticulture, les eaux et forêts, le génie rural, l'économie et la sociologie rurales, l'aménagement des territoires, les industries agricoles et agro-alimentaires, les bio-industries, etc.

(4) Voir aussi, à ce sujet, Sahai [1990] et Watts [1991].

Une deuxième source de difficultés est le caractère très dogmatique de tout l'enseignement antérieur, primaire et secondaire. Un tel type d'enseignement ne prépare pas du tout, bien au contraire, les étudiants à "appréhender l'aléatoire" avec une relative facilité[1].

Une troisième source de difficultés est le caractère abstrait de très nombreux concepts, même élémentaires, de la statistique. Il suffit de penser, à ce propos, à des notions telles que moyenne et variance, probabilité et variable aléatoire, valeurs théoriques relatives à une ou plusieurs populations et estimations de ces valeurs à partir des valeurs observées relatives à un ou plusieurs échantillons, etc.

Enfin, une quatrième source de difficultés, qui n'est pas totalement étrangère aux précédentes, est le fait que les exemples qui sont présentés et les problèmes qui sont posés aux étudiants n'ont en général pas de réponses parfaitement définies, mais au contraire des réponses qui, le plus souvent, ont tout au plus une certaine probabilité ou une certaine vraisemblance, difficile à chiffrer.

3. Les enseignants

Une question qui est souvent posée est celle de savoir si l'enseignement de la statistique en agronomie doit être confié à un mathématicien ou un statisticien, ou au contraire à un agronome de l'une ou l'autre spécialisation (agronome généraliste, forestier, etc.).

Cette question ne nous paraît pas essentielle, mais ce qui nous semble par contre fondamental, c'est que les personnes responsables de l'enseignement de la statistique en agronomie aient une double qualification, à la fois dans le domaine statistique et dans le domaine agronomique, ou en tout cas une très bonne connaissance des deux domaines.

Une solution alternative peut être de constituer des équipes mixtes, réunissant des mathématiciens ou statisticiens et des agronomes, mais il s'impose alors que les différentes personnes constituant de telles équipes travaillent réellement en étroite collaboration de façon permanente.

4. Le contenu des enseignements

4.1. Principes généraux

Notre intention n'est pas de définir ici un contenu précis, pour l'un ou l'autre enseignement de statistique, ce contenu dépendant en général très largement de circonstances particulières, telles que le temps disponible, le niveau atteint par les étudiants, tant en mathématiques que dans le domaine agronomique, etc. Nous voudrions au contraire émettre seulement quelques considérations générales, qui tiennent compte notamment des différentes sources de difficultés énumérées au paragraphe 2.

(1) On notera qu'en Belgique, comme dans de nombreux autres pays, la statistique est totalement absente ou est présentée de façon extrêmement limitée dans l'enseignement primaire et secondaire. La remarque formulée ici perd sans doute de son importance lorsque des notions substantielles de statistique sont, au contraire, introduites dans l'enseignement secondaire.

Un premier point important nous paraît être d'assurer toujours un bon équilibre entre la théorie et les applications, pour que les étudiants puissent arriver à un niveau suffisant, à la fois, de formation de base, nécessaire à une bonne compréhension des méthodes statistiques, y compris leurs conditions d'application, et d'expérience de l'utilisation concrète de ces méthodes.

Un deuxième élément qui nous paraît important est d'organiser l'enseignement en allant toujours du concret vers l'abstrait, par exemple en prenant en considération la statistique descriptive, y compris le traitement de données réelles, avant l'étude des distributions théoriques et l'introduction de notions d'inférence statistique.

4.2. Les notions de variabilité et de distributions d'échantillonnage(1)

La variabilité et les distributions d'échantillonnage nous semblent être des notions essentielles, auxquelles une attention toute particulière doit être accordée. Il importe en effet que les étudiants prennent parfaitement conscience du fait que les résultats obtenus à l'issue d'une enquête ou d'une expérience ne constituent pas une image intangible de la ou des populations concernées et, en conséquence, que la répétition de la même enquête ou de la même expérience doit tout naturellement conduire à des résultats différents. Il importe aussi que les étudiants prennent conscience dans une certaine mesure de l'ordre de grandeur de ces différences.

Nous pensons que la réalisation d'un certain nombre de simulations, auxquelles les étudiants prennent une part active, doit contribuer à l'introduction de ces notions : simulation d'échantillonnages, mettant bien en évidence les différents risques d'erreur liés à l'échantillonnage, et simulations de distributions d'échantillonnage de paramètres tels que moyennes, médianes et variances. Ces simulations peuvent être réalisées de différentes manières, notamment par un travail collectif, organisé en salle de cours avec la collaboration de l'ensemble des étudiants, ou par un travail individuel des étudiants sur ordinateur.

Des simulations très simples peuvent en effet servir à introduire un grand nombre de notions : échantillonnage aléatoire et simple, biais, estimation d'un pourcentage ou d'une moyenne, etc.

4.3. Les notions d'intervalle de confiance et de test d'hypothèse(2)

L'introduction des notions d'intervalle de confiance et de test d'hypothèse présente les mêmes types de difficultés et nécessite la même attention.

Ici également, la réalisation de simulations peut être fort utile, notamment pour bien faire comprendre le sens exact des différents risques d'erreur et l'importance de ces risques, en particulier en ce qui concerne la puissance des tests.

4.4. Les exemples et les exercices(3)

Les exemples et les exercices jouent un rôle fondamental dans tout enseignement de statistique à orientation pratique et doivent aussi être l'objet d'une attention toute spéciale.

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(1) Voir aussi à ce sujet, Dagnelie [1992, § 8.4.3], Stirling [1987] et Van Vyve-Genette *et al.* [1986].

(2) Voir aussi, à ce sujet, Foucart [1991], Stirling [1987] et Van Vyve-Genette *et al.* [1986].

(3) Voir aussi, à ce sujet, Preece [1986] et Singer et Willett [1990].

Les exemples destinés à illustrer l'enseignement doivent être relativement simples, peu "volumineux", mais néanmoins réalistes, ce qui pose souvent des problèmes de choix assez délicats. Quant aux exercices ou aux applications, qui sont donnés aux étudiants en complément à l'enseignement proprement dits, ils doivent également correspondre à des situations réelles, avec un "arrière-plan" agronomique suffisant, en ce qui concerne notamment les problèmes concrets étudiés et les modalités de collecte des données, et ils doivent être assez diversifiés, sans être toutefois trop spécialisés.

Dans tous les cas, l'accent doit être mis en particulier sur les problèmes de choix des méthodes statistiques les plus adéquates et sur les fondements théoriques et les conditions d'application de ces méthodes. En outre, il importe que tous les exemples ou applications correspondent non seulement à des situations réelles, mais reviennent aussi aux problèmes concrets, les conclusions finales devant toujours être exprimées en termes agronomiques, et pas uniquement en termes statistiques.

Les mêmes principes s'appliquent évidemment aussi au choix des questions d'examens, qui viennent d'ailleurs régulièrement enrichir, pour les années ultérieures, les collections d'exercices disponibles.

4.5. Les mémoires ou travaux de fin d'études

La préparation des mémoires ou des travaux de fin d'études est souvent une excellente occasion de mettre en pratique les notions acquises dans le cadre des enseignements de statistique.

Au-delà de l'utilisation relativement classique des méthodes qui leur ont été présentées antérieurement, les étudiants sont fréquemment amenés, à ce stade de leurs études, à avoir recours à des méthodes nouvelles pour eux, ce qui est à la fois l'occasion de leur faire prendre connaissance de leurs propres limites et d'entrer en contact avec l'un ou l'autre système de consultation statistique. Encore faut-il, pour que ce type d'apprentissage soit tout à fait bénéfique, qu'un service efficace de consultation soit opérationnel et que les étudiants prennent l'initiative d'entrer en contact suffisamment tôt avec ce service, ce qui est malheureusement loin d'être toujours le cas.

4.6. Les représentations graphiques et les moyens audio-visuels(1)

Les moyens actuels de traitement de l'information permettent d'illustrer, beaucoup plus que par le passé, les matières enseignées et les résultats obtenus, par des représentations graphiques. C'est un autre point auquel il y a lieu d'être très attentif, et cela à tous les niveaux de l'enseignement (cours théoriques, exemples, exercices, etc.). En particulier, la projection sur grand écran de résultats apparaissant sur terminal ou sur micro-ordinateur ouvre des perspectives nouvelles en matière de présentation de notions théoriques et de discussion de résultats d'exercices, et doit être utilisée au maximum.

Dans le même ordre d'idées, on peut penser à l'utilisation accrue de l'ensemble des moyens audio-visuels (présentation de montages de diapositives, films didactiques, etc.). Nous n'en avons toutefois qu'une expérience relativement limitée, dans une certaine mesure sans doute parce que le matériel disponible en la matière n'est pas très abondant.

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(1) Voir aussi, à ce sujet, Moore [1993].

4.7. L'exécution des calculs[1]

Nous dirons quelques mots, au paragraphe suivant, du recours à l'ordinateur et de l'emploi de certains logiciels. Mais nous pensons que, quels que soient les moyens informatiques mis à la disposition des étudiants, il s'impose de continuer à leur faire exécuter certains calculs "à la main", c'est-à-dire à l'aide de calculettes non programmables (sauf en ce qui concerne éventuellement quelques fonctions élémentaires, telles que les calculs de moyennes, de variances, etc.)[2].

L'exécution "manuelle" de certains calculs est souvent une excellente façon de bien saisir le sens des méthodes étudiées ou, au moins, d'en avoir une meilleure compréhension ou une autre vision. Ce travail "manuel" permet aussi de prendre mieux conscience des risques inhérents à une utilisation aveugle des logiciels statistiques.

En outre, il importe d'apprendre aux étudiants à obtenir par raisonnement ou par calcul mental, chaque fois que c'est possible, des ordres de grandeur relatifs aux résultats qu'ils attendent. Il faut en effet qu'ils acquièrent le réflexe de toujours regarder avec circonspection les résultats qui leur sont fournis et de toujours vérifier au moins si ces résultats sont vraisemblables ou plausibles, et cela quels que soient les moyens de calcul utilisés.

5. Les supports pédagogiques

5.1. Les manuels et les livres

En matière de manuels ou de livres, il nous paraît essentiel d'imposer aux étudiants l'utilisation de documents dont le contenu déborde largement les stricts besoins de l'enseignement et qui comportent de nombreuses références bibliographiques. L'emploi de polycopiés peut évidemment faciliter grandement, à court terme, la tâche des étudiants, mais leur rendra plus difficile l'accès ultérieur à d'autres documents et, de ce fait, les amènera inévitablement à se limiter souvent aux seules notions vues dans le cadre des enseignements reçus.

A ce propos, on se souviendra toujours, d'une manière générale, du fait que l'enseignement a pour but de donner une formation de base et une ouverture sur des notions qui ne sont pas enseignées, et non pas seulement de conduire à la réussite des examens !

5.2. Les logiciels[3]

Il s'impose évidemment de mettre à la disposition des étudiants des moyens informatiques adéquats, tant en matériel qu'en logiciel.

A cet égard, notre choix s'est porté principalement sur le logiciel Minitab, dont l'apprentissage est extrêmement simple, qui comporte une diversité largement suffisante de méthodes de base et qui a aussi l'avantage de ne pas être exclusivement statistique, ce qui le rend utile également pour d'autres enseignements. Le logiciel SAS est aussi disponible pour

(1) Voir aussi, à ce sujet, Khamis [1991].

(2) A cet égard, on notera également l'existence de certains logiciels qui permettent de traiter les opérations matricielles comme si on travaillait à l'aide d'une calculette [Quris, 1993]. De tels logiciels peuvent être fort utiles notamment dans l'apprentissage des méthodes d'analyse statistique à plusieurs variables.

(3) Voir aussi, à ce sujet, Stephenson [1990].

nos étudiants, pour compléter éventuellement Minitab dans le cadre de la réalisation des travaux de fin d'études.

6. Le recyclage ou la formation permanente et la formation des spécialistes en statistique

Les différents principes que nous avons exposés nous semblent devoir s'appliquer également, moyennant certaines adaptations, au recyclage ou à la formation continue des chercheurs et techniciens du secteur agronomique. Sans entrer dans trop de détails, disons par exemple qu'en matière de recyclage, on se trouve bien sûr normalement en présence d'un public mieux formé et plus motivé, et déjà bien conscient en général de notions telles que la variabilité des résultats d'enquêtes et d'expériences. Il n'empêche qu'avant de vouloir introduire des notions nouvelles, il nous paraît essentiel de refaire le point au sujet de certaines notions de base, notamment en matière de distributions d'échantillonnage.

De même, les principes présentés ci-dessus s'appliquent très largement aussi, toujours moyennant certains aménagements, au cas de la formation des spécialistes en statistique ou en biométrie appelés à travailler dans le secteur agronomique. Bien sûr, la formation sera ici plus poussée et, dans une certaine mesure, plus fondamentale, mais il faudra rester extrêmement attentif à donner aussi une vision simple des choses et à toujours revenir aux problèmes concrets. Le statisticien ou le biométricien appelé à exercer des fonctions de consultation devra en effet, impérativement, pouvoir s'exprimer de façon très simple et dans le langage de ses interlocuteurs[1].

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Statistics in practice:
why is the reality so different from the expectation?

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1. INTRODUCTION

For a statistician, the move from a university to an international bioscience and plant breeding company was an eye-opening experience! ZENECA Seeds (formerly ICI) is in some ways atypical. It employs two groups of specialist statisticians (one in the UK, one in the USA) to support the worldwide operation. In addition, statistics as a key tool for the bioscientist and plant breeder to aid the efficient use of scarce resources and the effective interpretation of results, enjoys strong management support throughout the organisation. This is actually a double-edged sword! On the one hand there is encouragement for the statistician to propose and implement new ideas. On the other hand the scientists and experimenters are likely to request help with a range of complex and new ideas which they do not fully understand, which it may not be appropriate to use, but which have been proposed in a paper by someone from a competitor company or a well-known research institute.

Both are exciting challenges, but both require the statistician to overcome the obstacles produced in the initial training of these scientists. We who at university were closely involved in that training, have much to answer for.

Statistics for agriculturalists in many places is low on the priority list of courses which are offered - frequently taught by non statisticians or junior staff who learn something of the art of teaching here rather than in courses "where they can do real damage". It is small wonder that many agriculturalists have a fear of statistics (and hence of statisticians) and have a limited understanding of a limited range of techniques. Emphasis has typically been on analysis rather than design; because it is easier to teach and easier to set and mark examination questions! There must be more to life than randomised block designs, t tests and simple linear regression.

In this paper I discuss the general philosophy of the use of statistics and the training of staff which is being adopted within ZENECA Seeds and discuss the requirements of the staff in several specific areas - experimental design for plant breeding, analysis and interpretation of data and specialised bioscience applications. These requirements will frequently require statisticians to develop a detailed understanding of new areas of application and to be creative in the development of relevant statistical ideas.

2. A STRATEGY FOR THE USE OF STATISTICS

As computing facilities, hardware and software, develop the importance for experimenters to understand the finer points of the techniques employed in the analysis of data diminishes. The black box if carefully tuned to the specific needs of the data can remain closed. The key questions are then:-

> "What should I do to obtain quality data as efficiently as possible for input to the analysis?"
> "When I get my output what does it all mean?"

> "How much should I expect to do myself and how should I decide at what point to ask for specialist help?"

Our strategy has been to get as much design and analysis capability as possible under the control of PC based experimenters. For the majority this means AGROBASE (Mulitze, 1990) and EXCEL (Microsoft, 1992). In addition, an in-house development PBIS (Plant Breeder Information System) is nearing completion. Through these tools the experimenter will have the capability to design, analyse, and present results from much of the work done in the plant breeding part of the company. This of course does not answer any of the three questions posed above. The skill comes in assisting the plant breeder in the provision of a broad strategy for experimental design for the different phases of the breeding programme and creating an environment in which specific advice can be sought and given and in which advice will be sought. If broad design strategies are in place tools can be provided, and these will frequently be graphical in nature, to aid interpretation of results. These tools are developed over time by scientist and statistician working together. Training courses, tailored to specific groups of users, help to foster this way of working, and help the scientist, through discussion, to understand better the interpretation of results and problems with data which can arise in practice.

Statistical consultants have for many years been aware of a number of key problems. The person, who needs your advice most, rarely seeks it and is usually the least willing to accept it. Certainly you cannot expect to make the first move. It is better to concentrate your efforts where you can hope to have a successful influence; and to provide an environment where even the reticent can come without feeling guilty.

There remain specialist bioscience applications, for example genetic mapping and the search for QTLs (quantitative trait loci) which involve the use of statistical ideas covered typically in postgraduate statistics courses. Our strategy for these areas is to ensure that specialist statistics staff are based close to the bioscientists with access to appropriate software packages and a remit to support the day to day work and also to research new and innovative ideas of potential value. The teaching effort here is one where the statistical ideas pass from statistician to bioscientist through the osmosis of synergistic team working.

3. THE REALITY OF STATISTICS IN PRACTICE

i) Experimental Design for Plant Breeding

It remains a well-known fact that the statistical advances of 50 years ago, become today's practical innovations. The plant breeder's major problem is field heterogeneity, stemming from the desire to compare many genotypes in plots of say 6 m x 1.5 m with as few replicates as possible spread over several locations. Moreover, he is likely to be under severe pressure either to reduce the amount of land used or to increase the size of the breeding programme with no increase of land.

Of course the statistician can help, but only by educating the experimenter about the potential benefits from smaller but incomplete blocks and designs without complete balance - both of which go against the whole of the experimenter's basic training and instinct! But the reality remains. The introduction of lattice designs can be expected to reduce coefficients of variation; and hence increase precision for the same use of resources or

retain the existing precision with less resources. The real bonus in this education process is to have one experimenter who trusts you enough to chance his credibility with his colleagues - and who wins!

This of course on the positive side opens the flood gates with requests; but also, and inevitably, initiates the debate between the contented practitioner and the ambitious academic. The demand on the one hand says "I would like to extend the design ideas to using α-designs (Patterson & Williams, (1976)) but I am likely to need your expertise to analyse them using SAS or REML". "On the other hand I could always use randomised block designs and get you to do a Nearest Neighbour Analysis". I am rapidly learning the language of compromise.

Another area where it has been possible to exert a positive influence has been in the production of early stage screening designs; where normally only a single replicate plot is used for very large numbers of genotypes. We have adopted the modified augmented designs first proposed by Lin & Poushinsky (1983, 1985) which use check varieties placed in such a way that row and column adjustments can be made to each genotype, based on analysis of the check plot varieties. There are two types of design, one suitable for square plots or plots in a glasshouse and the other which is more appropriate to the standard rectangular field plots.

ii) Analysis of Data

Experimental design can be a statistical consultant's downfall unless due consideration is given to the notion that the advice will be accepted and that subsequently data will arrive for analysis and interpretation. Analysis is easy

- provided the design was faithfully followed and the correct form of black box is available. Interpretation is a different matter. I can offer two thoughts. What is wrong with the LSD anyway - provided it is understood that it is only really valid as a test of adjacent means in rank order, and as such can only be used to help define groups of means. The idea of expanding to comparison of means by use of one-dimensional cluster analysis (Nelder (1971) in discussion of O'Neill & Wetherill, and Calinski & Corsten (1985)) is worth developing. The other really useful tool is to develop thoughtful colour graphics which are readily accessible to experimenters. We have worked on this specifically for the interpretation of genotype * environment interaction and general and specific combining ability estimated from diallel or design II analysis. In addition, with the introduction of integrated systems for experimental design and analysis which include the production of graphical field plans, it is possible to present residual patterns visually superimposed on the originally produced field plan. All of these techniques have been found to be valuable by the experimenters.

iii) *Bioscience Applications*

There is now wide acceptance and increasing use of the techniques of genetic fingerprinting by bioscience companies. For companies like ZENECA Seeds we are interested in acquisition of a wide range of genetic probes and the production of genetic maps for the major crops in which we have an interest (Berry et al (1994)). This can then be employed in the isolation of QTLs believed to influence traits of particular interest. Probes flanking these QTLs can then be used to aid the breeding process for the efficient introgression of any of these traits into elite germplasm.

The result of this revolution has been the evolution of a generation of bioscientists for whom the jargon slips off the tongue - recombination fractions, influence of distorted segregation, interval mapping, ghost QTLs, maximum likelihood, flanking marker regression; and so on. An understanding of the statistical underpinning of the analysis, the assumptions required of the data and the potential problems caused by their violation can easily become of secondary importance to the novel and exciting nature of the results. Again the ready availability and relative cheapness of software can encourage such unthinking analysis.

For a commercial company there can be real dangers associated for example with detection of false positives. A rather more serious danger is missing real positives, even though detecting their general region, through failing to understand the meaning of standard errors.

4. COPING WITH THE REALITY

I referred earlier to the osmosis of synergistic teamwork. This really is the key. The shock for newly graduated statisticians is to find that many of the practical techniques used on a weekly basis seem to start near to where their university courses ended. Moreover the customer appears so knowledgeable. This is often a false impression and can be countered by the statisticians who trust their own intuition, confess ignorance and ask many questions. From this can be built the trust through which the teamwork can develop.

Some of us are fortunate to work with highly intelligent and strongly motivated colleagues who are keen to succeed and are open to considered

suggestion. Mutual success is reward enough coupled with the knowledge that we have also climbed an extra 10% of the way up the learning curve. The challenge then passes to management to ensure that success prompts recognition which in turn fosters continuing motivation.

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Le dispositif de formation permanente à la statistique de l'Institut National de la Recherche Agronomique en France

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Résumé Pour répondre aux besoins en statistique exprimés par les personnels scientifiques et techniques dé l'INRA, un plan de formation a été réalisé en collaboration entre le Département de Biométrie et le Service de la Formation Permanente. Animé par les biométriciens, il a été l'occasion de recherches pédagogiques et de la création d'un matériel de formation.

Introduction

Avec l'utilisation croissante des statistiques en recherches agronomique et biologique, le besoin de plus grandes connaissances en statistique s'est imposé à l'Institut National de la Recherche Agronomique (INRA). Au cours des dix dernières années, les analyses statistiques des données expérimentales sont devenues naturelles ou inévitables pour la plupart des biologistes. Par ailleurs, les recherches nouvelles en statistique appliquée doivent être comprises par les biologistes pour lesquels elles sont développées. Comment transmettre ces résultats nouveaux si les connaissances de base en statistique de nos interlocuteurs sont limitées?

Parallèlement à cette évolution, de nombreux logiciels statistiques, parfois très puissants, sont devenus facilement utilisables. La compréhension des manuels de programmation ou le choix de différentes options d'un logiciel impliquent des connaissances précises en statistique qui n'existent pas nécessairement dans les laboratoires.

Toutes ces raisons se traduisent par un accroissement permanent de la demande de formation en statistique, demande souvent mal formulée et dont la réponse externe est rarement bien adaptée. Les formations qui sont proposées sont en général trop formelles et semblent très éloignées des préoccupations des praticiens. Une des contraintes des actions de formation permanente est la nécessité d'être très liée à l'activité professionnelle des stagiaires et d'être immédiatement utilisable. Ceci est particulièrement important pour les cours qui s'adressent aux techniciens afin d'éviter de provoquer un refus de tout processus de formation. Travaillant dans un institut de recherches, ces derniers ont aussi besoin de techniques statistiques complexes. Il faut donc faire preuve

d'imagination pour mettre en place des cours qui rendent compréhensibles des notions parfois difficiles à partir d'explications simples et pratiques. Pour les scientifiques, les mêmes exigences existent, mais à un autre niveau.
Enfin, le besoin d'un matériel de formation et de référence s'est imposé. Des documents de cours complets sont nécessaires pour assurer l'homogénéité des formations proposées dans les différents centres de recherches INRA et pour servir de documents de référence en statistique. Ces documents ont aussi pour vocation de servir de base aux consultations de statistique assurées par les ingénieurs de biométrie et devraient permettre d'optimiser ce travail de conseil.

1 Caractéristiques du dispositif

1.1 Les niveaux

Trois niveaux de formation ont été distingués en fonction de l'activité professionnelle des agents et de leur formation initiale. Le niveau 1 concerne les agents qui mettent en place les expérimentations, collectent et présentent les données. Le niveau 2 concerne les scientifiques qui élaborent les protocoles, traitent et analysent les résultats par des méthodes standard. Le niveau 3 s'adresse aux scientifiques qui ont besoin de méthodes statistiques non standard ou des méthodes récentes développées par les statisticiens.

1.2 Les formateurs

Alors que la formation de niveau 3 ne peut être prise en charge que par des statisticiens professionnels, les formateurs de niveau 1 et 2 ont été recherchés parmi les chercheurs des différents départements de recherche qui utilisent régulièrement les statistiques. Un intérêt de ce choix sur l'utilisation de statisticiens professionnels est qu'ils connaissent les niveaux de besoin en statistique et les pratiques des laboratoires de leur département de recherche. Un autre avantage est de créer des relations entre des scientifiques et des ingénieurs de différents départements de recherche pratiquant la statistique et, à travers la préparation des cours, de fournir à ces formateurs un encadrement très compétent et une formation personnelle d'autant plus motivée qu'elle doit leur permettre d'enseigner à leur tour.

1.3 La préparation des formateurs et des documents

Pour chaque module, elle a consisté en un cours fait par un animateur biométricien, un choix collectif d'objectifs et de contenus, la préparation de

transparents commentés, de questionnaires de positionnement, de procédures d'évaluation et pour les formateurs de niveau 1, une formation pédagogique (pédagogie par objectifs, animation de groupe). Les résultats de cette méthode de préparation ont été :
- une appropriation des contenus de cours par les formateurs qui ont manifesté une grande exigence de précision de la part du biométricien animateur,
- l'efficacité d'un travail organisé en commun, les échanges d'expériences d'enseignement ainsi que la relation avec des biométriciens qui leur assure un soutien technique indispensable.

1.4 Prérequis - Evaluation

Pour une formation efficace, l'inscription à chacun des modules a été conditionnée par l'acquisition préalable de connaissances prérequises. Ces prérequis sont détaillés pour chaque module et vérifiés. Ils peuvent être acquis par les chercheurs dans un autre module ou par un travail bibliographique. Pour les techniciens, une articulation avec des formations en mathématiques a été systématiquement mise en place. La cohérence entre l'activité professionnelle du stagiaire et la formation envisagée est vérifiée par des entretiens.
Chaque session de formation fait l'objet d'une analyse collective rapide concernant l'adéquation du cours, du rythme, du fonctionnement et d'un bref rapport du formateur. Pour les formations de niveau 1, une évaluation après chaque séance permet, dans des délais très brefs, d'adapter la formation aux stagiaires de chaque session et de mesurer efficacement les acquis immédiats.
A un niveau plus global, une évaluation de l'ensemble du dispositif a été mise en place pour permettre au groupe responsable de piloter le dispositif et de faire un bilan de l'efficacité de l'opération. Ce bilan tient compte du contenu scientifique aux différents niveaux du dispositif et des conditions d'efficacité (formateurs disponibles, attitude des chefs de service et de départements, disponibilité des responsables formation des centres, facilité de l' accès à l'informatique ...).

2 Les méthodes pédagogiques et les contenus

2.1 Le niveau 1

Pour réaliser l'objectif de liaison forte de la formation avec l'activité professionnelle des stagiaires et éviter des préliminaires théoriques peu acceptables par les personnels concernés par cette formation, l'accent a été mis sur le

choix des méthodes pédagogiques et des contenus après une analyse par objectifs (Turckheim et Lavergne, 1991).
Les objectifs ont été déterminés avec des ingénieurs et des scientifiques des différents départements de recherche connaissant bien les tâches confiées aux techniciens. Ils ont été hiérarchisés à partir de deux points de vue, la mise en place des expériences et la collecte de données puis la présentation et les premiers traitements de ces données. La hiérarchie a ensuite été construite jusqu'à la description précise des tâches à réaliser.
Dix scénarios de séquences d'apprentissage ont été inventés par les formateurs, ils sont assez variés au plan des techniques pédagogiques proposées et des exemples choisis qui viennent de l'agronomie, la physiologie, la microbiologie, la génétique, et du domaine général. Les scénarios sont : protocole expérimental ; planification expérimentale ; échantillonnage ; représentation d'une série de nombres ; liaison entre deux variables ; ajustement à une droite ; tableaux de contingence ; tableaux à deux entrées ; estimation d'un paramètre ; utilisation d'un test statistique : comparaison de deux échantillons.
Chaque scénario se compose d'étapes de type différent qui peuvent être la description d'une situation concrète, des propositions du groupe pour résoudre un problème posé, la conceptualisation des propositions des stagiaires, la construction de tableaux, de graphiques, des calculs simples et des étapes d'évaluation collective ou individuelle par des questionnaires à choix multiples, des graphiques à compléter, des dicussions générales sur des exemples ou sur la pratique des stagiaires dans leurs laboratoires.
Pour cerner au mieux le niveau mathématique de chacun des postulants afin d'organiser l'acquisition des notions indispensables au bon déroulement des formations statistiques, un outil de positionnement a été mis au point. Il se présente sous la forme de deux questionnaires pour les stagiaires. A l'issue du test, chaque dossier individuel est soigneusement examiné par les formateurs en mathématique et en statistique. Les renseignements obtenus permettent de constituer des groupes homogènes, de préparer une remise à niveau individualisée et d'ajuster au mieux la séquence formative.

2.2 Le niveau 2

Ce niveau est conçu pour des chercheurs, ingénieurs ou scientifiques en général, son contenu a été précisé à partir de l'expérience des biométriciens qui collaborent régulièrement avec les scientifiques des autres départements de recherche.

La pédagogie choisie est plus traditionnelle avec la prise en charge par chaque stagiaire de son programme de formation et de l'acquisition des connaissances prérequises. Le cours est généralement présenté avec des transparents dont une copie réduite avec un espace pour prendre des notes est distribuée aux stagiaires. Le formateur dispose d'une version dans laquelle chaque transparent est assorti de commentaires techniques et pédagogiques. Un cours écrit par l'animateur ou par le groupe de formateurs sert de texte de référence. L'utilisation de programmes informatiques pour traiter des exemples a été conçue et adaptée à chaque module : interfaces simples avec SAS et S, logiciel de simulation de plans d'échantillonnage, logiciel pour l'interprétation statistique de l'interaction entre deux facteurs (INTERA). Le matériel de chaque module comprend aussi une présentation du module pour l'information des services, un questionnaire de positionnement des connaissances et des feuilles d'exercices permettant l'évaluation des connaissances acquises. Les modules actuellement prêts sont les suivants :
1- Introduction à la décision statistique. L'objectif prioritaire est l'acquisition des bases de la statistique inférentielle. Comme les besoins en statistique non paramétrique sont réels, ce module s'appuie essentiellement sur ces méthodes. Pour accompagner ce module et fournir aux stagiaires des documents plus complets, l'animateur de ce module a traduit le livre de Sprent (1989, 1992) et les formateurs ont réalisé un lot de fiches sur les tests classiques qui complète les documents disponibles.
2- Algèbre matricielle. Ce module a été individualisé pour introduire la représentation matricielle et les concepts géométriques associés. Il permet, d'unifier la présentation des principales méthodes statistiques enseignées aux niveaux 2 et 3, de montrer comment on peut automatiser les calculs et de rendre plus concrets les calculs statistiques par le truchement des représentations graphiques. Ce dernier point est d'importance puisqu'il touche au domaine essentiel de l'interprétation.
3- Le modèle linéaire. Central dans l'esprit des utilisateurs, ce module correspond à la demande la plus fréquente. Bien qu'il existe de nombreux ouvrages ou matériels pédagogiques à destination des biologistes tels que celui de l'ITCF (Gouet et al. 1989), un matériel a été refait, il répond aux principes suivants : centrer le cours sur le modèle statistique et les conséquences des décisions statistiques prises dans un modèle donné ; utiliser la formulation matricielle pour montrer qu'en régression et en analyse de la variance, la méthode est la même ; utiliser la représentation géométrique du calcul des sommes de carrés ;

analyser des données réelles, donner le moyen de faire les calculs simplement et insister sur l'interprétation des résultats ; ne pas simplifier des problèmes qui ne le sont pas dans la pratique ; ne pas ignorer les problèmes difficiles comme celui des comparaisons multiples ou du choix des régresseurs pour le *meilleur* modèle.

4- Analyse statistique de l'interaction entre deux facteurs. Dès que les facteurs d'une analyse de variance ont un grand nombre de niveaux ou que l'action des covariables a une grande étendue, la prise en compte des interactions est inévitable sous peine de se livrer à des simplifications abusives (n'interpréter que les effets principaux). C'est pour ces raisons que la modélisation statistique des interactions a des champs d'application extrêmement nombreux à l'INRA. L'ambition de ce module est de donner des idées concrètes et opérationnelles sur les grandes familles de modélisation de l'interaction. Par rapport aux autres modules du niveau 2, c'est le plus spécialisé et nécessite le plus de prérequis.

5- Introduction à la pratique de l'échantillonnage. Ici, le but est de donner quelques notions sur les différents plans d'échantillonnage classiques pour l'estimation d'un paramètre simple (la moyenne d'une variable aléatoire) et les connaissances nécessaires pour choisir l'échantillonnage le plus adapté à un problème donné.

6- Classification et analyse de données multidimensionnelles. Comprendre et savoir interpréter les méthodes d'analyse en composantes principales, d'analyse des correspondances et de classification sont les objectifs de ce module. Il est orienté vers une compréhension géométrique intuitive avec le même souci de représentation graphique que dans les scénarios du niveau 1. Il fait participer les stagiaires par de nombreux travaux pratiques sur ordinateur (la moitié du temps de formation) qui sont autant des étapes de découverte de problèmes nouveaux que des applications de notions présentées en cours.

2.3 Le niveau 3

Le niveau 3 correspond à la vulgarisation dans l'institut des travaux de recherche des biométriciens. Deux formations ont été mises en place :

1- Le modèle mixte - Application à la sélection. Cette formation a pour objectifs de permettre aux stagiaires de comprendre les bases statistiques du logiciel SELECT (Mangin et Vincourt, 1992 ; Mangin, 1992) et de devenir autonomes dans son utilisation. Ce logiciel a été conçu pour traiter des informations multivariables, multilocales, multigénérations, avec des données manquantes, dans le cadre des expérimentations végétales. Il traite du modèle linéaire mixte pour analyser des données recueillies sur des dispositifs de sélection, il permet d'estimer des paramètres caractéristiques des populations observées tels que la variance ou la corrélation génétique et d'optimiser la sélection. A partir de la description du schéma de sélection, une interface graphique construit automatiquement le modèle statistique puis calcule les estimations des paramètres du modèle, les variances de ces estimateurs, les meilleures prédictions linéaires sans biais des différents effets génétiques, les index de sélection qui en découlent et le coefficient de détermination des ces index.

2- La régression non linéaire et le modèle linéaire généralisé. La régression non-linéaire et le modèle linéaire généralisé demeurent aujourd'hui des méthodes sous utilisées car les théories sous jacentes ne sont pas simples et la mise en œuvre des calculs réclame l'intervention directe de l'utilisateur. Les objectifs de cette formation sont de permettre aux stagiaires de comprendre les bases statistiques des analyses non linéaires et de devenir autonomes dans le traitement des données.

Pour des observations indépendantes, des variables continues et des variables explicatives fixes, une méthodologie cohérente de la régression non-linéaire concernant l'estimation, les diagnostics d'écart au modèle, les intervalles de confiance et les tests a fait l'objet de la publication d'un ouvrage (Huet *et al.*, 1992) et d'un module de formation illustré par de nombreux exemples.

Pour le modèle linéaire généralisé la formation porte sur l'analyse des caractères discrets pour des modèles à effets fixés et des modèles mixtes. Un effort particulier a été fait sur les problèmes de choix des modèles, de test et de pertinence d'un modèle en s'appuyant sur des études de cas dans différents domaines de la biologie.

Conclusion

L'objectif de ce programme est de fournir une formation statistique adaptée à 2 000 agents INRA sur quatre ans. Il a débuté en 1992, a approximativement coûté 1 MFF pour la préparation des différents modules, la production des documents et l'organisation des sessions de formation. L'investissement humain est, pour le département de Biométrie, de l'ordre de six années de scientifiques. Deux modules du niveau 2 restent à préparer (la planification expérimentale, l'analyse discriminante) et on estime que 30 formateurs sont

nécessaires pour mener à bien ce programme (enseignement, évaluation et échange d'expériences). Actuellement, environ 400 agents INRA ont été formés et nous souhaitons que cette expérience de formation puisse servir à d'autres. Une évaluation précise des résultats obtenue par une enquête dans les services, ainsi que des estimations plus subjectives s'appuyant sur des avis exprimés librement, montrent que cette opération a été très réussie. Outre, la satisfaction d'un besoin urgent de formation, le soin apporté à la conception et à l'organisation de ces formations ont été très appréciés dans l'INRA.

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Teaching Applied Statistics to Agricultural Students and Researchers in Zimbabwe

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Biometry is an essential tool in Agricultural Research.

The absence of mathematical training makes the teaching of Biometry a challenge. This paper explains how introductory courses overcome this problem and how further training in advanced courses is achieved with the minimum of mathematics. Further workshops are given to researchers involved in agricultural research.

La formation en biométrie des diplômés en agronomie au Maroc : situation présente et perspectives d'avenir

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L'Institut Agronomique et Vétérinaire Hassan II offre un enseignement supérieur en agronomie avec un grand nombre d'options possibles.

Le programme de formation de l'option biométrie comporte des cours approfondis en statistique appliquée à la recherche agronomique et biologique.

Les ingénieurs agronomes biométriciens assurent des fonctions dans différents services du secteur agricole.

Cependant, des besoins en formation se font sentir chez certains d'entre eux. Ces besoins concernent souvent les problèmes liés à la réalisation d'enquêtes par échantillonnage, l'analyse multivariée, ainsi que l'étude de modèles économétriques.

Ces éléments d'information doivent, sans doute, être pris en considération dans une réflexion sur les perspectives d'avenir de cette formation.

L'interprétation des hypothèses d'intérêt agronomique dans le cas des échantillons déséquilibrés

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En raison de sa simplicité, le modèle linéaire de Gauss-Markov est le plus utilisé pour l'analyse des données dans de très nombreux domaines différents. La recherche agronomique ne manque pas à cette règle.

Il faut toutefois noter que, si l'interprétation des hypothèses testées à partir des sommes des carrés d'écarts fournies par les logiciels classiques ne soulève pas de difficultés dans le cas où les données sont équilibrées, il n'en va pas de même, pour des chercheurs non spécialisés en statistique, quand les échantillons sont déséquilibrés. Dans ce contexte, il n'est pas rare qu'un chercheur pense tester une hypothèse $H_0^{(1)}$, alors qu'en réalité, la structure déséquilibrée a pour conséquence d'associer au test une autre hypothèse $H_0^{(2)}$, qui est sans intérêt agronomique.

Peut-on espérer qu'un chercheur qui travaille dans le secteur agronomique et qui n'est qu'un utilisateur de logiciels statistiques fasse un choix correct parmi, par exemple, les quatre types d'hypothèses que fournit le logiciel SAS ? Peut-on supposer qu'il fera ensuite des comparaisons correctes de ses propres résultats avec d'autres résultats qui auraient été obtenus par exemple à l'aide de BMDP, SPSS, Minitab, Genstat, etc. ? Il y a là un important problème de formation.

L'objectif de cette communication est de présenter les hypothèses les plus couramment testées par les principaux logiciels statistiques, de manière à conduire à une interprétation correcte des hypothèses d'intérêt agronomique.

Teaching statistics for students of medicine - necessity, contents and concepts

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Statistics in medicine is a scientific discipline which was introduced into the medical curriculum in Germany not before the mid seventies although its foundations can be localized at a time more than 200 years ago. This circumstance seems especially remarkable when its enormous importance and its broad application in all fields of medical research is taken into consideration. However, 20 years after the beginning of teaching statistics to medical students we have to face the situation that hardly any medical student would voluntarily choose to participate in courses of medical statistics. Additionally, at least a large minority finishes the compulsory course on statistics in medicine which is now part of the medical curriculum with the opinion that they learned nothing of practical importance neither for their lives nor for their medical profession. Hence, we have to realize that something in our current practice needs review and perhaps revision.

Necessity

Do medical students need to know anything about statistics and if so, what? There seem to exist a number of different opinions about why medical students should have some basic ideas about what statistics is all about. One is that students will be involved in some kind of scientific research especially when they are working on their thesis for which they should be able to use and to understand statistical tests and analysis procedures. One other opinion is that medical students and physicians should be able to understand published results even if they were not doing research themselves. These published results must be regarded as the only valid basis of information. Considering the "flood" of publications it must be regarded as seriously important that physicians are able to extract the ones with relevant and scientifically valid information. The third opinion is that treating patients by making decisions and evaluating their consequences in itself is based on some kind of statistical thinking and may be improved by improving the statistical knowledge of practicing physicians.

It is one problem of teaching statistics to medical students that courses have to cover all three areas and that it seems additionally appropriate that different aspects including depth of the subject taught, selection of items and even language have to be considered. As those who use statistics for their own research are the minority - concerning the number of persons as well as the time of their scientific working - this will have to be considered when concepts as well as subjects are outlined. Perhaps one of the most difficult problems, however, which has to be overcome before being able to start teaching statistics to medical students is the motivation of the students for this subject, i.e. letting them know that medical statistics will help them to improve their practical work.

Contents

Medical students, especially those who will not be involved in scientific research do not need to know details about statistical techniques. The main subject of statistics in medicine which should be taught to medical students is the concept of validly collecting experience. They should be taught how answers can be obtained to relevant medical questions in a way that these answers can be trusted and used for the treatment of patients. They should be taught the design of experiments and do the designing themselves to learn possibilities, problems and limitations, theoretical as well as practical. This is one major aspect. The other aspect of major importance is the concept of probability. Medical students should be provided with probability as a basic concept to

deal with the uncertainty which is inherent in their every day medical work. They should be taught probability theory and practical application, e.g. decision-making, as a possibility to deal with and to work in this uncertainty. Of course, concepts of confidence-intervals and statistical tests should be presented but it should not be the primary aim of teaching to provide technical instructions, e.g. how to choose a certain test procedure dependent on some information about collected data. It should be clearly borne in mind that reading and judging medical publications in most cases does not need deep insight into statistical procedures.

Concepts

Teaching statistics to medical students should not begin with providing them with statistical theory and formulas. It should rather pick students up where they have and realize medical problems. The best thing would be if problems with which they are faced can be taken as a starting point for discussion and if it can be demonstrated how the problem can be solved or at least investigated by means of statistical methodology. This, however, leads to the critical problem that a one-time course in medical statistics is likely to take place at the wrong time during the curriculum. It can be located too early because one needs at least some basic clinical experience and knowledge to have or to realize problems the solution of which must be considered as relevant by the student and maybe made possible with the help of methods of medical statistics. On the other hand the course can be located too late when increasing medical knowledge and certain attitudes have consolidated. Like every beginner the medical student tends to compensate his or her uncertainty by uncritical acceptance and accumulation of information. In this situation medical statistics is in a difficult position. Not primarily because the subject is new or difficult but especially because the sceptical and critical position of medical statistics as we understand it may make the students unwilling to accept it at this stage of their medical training. Medical statistics breaks into the certainty, which the student thinks to have achieved. Therefore it finds itself in a destructive position with only limited possibilities to motivate students for the subject.

To avoid this situation and to establish medical statistics as a basic and useful discipline suitable to accompagny and support all kinds of medical work, the ideal concept would be to introduce courses of medical statistics throughout the clinical education of medical students. At least, it should be placed somewhere in the middle of the clinical education when students have basic clinical knowledge and may be especially open to the possibility of solving medical problems by structured methodology. The concept of teaching should include a basic course for all medical students closely related to the interpretation of scientific information and of clinical problem solving with the additional opportunity to deepen this knowledge through additional courses especially for those students who are going to do their own scientific research and therefore often have special methodologic problems.

Additional to the content and concept of the course itself, however, it seems that something has to be done to improve the competence of the teachers. This in some parts also includes statistics but it especially comprises the primary subject of teaching medical statistics that is to teach and to talk about medical or clinical problem solving. It is a rather long way to overcome especially these personal problems.

Statistics in medicine is a subject much too important to leave its education to not sufficiently trained teachers, who leave the impression to medical students that this discipline is a boring matter of pocket calculation rather than a fascinating subject of problem solving in medicine.

Teaching Statistics across the Medical Education Continuum

by
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1. Introduction

Since our goal in writing this paper is to present the aforementioned approaches to understanding human learning, we are compelled to approach the teaching this paper does from those same perspectives. Adult learning theory, for example, reports that adults are practical learners (Knowles, 1980); they almost never learn solutions to problems they do not already have. Thus we begin this paper by posing a teaching problem we hope readers will recognize, and we will propose a solution to it invoking the four approaches.

Adult learning theory also asserts that adults want to be involved in their own learning (Knox, 1986); they do not want to be passive learners. Thus we hope that, in reading this paper, you will be comparing what we have to say with your experience as a teacher of statistics finding both points of agreement and disagreement. We also anticipate that such an analysis will raise questions in your mind that are beyond the scope of these eight pages. Such questions can be addressed either through the references at the end of the manuscript, or through conversation with us (hank.slotnick@medicine.und.nodak.edu).

The problem we consider is Bayes Theorem, a topic we initially taught through first presenting background information (e.g., probability was defined as long-run relative frequency), then presenting the equation itself, and finally demonstrating the equation's use to compute p(D|F) in a variety of circumstances. The result of these efforts was confusion and unhappiness on the students' parts: They could substitute values into the equation and solve, but they did not see the theorem's range of applicability, they could not interpret the findings consistently and, most amazing of all, evaluation of the teaching session turned up the conclusion that "Bayes Theorem is not related to the clinical practice of medicine."

2. Reconceptualizing the Teaching Problem

This problem emerged about the time we began a study of adult learners on our campus (Slotnick, et al., 1993), and so we applied the two "principles" of adult learning cited above to teaching Bayes Theorem. First, we told students they were to be diagnosing a patient who happened to have low back pain. Indeed, we asked for a "physician of record" (called the physician in the sequel) who would make the diagnosis with "consultation" from the other "specialists" in the class. Our goals were: (i) to identify a problem the students could see themselves having and to have them solve it in a way they could understand given their lack of clinical experience, and (ii) have students become actively involved in their learning. We subsequently learned that the approach also (iii) allowed students to "try on" the role of diagnostician, a professional identity development activity addressing the insecurities students feel when they learn something which is both new and important to them.

Next, we structured the learning situation by introducing physical representations of the patients involved: Fifty paper dolls represented the physician's previous experience with low back pain (each doll had its findings and diagnosis written on its front), and one "patient" (an unknown with findings only written on it). These manipulables reduced the abstract nature of what we were to teach.

We asked the physician to diagnose the patient, a task which he did not know how to approach. One of the specialists suggested he find those patients from his past whose symptoms were the same as those of the patient; such past patients' diagnoses might be applicable to diagnosing the current patient. And, indeed, the physician removed from consideration those patients who did not share the patient's first finding (i.e., he picked up and set aside all paper dolls not sharing the first finding with the patient). This satisfied the physician and the specialists; all agreed to repeat the procedure with each of the remaining findings until all that were left were five dolls whose findings matched those of the patient.

3. Defining Probability

Three of the dolls suffered from one diagnosis, and two from a second. The physician then announced there was a 60% chance the patient suffered from diagnosis 1, a 40% chance from diagnosis 2. The specialists agreed, and so did we.

We then pointed out three things to the students: First, they were defining p(D|F) as the degree of confidence they had that something was true (i.e., the diagnosis applied to the patient) given their past experience (i.e., previous patients with the same findings); second, they were making a speculative leap in declaring that past experience applied to current cases, and, third, that even though they were only 60% certain of the diagnosis, they were behaving as if they were 100% certain in ordering treatment. In the first case, we provided them with a definition of probability they could use (vs the more abstract notion of long-run relative frequency), in the second and third, we pointed out the limitations of probabilistic reasoning.

4. True and False Positives

Finally, we asked the physician to turn over the patient and read the correct diagnosis on the back. It was, indeed, the diagnosis with the highest probability, and everyone was pleased. We then asked the specialists to define the terms true and false positive, and we asked the physician to repeat the entire diagnostic procedure this time noting the proportion of true and false positives after each symptom was considered. This exercise demonstrated that useful findings allowed the proportion of true positives to increase because (mostly true) negatives were eliminated; it took little imagination on the students' parts to see that as negatives were dropped, the proportion of true positives increased, and that this made the diagnosis simpler. The students summarized this with the equation

$$p(D|F) = p(TP)/(p(TP) + p(FP)).$$

After the last finding was used, we suggested to the students that their patients might find a doctor who diagnosed using paper dolls a bit off-putting, and so it might be useful to find some other way of determining the proportion of true and false positives. The students agreed, and so we introduced the concepts of prevalence and sensitivity

and showed that their product equalled the proportion of true positives. We also introduced the concept of specificity and showed how it could be used to compute the proportion of false positives. Finally, substituting these identities for TP and FP in the previous equation produced the desired result: A way of computing p(D|F) without resorting to paper dolls.

5. Bayes Theorem

The discussion which ensued allowed consideration of: how diagnoses changed with changes in prevalence, sensitivity, and specificity; how probabilities computed were interpreted under these circumstances, and so on. Additional patients were also diagnosed (though the physician of record changed each time), and additional patient problems were solved. The students were also told their equation was called Bayes Theorem.

6. Analysis of the Teaching

Evaluation results produced findings such as (in response to "what was the most important thing you learned") "how clinically important statistics is" as well as a greater prevalence of students both correctly using Bayes Theorem and interpreting its findings. The question remaining was why did this approach succeed. Because we have already provided an explanation from the perspective of adult learning, we turn now to the other three approaches cited in the abstract.

Cognitive psychology We consider cognitive psychology addresses both how knowledge and skill is learned (Anderson, 1985), and how problem solving is approached (Schmidt, Norman, & Boshuizen, 1990). In the former case, new learnings are related to what the student currently knows so that the stronger and more numerous the relations, the easier it is to recall the new learning later. In the current case, we presented the statistical learnings (e.g., the definition of probability, Bayes Theorem) in relation to a task students wanted to master: How to diagnose illness. Further, in repeating the task three times, each time emphasizing a different aspect of the process, we allowed students to create more elaborate relationships among what

they already knew and what they were learning.

Problem solving expertise Recent work in the area of how physicians move from novice to expert problem solvers shows that novices work exclusively by applying the basic science they know to the clinical situations they are to explain (Norman & Schmidt, 1992). The teaching described here shows principles students could apply in making diagnoses: What is the most prevalent diagnosis? Is the finding sensitive? specific? How confident can a physician be that the patient is a true positive?

Reflective practitioner Finally, the reflective practitioner literature depicts (in this case) physicians as applying technical knowledge and skill in situations which are unclear (Schön, 1987). The doctor's first task, indeed, is problem framing: Deciding which attributes of the situation need consideration and which do not. The second task is creating and doing an "experiment" to resolve the framed problem, and the third is reflection on the experiment's outcomes.

The learning task addressed these issues by providing students with ways of framing problems (e.g., using proportions to summarize experience), opportunities to set up experiments (e.g., in deciding which of the patient's finding to use next and considering what the results meant), and opportunities to reflect on what was learned (e.g., in recasting the equation in terms of prevalence, sensitivity, and specificity). In providing these opportunities, the activity both modeled professional functioning for these physicians-in-training and guided them through the process.

7. More Mature Students

Our research on adult learning, and our research on continuing medical education in particular (Slotnick, et al., in review), show the four aspects described here to be important across the continuum of medical education. Differences among medical students, residents, and practicing clinicians do appear, and they are both identified and understood using the constructs reported here.

Residents and fellows In contrast to medical students, residents and fellows have better developed professional identities, and so they look for teachers who will validate the subject matter being taught. Put

simply, because they see themselves as doctors, they do not need as much support from their teachers as did medical students. Further, and like all adult learners, they want practical knowledge and skill, skill and knowledge they can use when they have to apply basic science reasoning in making diagnostic and treatment decisions.

Practicing clinicians The literature on the development of expertise indicates that experts have more "instances" they can use to make diagnostic and treatment decisions than do novices (Norman & Schmidt, 1992). Thus practicing clinicians are more likely to solve their problems by matching the patient to one treated successfully in the past. Further, there is evidence that when these doctors seek additional learning, they do so with specific patient care problems in mind (Slotnick, et al., in review), problems they intend to discuss with other physicians as well as the teachers they learn from. This implies that suspending reality (as we did with the paper dolls) might be less effective with practicing clinicians; these learners might be best addressed using the problems they bring with them as examples to be used during teaching.

8. Conclusions

We draw several conclusions from the experiences presented here. First, good teaching addresses the identifiable needs of students as opposed to covering only what teachers consider to be important points. This means that while the statistician's notion of what Bayes Theorem is and how it works is necessary to understanding the equation, because these understandings are not what is needed in medicine, they are of lesser importance. Second, to say we are teaching statistics underestimates what we do; in fact, we are teaching how to be reflective practitioners, for example, and we are helping people move to more sophisticated positions along the novice/expert continuum.

Finally, we suggest that as statistics teachers become more sophisticated in the areas of adult learning, cognitive psychology, the gaining of expertise, and the reflective practitioner, the teaching of statistics will become both more powerful and better received by students.

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POSTGRADUATE EDUCATION IN MEDICAL STATISTICS IN EUROPE

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SUMMARY

The results of a one year European Community funded ERASMUS project to create a European network for postgraduate studies in Medical Statistics are presented. Current opportunities for postgraduate study have been identified and course content analysed. Preliminary work towards harmonisation has been completed with the production of a recommended model for European courses.

Introduction

In the last fifteen years Medical Statistics has emerged from being one of a number of applications areas of statistical theory and methods to become an established specialism with professional interest groups and International Societies such as PSI (Statisticians in the Pharmaceutical Industry) and ISCB (International Society for Clinical Biostatistics). Career opportunities for qualified Medical Statisticians are varied arising in research groups of university hospitals and medical schools, public research institutions, the national and international health services and pharmaceutical companies.

Medical Statistics - The Scientific Discipline

Medical Statistics (Clinical Biostatistics, Medical Biometry) is an interdisciplinary subject having its foundations in both Mathematics and

Medicine. It is a methodological science, concerned not just with statistical theory and computational methods, but with the translation of a medical problem into statistical terminology and the interpretation of the numerical results in terms of the original practical problem. Usually the Medical Statistician is involved in discussions concerning the selection of adequate biomedical parameters and the planning of laboratory experiments, clinical trials or epidemiological investigations. Computer Science or Medical Informatics also has a critical role to play providing tools which are indispensable for the practising Medical Statistician.

From the above "definition" of Medical Statistics it is clear that training must be based on educational programmes that promote an interdisciplinary approach. Successful empirical research in medicine requires that there is a mutual understanding between research partners i.e. the physician has to be familiar with basic statistical concepts and the statistician must be able to explain his models, their assumptions and implications in appropriate terminology. The communication will be much facilitated if the statistician is familiar with medical problems and medical terminology. It follows that the Medical Statistician needs a thorough background in statistical methodology, an understanding of the scientific research methodology in medicine and knowledge of computer tools such as statistical software and databases.

In the past many Medical Statisticians have learnt their profession "on the job" after studying Mathematics or Statistics. A few have started with a medical or other background (e.g. psychology) and learned the statistical methodology they needed afterwards. In Europe, only a few educational programmes for Medical Statistics exist at a pregraduate level. These are usually programmes in statistics which include some specialist topics relevant to medical applications, such as survival analysis. Entry into Medical Statistics as a specialism usually takes place at the postgraduate level. By "postgraduate" we mean that students already have a qualifying

degree such as the B.Sc. in England, the Maitrise in France, the Diplom in Germany, or the Laurea in Italy. Many of the current vacancies in Medical Statistics require a specialist Masters qualification, most undergraduate degrees being considered as not providing sufficient depth of coverage of Medical Statistics concepts and methodologies.

The European Study

In this European community funded study we have sought to identify current opportunities for postgraduate training in Medical Statistics in Europe, examine the diversity of programmes available and consider the problems and benefits of humanisation and student/staff exchange. Funds were provided under the ERASMUS programme (European Community Action Scheme) which aims to promote broad and lasting inter-institutional co-operation between European Universities. A network of collaborating institutions was established and several one day meetings organised to facilitate data collection, discussion concerning harmonisation and the production of a European Study Guide(Holle, 1993). The initial study, which lasted one year, was completed in September 1993.

In order to collect information about existing postgraduate programmes in Europe, the procedure was as follows: Project members and contact persons in 15 countries collected a list of 36 institutions with possible activities in postgraduate training in Medical Statistics or related fields. These institutions were contacted and asked to provide detailed information on a four page questionnaire. 18 institutions provided information about existing education programmes. Some were not included, either because their programme had not started or because they failed to supply important parts of the requested information.

Diversity of Programmes

The programmes in different countries differ in many respects and one

reason for this is the diversity of educational systems. In some countries there are regulations which restrict, for example, the duration and the teaching time of postgraduate programmes.

Our findings can be summarised as follows :-

- many programmes last one full year, whilst some take up to three years.
- The amount of class teaching time varies considerably, ranging from less than 200 to more than 1000 hours in total. The minimum of 200 class hours is typical of theoretically oriented programmes, where much of the learning takes place in the form of private study work. If training in practical skills and involvement in interdisciplinary discussions are critical features, formal instruction time including lectures, seminars and practicals appears to be close to 400 hours.
- Tuition fees vary greatly from one country to another.
- Postgraduate training is usually organised as a full-time programme, but most institutions offer a part-time mode for students who wish to remain in employment.
- Programmes have been established by institutions located either in the Medical or in the Mathematical Faculty. The majority of students have either a medical degree or a primarily mathematical background, although many courses accept suitable students from the complementary field.
- there are a number of Medical Statistics programmes in the UK where there is a long tradition of running one year Research Council Funded Masters programmes in Statistics.

In the comparison of curricula one has to face the problem that the combination of topics into course units and the labelling of these units will differ. For example, the topic "repeated measures analysis" appeared under "longitudinal data" as well as under "multivariate

methods". Therefore, in the questionnaire we gave an extensive list of subjects and asked which ones were included in compulsory or optional course units. The results showed that, although the curricula of different programmes in Medical Statistics overlap considerably, there is still much variation. Some programmes include a large number of statistical topics treated in a strictly mathematical way, whilst others place more emphasis on applied topics and/or software tools. The emphasis depends partly on the background of the students and partly on whether the programme is directed towards research or professional skills. Some topics such as "Planning and Analysis of Clinical Trials" appear to be an essential part of every curriculum in Medical Statistics. Almost all programmes involve a period of about three months at the end of the course where the student has to work on a particular medical project. This is usually the most practical part of the training, where students may be engaged in discussions with doctors/scientists, performing statistical analyses, and writing a full project report.

Harmonisation

Many people are sceptical about harmonisation and clearly it is an advantage for students to have a wide spectrum of programmes in Medical Statistics to choose from. Harmonisation does not however imply complete standardisation, rather if a common core can be identified, student exchange programmes can provide a means, for those seeking training, of exploiting more specialist topics that are only available at certain institutes. Such student exchange will require that certificates from other universities are accepted at the students home university. Student exchange is, however, not the sole justification for seeking harmonisation. Developing EC guidelines for drug regulation will impact greatly on the practice of Medical Statistics and the establishment of a more generally accepted degree in Medical Statistics within EC countries is likely to be both timely and relevant.

European Model

What then are our recommendations for harmonisation? The following recommendations were generally agreed upon after an extensive discussion.

As **prerequisites** students should have a University degree (e.g. B.Sc., Maitrise, Diplom etc.) which requires at least 3 years of university education, usually in Mathematics, Statistics or Medicine. Students with other degrees may also be accepted. Students without mathematical background should be required to attend a preparatory course in basic mathematics, if this is not included in the curriculum.

The duration of the programme should be two academic years or one full year including the project work. For one-year programmes preliminary preparation in the complementary field should be encouraged and offered, if possible .

Formal instruction time should be at least 400 hours, this includes lectures, seminars and practicals in which a staff member is in attendance, but not project work.

Degree: A degree should be given to students who have successfully attended the whole programme. The degree could be a "M.Sc." or a diploma such as the "D.E.A." in France or "Diploma di Specialista" in Italy.

Institution: The postgraduate programme should be held at a university, and a Medical Faculty should be involved in conferring the degree.

Name of programme: The name of the programme should include the term "Medical Statistics", "Biostatistics", "Medical Biometry" or some equivalent in the native language. "Applied Statistics" without any

reference to Medicine is not sufficiently specific, and "Epidemiology" or "Clinical Epidemiology" are regarded to be only partly related to Medical Statistics.

The curriculum should be structured in the form of different modules (units), some of which are compulsory and some optional. These modules should have a well defined content and a minimum number of about 30 hours. Credits or certificates should be given for the successful completion of each module. Modules forming the compulsory part of the proposed core curriculum should be compulsory for students in every course, whereas modules from the optional part may be compulsory in some programmes, optional or not included at all in other programmes. A selection of modules has been defined which constitutes the compulsory part of the curriculum constituting a total of at least 260 hours and comprising Basic Statistics, Statistical Models, Survival Analysis, Clinical Trials, Basic Epidemiology and Statistical Analysis Software. Also compulsory is project work of three months full-time duration involving a medical research topic and the production of a final project report.

Complementary Training

We think that a specialisation in Medical Statistics requires well founded basic knowledge in Statistics or in Medicine and some additional education in the complementary field. Basic mathematics and/or basic medicine should be taught to students who lack knowledge in either one of these. The minimum amount of class hours for the complementary training should be 100 hours. This may be offered in the form of a preparatory course lasting about three months or as specific modules spread over the whole duration of the programme.

An introduction to mathematics must enable the medical student to follow the core curriculum of the programme. Therefore, mathematical

notation, terminology and techniques taught at first year university level to mathematics students are required. The main subjects of the introduction will be restricted to Calculus, Linear Algebra and Probability.

An introduction into medicine as a complementary part of the curriculum can obviously contain only a small part of the curriculum that is taught to medical students. Further, the classical method of teaching medicine is to divide it into different disciplines/subdisciplines and to teach a multitude of facts, whereas for Medical Statisticians the curriculum should concentrate on the presentation of general principles and their illustration by selected examples. Topics must include pre-clinical as well as clinical medicine, and the student should become familiar with the scientific terminology and methodology of each discipline.

Future Work

The above recommendations should help to define a model for future postgraduate programmes under development in different parts of Europe. Some harmonisation is an essential pre-requisite for student exchange. The project group are currently preparing an application to the European Community to support student and staff exchange as part of an Inter-University Co-operation Programme.

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FOUR YEAR EXPERIENCE OF TEACHING STATISTICS AS A MANDATORY COURSE IN THE FACOLTÀ DI MEDICINA E CHIRURGIA DELL'UNIVERSITÀ DEGLI STUDI OF MILAN (ITALY)

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1. Introduction

In Italy the *Faculty of Medicine and Surgery* includes the *Medical School*, and the *Dental School* lasting 6 and 5 years respectively. Actual regulations of both of them have been recently revised by the Ministry of Public Education and published in the Gazzetta Ufficiale as Table XVIII and Table XVIII bis respectively (1986, 1989).

Teaching of statistics is mandatory in the Medical School whilst it is optional in the Dental School; afterwards our interest will be limited to the Table XVIII: firstly, by outlining the main features of the table itself and, secondly, by showing some data emerging from its application in the Facoltà di Medicina e Chirurgia dell'Università degli Studi of Milan.

2. Synopsis of the first cycle of courses in the Medical School

The whole curriculum studiorum enabling the student to get the degree (laurea) of Medical Doctor implies not less than 5500 hours of lessons, tutorials and practicals. The curriculum is divided into two cycles of three years each and the first cycle aims at giving to the student:

/i/ a solid biological background with a good knowledge of the scientific method;

/ii/ a deep knowledge of human physiology and pathology;

/iii/ a good understanding of causes and mechanisms of the most important impairments.

The first cycle is, in its turn, subdivided into six didactical areas, each of which is characterized in terms of: /i/ aims; /ii/ integrated courses which are mandatory and

peculiar to the area itself; /iii/ subject matter of each integrated course and /iv/ minimum amount of hours of teaching.

Medical Statistics belongs to the integrated course of Statistics and Mathematics which includes also Biomathematics. This integrated course is inserted into the area N° 1 named **Area of experimental methodology applied to the medical studies**. This area includes five other integrated courses, namely: physics, chemistry, general biology, genetics and histology and embriology. These matters are taught in the two first semesters of the curriculum so that, at the end of the first year the student, by showing awareness and ability to utilize the fundamental principles of physics, statistics, biology and genetics is expected to face problems arising from the qualitative and quantitative analysis of biological phenomena and particularly those strictly related to the medical field.

3. Integrated course of Statistics and Mathematics: four-year experience of the Facoltà di Medicina e Chirurgia dell'Università of Milan

In this medical school 650 students per year are admitted according to their score in a multiple choice test aiming at investigating their basic knowledge of mathematics, physics, chemistry and biology and at evaluating their skill in solving simple problems one can face in every day life.

The integrated course of Statistics and Mathematics is given in the first semester together with Physics and Chemistry; it implies 60 hours of teaching, 45 hours of lessons and 15 hours of practicals. As regards Statistics the main topics are:

/i/ data description (summarizing and displaying date);

/ii/ introduction to probability and decision making (rules of probability, calculus, Bayes theorem, binomial, Poisson and gaussian distributions)

/iii/ sampling distributions and the central limit theorem;

/iv/ statistical inference (confidence interval, test of significance; t test, chi-square test);

/v/ correlation and regression (linear relationship).

Contents and level of mastering are comparable to the corresponding ones in the well known book by Colton (1974).

The performance is evaluated in four written ad interim examinations; if the relative scores are sufficiently high the student is admitted to the oral examination scheduled about two weeks after the end of the course. Otherwise the student must pass a written test, comprehensive of the whole programme, before being admitted to the oral examination.

Though the new regulations have been adopted by the Milan Medical School since the academic year 1988/89, I will limit my comments and considerations to the first four years (Morabito and Bossi, 1992). The distribution of students who passed the examinations relative to the six integrated courses during the first year of their curriculum is given in Table 1. It appears that the percentage of students who passed the whole set of examinations during the first academic year increased from 23.4% in 1988/89 to 45.6% in 1991/92. Similar findings have been observed in other medical schools (Curtoni, 1991).

TABLE 1 - Percentage of students passing 0 to 6 exams during the first year of the Curriculum (in the Academic Year 1988/89, 1989/90, 1990/91, 1991/92)

	ACADEMIC YEAR			
NO. OF EXAMS PASSED	1988/89	1989/90	1990/91	1991/92
0	20.6	15.9	9.0	10.4
1	8.6	6.9	2.7	4.4
2	9.6	8.3	4.8	5.3
3	11.1	7.1	5.6	5.6
4	11.8	11.0	12.9	10.2
5	14.9	17.9	17.0	18.5
6	23.4	32.9	48.0	45.6
Total	637	636	630	664

By considering separately the percentage of students passing each examination in the first year (Table 2) we can investigate the impact of each of them on the *natural history* of our students. Roughly speaking there is a positive trend in all the

integrated courses in the four year period we are considering. However Physics and Statistics and Mathematics appear to be the two most selective courses.

TABLE 2 - Percentage of students passing all the first year exams within the first year of the Curriculum (in the Academic Year 1988/89, 1989/90, 1990/91, 1991/92)

	ACADEMIC YEAR			
EXAMS	1988/89	1989/90	1990/91	1991/92
Chemistry	69.1	81.0	81.1	83.1
Physics	34.2	52.7	70.0	62.5
Statistics & Mathematics	57.1	53.6	61.9	64.2
Histology	63.4	61.0	70.0	74.4
Biology	51.0	62.7	86.3	80.0
Genetics	47.4	64.6	84.4	74.8
Total	637	636	630	664

We now focus our attention on the integrated course of Statistics and Mathematics. Figure 1 reports the percentage of students who passed the examination either during the first year of their curriculum or later. It clearly appears that only a minority of students were able to pass the examination in the second, third or fourth year of their curriculum.

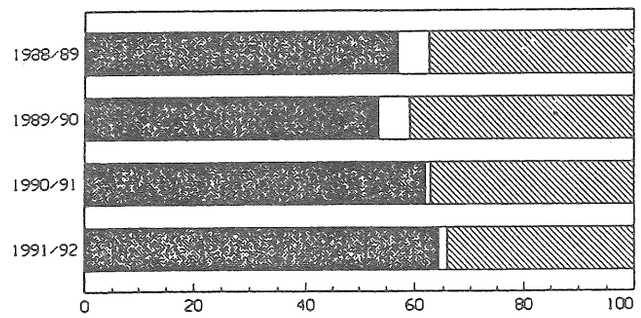


FIGURE 1 - Percentage of students who passed the exams of Statistics and Mathematics:
in the first academic year
in subsequent years
not yet

The distribution of scores for the academic year 1991/92 is given in Figure 2; remember that the scoring system adopted in Italian Universities is expressed in thirtieths and eighteen is the cut-off to pass the examination. The mean value is 24/30 and a high percentage of scores, some 45%, is over 25/30.

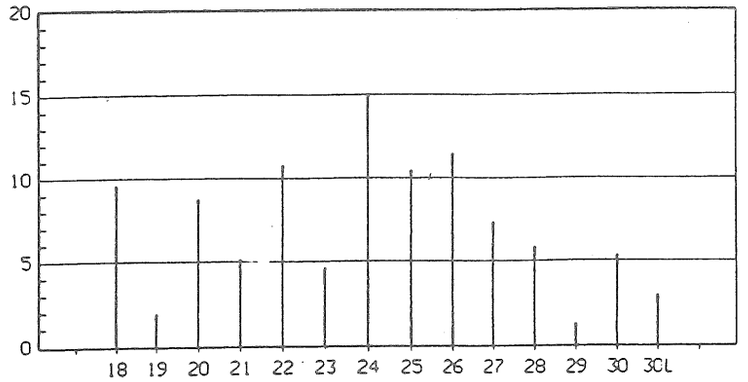


FIGURE 2 - Final score of the exam of Statistics and Mathematics obtained in the Academic Year 1991/92.

4. Conclusive remarks

From our experience it seems sensible to observe that:

/i/ the percentage of students who caught up with their examinations at the end of their first academic year is slightly lower than 50%;

/ii/ the two integrated courses of Physics and Statistics and Mathematics appear to be the most selective ones; about 40% of the students did not pass one or the other of the examinations relative to these courses;

/iii/ it is very difficult to pass, in the subsequent years of the curriculum, the examinations not given at the end of the semester in which the course was developed;

/iv/ the performance of students enrolled in the academic year 1989/90 and in the subsequent ones is better than that observed in the first year of application of the new regulations. Perhaps this could be due to a better selection attained by the admission test; in fact the number of candidates is regularly increasing along the calendar years.

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POSTGRADUATE EDUCATION IN MEDICAL STATISTICS AT THE CHARLES UNIVERSITY IN PRAGUE

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1. Joint European Project - EuroMISE

Since January 1993, the Joint European Project titled Education in the Methodology Field of Health Care - EuroMISE (European Education in Medical Informatics, Statistics and Epidemiology) has started under the scheme of the TEMPUS programme (the acronym for the Trans-European Mobility Scheme for University Studies, adopted by the Council of Ministers of the European Communities on 7 May 1990), that is funded from the Community's overall PHARE budget for assistance to the countries of Central and Eastern Europe.

Basic foundation of health care education consists in three overlapping methodology branches: Medical Informatics, Medical Statistics and

Epidemiology. To develop an appropriate scheme and forms of teaching in cooperation of Charles University in Prague with other EC universities and organizations involved in the EuroMISE project is the most desirable.

Table 1. EuroMISE organizations

Organization	Country Code
Charles University in Prague -First Medical Faculty -Third Medical Faculty -Faculty of Mathematics and Physics -Medical Faculty in Hradec Králové	CZ
Faculty Hospital in Prague	CZ
Institute of Computer Science	CZ
Catholique University of Leuven	B
Free University of Brussels	B
University of Heidelberg	D
GSF- MEDIS Institute Neuherberg	D
University of Marburg	D
University of Bordeaux II	F
Aristotle University of Thessaloniki	GR
Dublin University	IRL
Erasmus University of Rotterdam	NL
University of Limburg	NL
University of Manchester	UK

One of the main tasks of the project is to design a modularly structured EuroMISE course set, to develop teaching materials and tools in English for courses and to connect the EuroMISE project with other programmes and projects in this field. Running EuroMISE courses, especially for university teachers, should bring multiple effects in disseminating the acquired knowledge and skills.

Charles University in Prague, in comparison with other universities in Czech republic, prepare courses and make research in the highest number of disciplines. Nowadays trends in the science and education show the tight association of the science and education development on the interdisciplinary cooperation. Interdisciplinary cooperation enriches the cooperating disciplines in knowledge of different approaches that might contribute to problems solving. The important task of the project is to form new education / training strategies for people entering transformed health system in Czech republic. It is obvious that the process of transformation to new conditions can be accelerated by the education elucidating the new concepts and methods, new approaches and way of analysis and new technologies for their assurance. The need of the methodology education is general requirement of the modern scientific way of thinking. Here can play a very important role information sciences that force us to formalization, construction of exact notions, vocabulary and decision procedures.

Basic foundation of health care education consists in three overlapping methodology branches: Medical Informatics, Medical Statistics and Medical Epidemiology. A great methodological relationship among these disciplines can be seen in gathering medical and health information, in analysis of information flow, in designing medical databases and health information systems, in planning, conducting and analyzing clinical trials, epidemiological studies and surveys, introducing decision support tools, in system analysis, design, implementation and evaluation. It is obvious that health professionals should be well trained for the coming information age. They must be skilled in problem solving, concept formation, data processing and have the ability to analyze, summarize, make judgments and form valid conclusions.

2. Aims of the EuroMISE project

The main aim of the project is to create a teaching network for higher education programme in Medical Informatics, Medical Statistics and Medical Epidemiology in our country and to connect it with the teaching network in EC countries. It is very important to develop an appropriate scheme and forms of teaching in this field and to prepare in cooperation with other universities and organizations the project of higher education in the methodology field of health care. All basic methodologies for health care should be incorporated as the integral part of pregraduate curricula and in continuing

education of university staff and health professionals. We strongly feel that great priority should be given to education of university teachers that further could disseminate their knowledge in pregraduate or postgraduate courses organized at different levels at Charles University.

For Charles University it is very important to introduce and improve its structural capacities in higher education in this field. Concerning medical statistics education we plan to analyze existing curricula involving the transfer of education / training know-how between partners in order to introduce a European dimension into medical and health professional education.

One of the main tasks of the project is to design a size and modular structure of EuroMISE course set, to develop teaching materials and tools in English for courses and to connect the EuroMISE project with other programmes and projects in this field, e.g. Erasmus.

In frame of the EuroMISE project three core groups of university teachers from participating organizations are established under the leadership of the staff of the responsible cooperating university. The core group for Medical Informatics (CG-MI) is headed by the Erasmus University of Rotterdam, The Netherlands, for Medical Statistics (CG-MS) by the University of Heidelberg, Germany and for Medical Epidemiology (CG-ME) by the Université Libre de Bruxelles, Belgium. Core groups harmonize the

informatics, medical statistics and medical epidemiology for EuroMISE courses. To prepare the way of quality evaluation of EuroMISE courses and to develop a system of formal qualification for different levels, including e.g. diplomas, degrees and certificates, is also one of the aims of the EuroMISE project.

It is clear that medical statistics penetrates strongly into medical informatics (e.g. medical decision support systems) and epidemiology education in frame of the EuroMISE courses. However, the first EuroMISE course has been oriented to Czech university teachers in this field. In this condensed course three full weeks of the direct teaching (given by teachers of EC universities) are devoted to teaching of medical statistics. This EuroMISE course is taking place at the EuroMISE Center of Charles University in Prague during the year 1994. In 1995 we plan to prepare and open the EuroMISE courses also for applicants from other Central and Eastern European countries. Moreover, in connection with our other activities at Charles university in Prague we prepare during the next year also the courses for medical specialists, that also cover some medical statistics topics.

3. Conclusions

It seems that the used approach in the EuroMISE project is matching the nowadays educational needs in Czech republic as well as other Central and Eastern European countries and it might help to accelerate

European countries and it might help to accelerate the development of postgraduate education in the field of medical statistics to the level comparable with other EC countries. The long term effect of the EuroMISE project will consist in rapid increase of people with appropriate education entering into the new health system, ensuring that those staff involved in health care receive appropriate multidisciplinary training in this field. We intend to open the possibility of this type of education also for other Central and Eastern European countries during the the lasting teaching / training activities of EuroMISE higher education Center of Charles University in Prague.

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Can Statistical Consulting Be Taught?

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1 Introduction

There is continuing debate among statisticians about *whether* statistical consulting can be taught and, if so, *how* it can be taught. There are those who say that either you have the knack or you do not, and no amount of teaching will make any significant difference. Still others say that consulting is self-evident once you have a sufficient understanding of statistical theory and methods. These two views represent extremes on the axis of accessibility of statistical consulting capability. Another extreme view rejects the idea of statistical consulting altogether, contending that statisticians should be the initiators of scientific research and the leaders of research teams, rather than the "hired guns" to be brought in to mop up the final details. This view resonates with the self-gratifying assurance that statistics is at the centre of scientific research rather than at the periphery. A more traditional view, that statistics is a service discipline, lies in opposition to this position.

There will inevitably be a wide variety of opinion on what is meant by "statistical consulting". In my experience, in a large percentage of the cases where statistics is being used to solve data-related problems, there is a common core of activity arising in two-person conversations which boils down to

- communication of the problem,
- choice of a statistical solution, and
- implementation of the solution.

This, for me, is the essential core of statistical consulting. What I have to say addresses that core in a way that is applicable to the great diversity of contexts in which consulting is performed.

Those who allow the possibility of learning consulting are divided on pedagogical method. The classical approach is the master-apprentice model: the

apprentice watches the master in action; the master assigns small consulting tasks, decides how much responsibility is borne by the apprentice, observes or even controls the session, and conducts a critique of the apprentice's performance. A radically different approach to statistical consulting education with considerable merit has the statistician acquiring mastery in a subject area of application and then conducting research in that area using statistics. When statistical consulting is taught as a university course, applied statistics projects, report writing, and class presentations by experienced consultants often receive the major emphasis.

I became involved with teaching consulting when my department decided to mount a course starting in the fall of 1986. I was chosen to teach the course because I had some consulting experience and was going to become Director of STATLAB, the university statistical consulting service, in July of 1987.

In approaching the design of a consulting course, I immediately generated a number of questions to which I had no confident replies. What is statistical consulting? What is good consulting? How do I know when someone else's consulting session is going wrong? What could I recommend to redeem the situation? What should I do when I have the uneasy feeling that one of my own consulting sessions is going wrong but I don't know why? I knew from my own experience that consulting is not a trivial exercise.

Faced with a seemingly enormous task, I wanted a set of principles, a theory of consulting, that would allow me to design a course on a sound basis. By happy coincidence, I heard a talk given by Douglas A. Zahn of Florida State University who described a way of thinking about consulting that provided me with a basis for developing a theory and enabled me to design the course. I have taught the course annually since then, and have continued to study the consulting process. I will attempt to summarise my present understanding in the ensuing sections.

This paper is based on the point of view that statistical consulting *can* be learned – and therefore taught, that doing so requires a clear understanding of what makes for good consulting, and that the learning process is an ongoing one, as relevant to experienced consultants as to novices.

2 Consulting as Continuous Quality Assessment

It is quite clear that accomplished consultants engage in a process of evaluation as they consult – on-line, continuous quality assessment, in effect. By constantly monitoring their own behaviour – words, explanations, ques-

tions, instructions, decisions, directions – and the behaviour of their clients, they are almost instantly aware of the consequences of their actions and are able to conduct quality improvement on a very short time scale (seconds or minutes). An understanding of good consulting may be approached through the Quality paradigm by specifying the quality improvement system used by accomplished consultants.

2.1 Standards

The assessment of quality depends on a notion of standards. It is useful, therefore, to have a *philosophy of consulting* which sets out principles and policies for our work and our clients. We need to make explicit our values with regard to what we hope to achieve. This provides a target, an ideal toward which we may strive. Everyone will have his or her own philosophy of consulting. Practicing consultants will surely hold many values in common; the differences arise because of variation in the human response to a highly complex activity. One's philosophy is to be regarded as provisional, needing to be updated as experience brings new knowledge and understanding; nevertheless, it provides a useful standard of comparison in the short to medium term. The comments regarding a philosophy of consulting in McCulloch *et al.* (1985) are very much to the point.

2.2 Frameworks

The evaluation of events in a consulting session is aided by reference to one or more *frameworks for diagnosis* or sets of guidelines. Two of these that have proved useful are the Session Management Checklist (Zahn and Stinnett, 1992) and the Domains of Observation for Consulting Sessions (Boroto, 1992) (both are reproduced in Smith, 1992). The Checklist sets out tasks for the consultant under major headings according to stage of session. The first stage is preparatory; the second stage involves activities to begin the session. It is useful to examine the tasks laid out for the second stage:

1. Establish a relationship.
2. Align on purpose and clarify roles and constraints.
   (a) Set time frame for session.
   (b) If relevant, discuss fee.
   (c) Identify wants and needs of the client.
   (d) Express will and ability to meet client's wants and needs.
   (e) Identify inconsistencies.
   (f) Iterate until differences are resolved between wants and needs of client and willingness and ability of consultant.
3. Develop an agenda for the session: tasks, time estimates, deadlines, priorities.
4. Explain strategy as needed.

The Checklist is obviously useful as a tool for managing a session as well as for diagnosis. In this regard, items 2(c) through 2(f) above merit considerable thought and practice, for it is here that inexperienced consultants frequently meet with difficulty, and where experience is no guarantee of smooth sailing. The ideas put forward by Kirk (1991) on the use of negotiation may prove helpful in the parts of the session covered by items 2 and 3, especially 2(f).

The other framework for diagnosis, the Domains of Observation for Consulting Sessions, gives a set of contexts within which to assess the interaction at any given time. There are six domains: structure, technical aspects, attitude, relationship, experiencing, and language; these are given in more or less increasing order of complexity. The structural domain, for example, includes components of an effective consulting session; the Session Management Checklist provides a starting place for observing this domain. The language domain involves such things as the precision and clarity of language, the consultant's understanding of technical terms in the client's field, and whether requests and promises are clear and explicit, and include a time frame.

These two frameworks provide different kinds of prompts for discovering what is going well with the session and what is going badly. The Checklist indicates what is missing and the Domains help to localize the part of the "system" that is responsible and needs attention.

2.3 Diagnosis: Using the Frameworks

I have indicated that an experienced consultant spends a significant proportion of the session assessing the quality of the interaction. The consultant is thus collecting and processing a continuous stream of data in search of "defects" or "breakdowns" in the consulting process (for example, the client is not familiar with Analysis of Variance and is puzzled and dismayed when the consultant recommends using it, but does not feel encouraged to say so). These data can be collected haphazardly, or by designing and running small "experiments", that is, designing and posing probing questions that are likely to uncover gaps in the client's understanding. The data are very complex and often very noisy, having been collected by an instrument that is under considerable operating stress – the consultant's perception and recording physiology. Thus there is substantial work to be done to detect faults in the

process, and the task can be made easier by frameworks for diagnosis. We note that the over-riding priority is to detect the fault as soon as possible and repair it (for example, noticing the continued look of puzzlement and inviting the client's questions about what has been said; or better still, launching a probe by asking the client to suggest important interactions among the factors in the proposed ANOVA).

Use of the Session Management Checklist is fairly obvious. The consultant needs to be aware of which stage the session is in at any given moment, and this is not always obvious; for example, the discussion may have reverted to an earlier stage because the tasks in that stage were not completed before it was left (the most common example being the return to the problem formulation stage from the problem solution stage because the consultant began to solve the problem before it was sufficiently elucidated). Within any of the three stages involving the session proper, the Checklist items all need to be checked. For example, in the problem solution stage, the consultant needs to check that both the consultant and the client are clear about the content of the discussion (**clarity**), that important aspects of the problem are not being left out (**completeness**), that time and language are being used to best advantage (**efficiency**), and that the information being communicated is correct (**accuracy**).

Whereas the Checklist is useful for detecting a breakdown, the Domains of Observation list may be more helpful in deciding what to do about it. The Domains can give clues regarding the source of the breakdown and thus aid the choice of corrective action to be applied. Using the Domains of Observation to detect breakdowns may take considerable practice. A consultant needs to be familiar with these domains and willing to look into each one of them for an interpretation of what has occurred.

2.4 Quality Improvement

Maintenance of quality means that as soon as a breakdown has been diagnosed it is dealt with. This takes considerably more commitment than one may realize. Resolving a breakdown entails acknowledging that it has occurred. It is perhaps not surprising that many consultants are more comfortable ignoring breakdowns than acknowledging them, human nature being what it is. The anticipation of embarassment, for example, can exert a tremendous psychological pressure leading to sometimes ingeniously devised avoidance schemes. Some quiet and regular reflection on the benefits of improving quality, the view that breakdowns are opportunities in disguise, and the relative costs of embarassment and the consequences of letting the breakdown go unresolved can help to strengthen one's resolve to opt for quality

every time.

The ideal is clearly to resolve breakdowns as soon as possible after they occur. This is advantageous for at least two reasons: the sooner the breakdown is detected, the better the chance that it will not go undetected, and a breakdown that has not had time to accumulate serious detrimental effects will be easier both to acknowledge and to repair.

3 Learning as Quality Improvement

3.1 Learning to Consult is Learning to Consult Better

According to the understanding, presented above, of consulting as continuous quality assessment, learning to consult is a matter of learning to improve the quality of consulting. For this reason, it does not matter where you start your learning: if your aim is to improve your consulting, you can move ahead from your current level of ability. As stated in the Introduction, the learning process is just as relevant to the experienced consultant as it is to the novice.

3.2 Learning to Consult: The Steps

The program of quality assessment outlined in Section 2 is difficult for the novice to implement immediately. An interim learning program is necessary where there is an opportunity to examine the content of the session at leisure after the session is over and to develop skills for detecting breakdowns rapidly and effecting their resolution. This requires that the session be recorded in some form or other. Among the various possibilities – notes taken by the consultant during the session, notes taken by an observer during the session, recording on audio tape, and recording on videotape – I have found videotape to be the most useful by far in terms of the amount of data captured; the wealth of information in the visual record about the state of mind of both the client and the consultant at any given instant is worth the trouble to collect it. I have used videotaping extensively in my teaching of consulting over a period of seven years and have found it invaluable.

The following are *Steps to Learning* that incorporate the ideas presented thus far:

1. Write down learning objectives.
2. Write down a philosophy of consulting.
3. Conduct a session and record it.
4. Diagnose the session for quality breakdowns in light of the philosophy.

5. Review the session record, if possible with a coach.
6. Practice modified skills.
7. Review progress in light of the objectives.
8. Repeat steps 3-7 indefinitely.

4 Experiences with Teaching Consulting

The course STAT 869 *Statistical Consulting*, taught by the author at Queen's University, contains the following components: Introduction and Rudiments, Experiential Exercises, Enrichment Topics, Consulting Practice with Coaching, and Course Project. A fuller outline may be obtained upon request, along with a list of teaching resources.

Teaching consulting had been a tremendously rewarding experience for me because students are invariably surprised and excited by what they learn about themselves and by the realization that they can take charge of their own mastery of a challenging and complex task.

There are several ideas that students perennially have difficulty grasping and thus fail to implement in their consulting. Perhaps the most common example is the idea that the client's *wants and needs* must be understood completely by the consultant before work on a solution is begun (see Zahn and Boroto, 1989). There are several manifestations of the failure to appreciate this fundamental principle. Student consultants frequently spend a lot of time explaining the mathematical theory behind a statistical method when the client wants simply to know how to use the method, how to interpret the results, and perhaps what deficiencies in the data might invalidate the results. Another failure of the *wants and needs* principle is recommending a statistical procedure without having elicited some crucial details which would invalidate the procedure.

Another frequently occurring problem is the consultant's failure to check that the client has understood the information being conveyed. This can result in either complete mystification for the client after leaving the session, or the client carrying out instructions incorrectly and obtaining misleading or meaningless results; either way, at the very least the client wastes valuable time.

A serious situation can arise when the consultant does not understand certain terms that have a technical meaning in the client's field and is unwilling, for whatever reason, to interrupt the client's story to ask for an explanation. Some very amusing misconceptions, and equally some potentially disastrous situations, have arisen because of this lapse.

The good news is that, with practice and coaching, students are able to learn from the quality breakdowns in their consulting sessions, and many eventually attain a high level of competence. Near the end of the course, they are able to act as effective coaches for their fellow students, and are ready to be hired as Student Consultants who will handle real clients in the university STATLAB under the supervision of the Director (who has been their instructor in the course). Those who find jobs involving some aspect of statistical consulting report that employers react positively to their consulting education at the time of the job interview, and appreciate their previous consulting experience when their work is assessed.

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FRANCOIS DIVISIA
UN ECONOMISTE QUI ENSEIGNE LA STATISTIQUE DANS TROIS GRANDES ECOLES (1926-60)

Michel ARMATTE
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François Divisia (1889-1964) est polytechnicien et ingénieur des Ponts et Chaussées qui s'est tourné vers l'économie politique sous l'influence de son maître Clément Colson, principal inspirateur du groupe des ingénieurs économistes libéraux. La publication en 1925-26 d'un article célèbre sur *l'indice monétaire*, et, de *l'Economie rationnelle*, un ouvrage d'économie mathématique couronné par les deux Académies, le fait remarquer internationalement. Dès cette date il est associé à la mise en place de la *Société Internationale d'Econométrie* dont il sera le premier vice-président. Divisia est aussi un des acteurs du mouvement X-Crise qui mobilise une réflexion importante sur la science et la politique dans les années 1930.

François Divisia est suppléant puis titulaire (1926-1950) du *Cours d'économie politique générale et économie sociale* à l 'Ecole des Ponts et Chaussées. Il est professeur d'*Economie politique et sociale* à l'Ecole polytechnique (1929-59). Il est titulaire de la chaire d'*Economie Industrielle et Statistique* au Conservatoire des Arts et Métiers (1929-59). Bien que seul le dernier intitulé fasse mention de la Statistique, les trois enseignements lui font une part très importante, ce dont témoignent les cours rédigés qui ont été déposés dans les archives de ces trois établissements. Ces trois enseignements drainent un grand nombre d'étudiants en comparaison de l'Institut de Statistique de l'Universtié de Paris, seule formation spécialisée de cette période. De plus cet enseignement est original, d'une part parce qu'il est pour la première fois associé à des laboratoires (à Polytechnique et au Conservatoire), d'autre part parce que ce complexe enseignement-recherche représente un pôle de développement d'une "statistique géométrique" assez féconde, innovatrice de plusieurs dispositifs d'analyse des données, et intimement associée à deux champs d'application particuliers : l'économie et les techniques de l'ingénieur. Cette école française se présente aussi comme un pôle de résistance, trop souvent minimisé, au probabilisme qui envahit alors la statistique mathématique et l'économétrie. On présentera quelques-unes des caractéristiques de cette approche particulière de l'enseignement de la Statistique.

L'ECOLE NATIONALE DE LA STATISTIQUE ET DE L'ADMINISTRATION ECONOMIQUE (ENSAE-PARIS) : ELEMENTS D'HISTOIRE

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A côté des enseignements universitaires de statistique de type classique, la France dispose d'une autre institution, originale à plusieurs titres : l'ENSAE. Sa spécificité s'explique par son histoire, et, plus généralement, par la particularité su système français des "grandes écoles" : la plus connue de celles-ci est l'Ecole Polytechnique, dont sont issus bon nombre des ingénieurs des corps techniques de l'Etat, et notamment une majorité des "administrateurs de l'INSEE", les cadres de l'Office français de statistique. Créée initialement, en 1942, comme "Ecole d'application" destinée à former des "statisticiens économistes" pour l'administration, elle a été transformée en 1960 en "Ecole nationale de la statistique et de l'administration économique", mais les élèves fonctionnaires n'en constituent plus aujourd'hui qu'une minorité, bien qu'elle soit toujours rattachée à l'INSEE. La majorité de ses diplômés est destinée à des emplois du secteur des entreprises, publiques ou privées.

Depuis sa création, l'enseignement de cette Ecole a combiné la statistique mathématique (notamment la théorie des sondages) et l'économie. Dès les années 1950, l'économie mathématique et l'économétrie ont été enseignées par Maurice Allais et Edmond Malinvaud. La sociologie y a eu aussi sa place, à partir des années 1960, avec Pierre Bourdieu. La principale originalité de l'ENSAE est d'associer les méthodes mathématiques de la statistique (classiques dans les enseignements universitaires), d'une part aux techniques d'enquêtes et de constitution de fichiers de données, et, d'autre part aux usages de celles-ci, dans les sciences sociales et dans la gestion des entreprises et des administrations.

Dès les années 1940, l'Ecole a été composée de deux divisions, destinées initialement à former des cadres statisticiens-économistes de deux niveaux, dont les durées de scolarité étaient respectivement de trois et de deux ans, correspondant aux deux corps des "administrateurs" et des "attachés" de l'INSEE. Puis, l'Ecole ayant de plus en plus vocation à former des économistes et statisticiens d'entreprise, il est prévu que, à partir de 1995, deux Ecoles différentes prennent sa place, la première à vocation plus économique et économétrique, la seconde tournée plutôt vers la statistique et le traitement de l'information.

Depuis 1993, l'ENSAE est dotée d'un Centre de Recherche en Economie et Statistique (CREST), de type universitaire, accueillant des étudiants-doctorants, et rassemblant des laboratoires de statistique, d'économie mathématique, d'économétrie et de sociologie quantitative.

RÔLE ET IMPORTANCE DE L'ENSEIGNEMENT DANS L'OEUVRE D'ADOLPHE QUETELET

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Adolphe Quetelet est l'un des grands personnages du XIXème siècle qui a suscité de nombreuses publications soulignant les divers aspects de sa personnalité. L'astronome, le sociologue, le statisticien, l'organisateur de congrès sont autant de facettes qui ont intéressé le monde.

Notre propos sera, dans cet exposé, de centrer notre attention sur les différents aspects des activités de Quetelet en relation avec l'enseignement de la statistique et des probabilités.

Deux directions sont clairement indiquées. D'une part, Adolphe Quetelet a eu une activité d'enseignant dont les qualités sont certaines. Il s'agira de les mettre en évidence par rapport à la matière traitée et au contexte de son époque. D'autre part, il a été amené à user de ces mêmes qualités dans ses écrits.

Notre propos sera de souligner ces différents aspects tout en nous référant à notre conception actuelle de l'enseignement de la statistique et des probabilités.

EVOLUTION OF THE TEACHING OF STATISTICS IN COLLEGES IN QUEBEC

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Introduction

Twenty-five years ago, in the province of Quebec, the CEGEP, collège d'enseignement général et professionnel, was created. This opened a new era for post-secondary education: both professional and general education were offered in the same establishment to students leaving high school. The curriculum for all courses was new and statistics courses were introduced in many of them. More general courses were offered to a wide clientele, the scientific and business students, and other more specific courses, such as quality control, were given to future technicians.

A number of changes in the curriculum, in the teaching methods and in the students' knowledge have occurred since that time, and they have affected the teaching of statistics. This paper will present the evolution of the teaching of statistics in the past 25 years and try to outline these changes, their causes and their probable consequences. It is based on an analysis of college course outlines and textbooks used over the course of the period, and extended interviews with ten teachers in five colleges*.

Although it is not possible to give precise dates, we can identify four different periods. A first period can be termed "the mathematical period". A second one saw an expansion of the teaching of inference, the third period was particularly marked by the introduction of calculators. Finally, the fourth period has led to a more "applied statistics" approach influenced by the humanities' curriculum.

First period, 1969 - ~1975

The first period starts with the creation of the CEGEP in 1969 and lasted until about the mid-seventies. The creation of the CEGEP opened post-secondary studies to a wider clientele. For the first time in Quebec, the public system offered students the possibility of continuing their studies after high-school without any fees. Various curricula were offered. One could study to be a technician or to go on to university. There was two categories of curriculum, the professional and the general, from which came the name CEGEP: collège d'enseignement général et professionnel. If we look at the "Cahiers de l'enseignement collégial" which contains descriptions of all courses year after year, we see that at the beginning there were two principal statistics courses. The first one, still given in 1994, reserves two thirds of the sessions for the study of probability and probability laws, and the remaining sessions for statistics. The second one concentrates more on statistics, inferences and tests. An important difference is also that the first course requires two prior calculus courses, while the prerequisites for the second are only one. The first course, Probability and Statistics (307) was given mainly to students going into sciences or business, or economics and so on. The second one, Statistics (317-327) was taken mainly by humanities students. Apart from these two courses there were a few other more limited courses available, offering descriptive statistics and introductions to probability or correlation.

Initially, statistics teaching was very traditional, both in its approach and its content. The majority of the time was taken up by combinatorics and probabilities. This was followed by a brief introduction to distributions, mainly the binomial, Poisson and normal in a very theoretical form. Texts books were few and they had been written for university students.

Thus, looking into the classrooms we can see that teaching was very theoretical and had what we could call a "mathematical" approach. The new CEGEP teachers were freshly out of universities with a mathematics degree. Most of them had followed only one very theoretical statistics course in university, and tended to reproduce it in their classrooms. In the first years very little attention was given to testing and inference, the focus was more on combinatorics, probabilities and function of distribution. The courses were formal, used a lot of symbolism, and hardly dealt with any realistic applications.

Second period ~1975 - 1980

The second period covered the latter half of the seventies. Changes in the classrooms often precede their official recognition in the curriculum. In this period the teaching of statistical inferences and testing gained increasing importance. With this change we can also notice that the prerequisites for courses were lowered. In 1974, the course reserved for science students required only one calculus course and the other none. With time, statistical inference found its ways into the teaching of statistics. In this second period, the main change is a wider introduction to statistical tests: sampling, confidence intervals, mean and proportion test, χ^2, contingency tables, correlation and regression and so on. Nevertheless, teaching remained mainly artificial, the samples given in problems were very small and had little to do with real life situations. Similarly, the examples given in the textbooks were also unrealistic. Even though the contexts were real, the problems dealt with limited data: a population of 10 and a sample of 4. This was largely due to the limited computing facilities. It is worth remembering that before 1978-79, calculators were still few and very expensive, consequently a lot of time was devoted to computing techniques. Statistical tables were a necessity. During this period we can

also see that teachers developed more expertise, wrote their own notes and let go some formalism.

In addition, this period saw the reorganisation of the curriculum. Fewer students were enrolling in colleges, so in order to give greater access to college, many curricula were reorganised, fewer mathematics courses were required and where they remained, the prerequisites for entry were lowered. A few more specific statistics courses were introduced. For example, one such course focused on quality control in industry, and another on biometrics. Nevertheless, the two original courses, Probability and Statistics and Statistics were still the ones most widely offered. Some teachers argue that the reduction in prerequisiste may have played a role in the changes that occurred in the teaching of statistics. Since students now had less mathematical backgrounds this forced teachers to rethink their teaching approach. Nevertheless, an important factor in change was also the introduction of pocket calculators.

Third period 1980--1987

Around 1980, pocket calculators became more and more common in the classrooms. They opened the way for diverse teaching experimentation. The possibility of calculating faster and more easily allowed teachers to experiment with statistics that were closer to reality. In some colleges, teachers started having their students do surveys, collecting real data and using them to illustrate the statistics they taught in class. At the beginning, most calculators could not handle more than 100 data entries, so that was the limit. Very quickly, however, they became programmable, enabling them to compute correlation factors, chi-square and others statistics much more easily. The students using the data they had collected could plan their own "research", ask questions, make hypothese, choose a test, compute the necessary statistics and

reach conclusions. In other colleges, instead of using long-term surveys, teachers used a variety of materials to simulate experiments. One known to everyone, "throwing dice", was commonly used. For example, students collected data on the sum of two dice after first hypothesising the results. This was done before a formal study of probabilities. The data collected were tested against their hypothesis using a chi-square test. The results of the test provided an opportunity to discuss the concepts of hypothesis, sampling, sample size error, and could be referred to throughout the course. With material like pebbles, coloured beads and so forth, it was possible to simulate any kind of population and to experiment with sampling and, from there, go on to testing or finding confidence intervals, depending of the context proposed with the simulation. Both ways of creating data, by surveying or by simulations, manipulating different kinds of materials, gave a much more practical idea of what statistics could be used for. Although, in some cases, these experiments were not well integrated into the course, in other cases, they permitted a more conceptual approach to be developed. Contexts and realistic data were in some way more palpable and gave a grounding to the teacher's explanation, providing examples that were connected with the students' experience.

Nevertheless, these experiments were not common. Even though many teachers used them, they were in no way official or compulsory. For many, the blackboard and the book were still the main ways of teaching. Even calculators were looked at quizzically. In some classes calculators were used only as a complementary way of computing. Lessons on computing shortcuts which had usually been taught were replaced by lessons on the use of the calculator, again without integrating them into the structure of the course. However, the course offered to science students remained theoretical and more formal.

They were very few changes in the curriculum. For example, a statistics course for students in computer science

was designed but remained very similar to the others. Some new textbooks were published and were used much more than in previous periods, although they did not support an experimental approach. The difference was principally that the values were no longer as limited and they used more realist contexts for problems.

The teachers who developed this more experimental approach had no particular preparation for statistics. They were the same teachers who had started teaching in the CEGEPs ten years before. Those teachers interviewed described this process as based on trial and error, their own reading, and the development of teamwork approaches with colleagues, but no specific training as such. They developed their own expertise. They were more then ready for the arrival of computers.

Fourth period 1987-1994

The fourth period starts with the introduction of computers. The introduction of computers in schools enhanced innovations and encouraged more teachers to introduce an experimental approach. The use of surveys and other experiments became much more widespread. Calculations and tests can now be done with the help of statistical programs or with spreadsheets. More and more, activities have become integrated into statistics courses. Teachers can now have their students work on larger surveys, and long-term tasks are possible. One of the important consequences is that the statistics taught in schools have become closer to those used by sociologists, psychologists and other professionals.

Overall, the teachers see in the computer a way to illustrate more effectively a number of statistical concepts. Self-directed statistics teaching programmes have been developed to illustrate these different concepts. With the help of the computer and specially designed programs, the

students can generate various samples and see the results, or their graphics, illustrated. It helps them understand why, for example, there is a need to test; why an inference based on sample data cannot be directly transferred to the population; why we have to accept errors, etc. Therefore, with the arrival of computers, we can observe a wider establishment of what we could call a "statistical approach" of teaching.

Although the official description of the courses has not changed, a big reorganisation of the curriculum has more recently taken place. This affects humanities studies in particular, and will bring about important modifications in the teaching of statistics in colleges with the introduction of a "quantitative methods" course.

Since 1992 : Quantitative methods course

In 1992 the whole curriculum for the humanities was changed. One of the objectives of the new curriculum was to give greater unity to humanities studies. That was done among other things by introducing two new compulsory courses for every humanities student. One is a research methodology introductory course, and the other is the "quantitative methods" course. The study of statistics becomes compulsory although in a new form: "Statistics for everyone". This new course gives importance to inferential statistics, but without requiring the usual mathematics background. It is more of an introduction to statistics, and needs to be easily understood even by students who have little mathematical background. The concepts are required to be explained and illustrated. Formulas are seen as a symbolic language without any meaning, and, the use of computers is encouraged widely.

The use of statistical programs is also obligatory. The *de facto* reduction of mathematics courses for humanities

students affects the teaching of statistics because calculus is no longer a prerequisite.

A whole new series of textbooks has been introduced in the classroom (good ones and bad ones....) some supporting the experimental approach developed in the last few years. All of these text books provide realistic examples, exercises and activities. The contexts are varied, and many are extracted from real data. But while there are many improvements, the introduction of this new course brought up a new problem.

This new course has been seen as a humanities course by humanities teachers and not as a mathematic course, so they requested the right to give the course. In some colleges, some kind of collaboration has been developed between the mathematics teachers and the humanities teachers, but in most cases the decision about who is to give the course, and how, has been taken by administrators.

The evolution of the teaching of statistics toward a more conceptual understanding of its uses certainly represents an improvement, but is it really possible to acquire a deep understanding with a limited mathematical background? Is it really necessary to use mathematics, other than elementary computations, to do statistics? It is possible to work out inferential statistics with abstract concepts like probability, but without any mathematics? Are conceptual explanations and illustrations enough to initiate statistical reasoning? These are the questions left unanswered. It will be very important in the near future to study the results and the consequences of this wide-spread experimentation in the colleges of Quebec.

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* I would like to thank all the college teachers who took part in interviews for this study.

THE INTRODUCTION OF PROBABILITY INTO SOUTH AUSTRALIAN SCHOOLS

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The 1960s saw the introduction of new topics and new approaches to both primary and secondary mathematics teaching in many parts of the western world. In Australia many of these changes have subsequently fallen by the wayside. The teaching of probability is an interesting exception. Even though it has been removed from Year 12 academic courses in South Australia because it has proved too difficult to teach, it now has its own strand in the National Curriculum and is likely to remain a permanent part of Australian mathematics curricula.

Because probabilistic ideas are quite different from the algebraic and geometric ideas traditionnally taught in schools all aspects of their introduction have had to be constructed from scratch. So an investigation of the introduction and teaching of probability is particularly likely to highlight forces influencing classroom change.

This paper examines a number of possible influences such as overseas and Australian conferences, overseas New Mathematics projects ans Dienes' work in Adelaide, research into the teaching and learning of probability, and state and federal administrative forces within Australia's educational system. Actual practice in South Australia from 1959 to 1979 will be examined in detail to assess the relative influence of these forces.

Some writers have argued that curriculum change in Australia has been a mimicing of overseas trends. This has not been the case for the teaching of probability. Rather the forces for change have often been idiosyncratic, poorly integrated and poorly justified. Curriculum developers have until recently been concerned more with specifying content than with making optimal use of the information available or with the difficulties experienced by teachers teaching the subject.

The teaching of Statistics in Mexico
(a brief historical review)

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Abstract

The use of Statistics was known for the ancient cultures living in the American continent before the Hispanic domination (since 1521 to 1821 in Mexico). During the period of colonialism Statistics were an important element of the administration of the new possessions. A very complex system of statistics was created for the needs of the Spanish Empire. Parochial records, economical and demographical statististics and even astronomical observations were produced during 300 years. Later when Mexico became an independent country the development of Statistics was encouraged by the new governments.The Mexican Statistical and Geographical Society was one of the first in America. In this paper we show how the teaching of Statistics has been linked with the production of numerical information over each historical period. An emphasis is made on the present situation specially at the undergraduated and graduated level.

NEW ATTEMPTS TO PROMOTE PARTICIPATION OF STATISTICAL PROJECT COMPETITION

S. M. Shen and Sammy Yuen

The Hong Kong Statistical Society started launching an annual statistical project competition for secondary school students in 1986. The experience of the first four competitions has been reported by Shen, Li and Lam (1990). In spite of the various successes the competition has achieved, the popularity of the competition, however, needs to be improved.

Although a large effort has been put into the competition, each year only about 25 out of a total of 450 secondary schools participated the competition. The main problems were identified as

1) A large number of activities for school students are advertised through schools. The school principals may not realize the relative merits of all the activities and could tend to ignore those which appear to require some additional effort other than the input of an individual student.
2) Secondary school students do not have experience or training in doing a project and in writing a scientific report which the competition requires.

Two methods have been adopted for the 92/93 competition to promote the competition. The first is a project exhibition and the second is a seminar aiming at how to do a statistical project.

The exhibition displayed winning projects from the previous competitions so that students may gather the idea of what is a statistical project. The seminar introduced ways to collect data, demonstrated how to read into statistical data and dig out useful information from data sets, also how to write up a report. The students were, therefore, more ready to start doing a statistical project.

As a result, the participation rate has a significant increase. In terms of project entries the increase is ??% and in terms of participating schools the increase if ??%. Most encouragingly, the average quality of the projects have been much increased. The number of disqualified projects due to misinterpretation of a statistical project is effectively zero.

TRAINING TEACHERS TO TEACH STATISTICS IN THE SECONDARY SCHOOLS OF PUERTO RICO

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Keywords: Quantitative Literacy, Statistical Education

The purpose of this paper is to summarize our experiences of a recent project to provide Puerto Rican secondary school teachers with instructions in probability and statistics. The project was funded by the Dwight D. Eisenhower Mathematics and Science Education Program under the auspices of the Department of Education. Thirty secondary school teachers from the southern region of the Island of Puerto Rico took part in a one-year training program to acquire and improve their knowledge in the use and instructions of statistics in secondary schools. The program provided teachers with lecture and workshop activities on the statistical literacy material, developed under the auspices of the American Statistical Association and the National Council of Teachers of Mathematics, and on techniques for using these materials in secondary school instruction. During the school year following the summer training, four meetings were held to share classroom experiences in implementing the knowledge and skills gained during the summer period. The project included field trips to local industry where the participants witnessed the use of statistics in the work place and interacted with scientists and engineers of the company.

TEACHING STATISTICS IN SECONDARY EDUCATION. A DESIGN OF THE CONTENTS TO BE DEVELOPED IN FOUR STAGES

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During the secondary education, the student will study new areas of mathematical knowledge, which will endow him with interesting abilities, (abstraction, reasoning,...). Among them, Statistics will be formative, and an important basic tool to reach other disciplines which will allow the student his further proffesional training. In this contributed paper, a design of basic topics of statistics to be developed in four stages, is proposed.

The first three stages are general and for all the students. During these stages the basic contents in Descriptive Statistics and the random phenomena should be gradually and progressively introduced. Thus the student will be endowed with the elementary results of calculus of probabilities. The notions should be strongly based in intuition and practice.

The fourth stage will be more specific, depending on the student's further professional choice, (Sciences, Biomedical Sciences, Social Sciences, ...). Now the knowledge of Probability Theory should be enlarged, with new notions, (random variable, distribution of probability,...), and the study of certain probability models, (Binomial, Normal,...). The student will also introduced in Statistical Inference, by means of exposing its main questions and easy technics.

The aims of this proposal design are the following :

-To provide the student with enough statistical terminology to be able to understand the basic literature related to statistics.

-To show him how to tabulate, represent graphically, summarize and analize sets of data.

-To endow the student with enough basic technic of Statistical Inference to participate in certain research works.

THE HYPERTEXT IN THE TEACHING OF STATISTICS: SOME RESULTS OF A TEST ON AN EDUCATIONAL MODULE FOR THE BIVARIATE STATISTICS

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ABSTRACT

In this note the results of a test carried out to evaluate the performance of the hypertext in teaching statistics are reported.

The hypertext we realised aims at the study of the relation between two variables. This study has been divided in three principal modula depending on the nature of the variables: both qualitative, both quantitative, one qualitative and one quantitative[1].

The hypertext considered as a text existing only in virtual form, may aid the learning and use of statistics by means of three main kinds of intervention:

1) to systematise in a single connected system the strategies of analysis, research methodologies and techniques that allow the user to approach statistical analysis;

2) to provide the Statistics user with a tool which directs him to the learning of specific problems, but which allows him at any moment to construct his own map of statistical knowledge propaedeutic to the comprehension of the strategy followed;

3) to construct an informatic environment which attempts to induce the user to turn directly towards the solution of the problems of analysis and which, verifying the solution identified, through graphic and sound interaction, stimulate his intuitive ability, even if he doesn't possess the necessary formal tools.

The paper will describe the hypertext BIVAR1 and the results of an analysis of the possible educational results on a sample of students and professional users of statistics. About the sample of professional users a sample of medical doctors has been chosen, according to their increasing demand of knowing statistics.

The results presented concern two different learning tests, one defined subjective test and the other objective evaluation. The first one is realised through a questionnaire, with coded and open questions about what the user thinks about his learning from BIVAR1. The results of the objective evaluation is realised through a "real exam".

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[1] A first experiment was presented in Perugia at the IASE-Congress of 1993: "Educational hypertext in the teaching of statistics: a possible use for an instruction module for the relations between two variables"; *forthcoming in acts of IASE congress, Perugia, Agosto 1993*. The hypertext presented here born using the other one as a basis, it has not only a demostrative aim, but a concrete teaching aim.

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Computer Based Instruction Systems to Support the Learning of Introductory Statistical Concepts : A Design and Development Case Study

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Abstract

The creative use of computer technology has the potential to assist students in overcoming their anxieties about learning statistics as well achieving an understanding of the necessary statistical concepts. Marcoulides (1990) and Collis et al (1988-1989) show an improvement in learner performance and attitudes towards statistics by using computer based instruction in introductory statistics' courses.

This paper outlines the design and development of two modules of computer based instruction courseware for introductory university level statistics subjects. The topic focus for these modules came from the literature, student feedback, and the authors' experience in teaching statistics both on campus and at a distance.

Module one provides, to distance students in particular, a powerful experimental tool. It contains graphical tools and simulations to assist with the normal probability distribution, and concepts related to sampling distributions. Plots of normal probability curves for different means and standard deviations superimpose, and probability areas under the normal curve shade and calculate. The creation of a sampling distribution is simulated by either building a histogram of repeated sample means or by an animated selection of a sample, the mean of which is shown on a dot plot.

The instructional methodology of the second module is quite different. It is a decision support system for choosing the appropriate hypothesis testing procedure. It interrogates the user until it has sufficient evidence upon which to make a recommendation as to which is the appropriate hypothesis testing procedure to use. The reasons behind the recommendation are given as well as a worked example of how to apply that hypothesis testing procedure. Help and information, often in the form of examples, are available at all points in the questioning process.

The paper details how the team approach was used to design the two modules and associated worksheets and how the Tencore Language Authoring System was used to develop the computer-based courseware. The paper concludes with an outline of the implementation of the modules in distance teaching.

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NONLINEAR INSTRUCTION OF STATISTICS

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ABSTRACT

With the latest developments in information technology, nonlinear organization and management of information has become easier and more cost-effective. This has facilitated the development of nonlinear instruction environments such as hypercourseware (hypertext-based learning materials). The potential of such environments is increasingly recognized by many researchers. In this research, we examine the potential of hypercourseware in teaching statistics. More specifically, this article describes the development of a hypercourseware for a graduate Business Statistics course and discusses the results of an empirical study designed to examine why and when the usage of such a system can enhance student performance. Both observed and perceived effects of the system are examined. The hypercourseware improves significantly student learning as measured by the performance of students in exams. Its effect is more significant when it is used in the initial stages of learning to enhance concept formation and understanding. These results are also supported by student perceptions. The hypercourseware is perceived by the students as more efficient and more enjoyable than a strictly linear environment. Furthermore, most students used the system in the initial stages of learning to understand and form new concepts, then relied on lecture notes to review already learned concepts.

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Abstract

Contribution to section 8 (ICOTS IV, The fourth international conference on teaching statistics)

Do we need teachware at all?

all those, who are teaching statistics in applied and life sciences are always interested in new ideas and techniques to make their lectures more interesting. Among others, teachware (i.e. programs that can be used to demonstrate concepts of probability and statistics with the aid of a computer in the classroom) have been introduced and discussed in the last years.

This contribution tries to give reasons for the following theses: Although at least basic knowledge in using statistical analyses systems is an important topic in the education of students in applied sciences and should not be neglected, the author doubts, whether the use of teachware improves the task of explaining basic concepts of statistics. Interesting examples can often be more convincing.

To develop this further, the main concepts we want to make the students in applied sciences acquainted with are reviewed and are contrasted with concepts that are usually covered by teachware systems. Some open points (i.e.: computers are able to provide random samples rapidly and repeatedly, but this might not help undergraduate students to experience chance) are addressed. Alternative proposals that are not requiring the use of computers in the lecture are presented. Attempts are made to clarify what remains open and to demonstrate examples that might be used in introductory courses to explain these concepts.

The author does not presume originality for his examples: almost all of them have been collected from publications and medical journals, but hopes that overview will give some new ideas to those who are teaching statistics in applied sciences and do not want to use computers in the lecture.

A computer Program for Teaching Statistics

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Abstract

The aim of this paper is to describe a software teaching tool deviced to give a completely autonomus support to students at a first course in statistics.

The main ideas used in designing this system come from the teaching experience of the authors. In fact students have many difficulties in well understanding some basic concepts both in the field of descriptive statistics and of inference. Computers (mainly PCs and workstations) are today widely available to use them for teaching purposes as well as enough powerful to allow a very interesting interaction among numerical computations and graphics. It seems possible to make use of these capabilities to present some statistical topics in a new, more friendly and intuitive approach.

Moving from this, the system try to give either some correct examples on how to organize data to compute the various statistics or a good, direct method to go insight their meaning. In this paper the Authors describe the teaching strategies used, with many examples, underlining the role of graphics in any case. For instance, when the student decide to explore the regression model using just one explanatory variable, a Dynamic Graphic approach has been used. The student can understand how the least squares method works to find the best regression line either moving over the diagram one or more points looking at the effect on the regression line, or can move the line itself looking at the variation of the sum of squares depending on the residuals.

The software has been completely written in C language (object-oriented) and, for making it portable among the most common computers, it uses the SUIT package which interfaces MS-DOS, Machintosh and UNIX systems.

TEACHING STATISTICS USING A SPREADSHEET

by Dr Neville Hunt, Coventry University, Coventry, UK
Editor, *Teaching Statistics* Journal

Abstract

For many years the author has used a statistical computer package (such as Minitab) as an integral part of teaching statistics. The advantage of the computer package is that it removes the drudgery of calculation, allowing students to concentrate on matters of interpretation. The danger of the computer package is that it becomes a "black box" from which students accept output as unquestionably true, without any real understanding of the mechanisms which produced the output. Against a background of declining mathematical ability among students, and the consequent dilution of theoretical content in syllabuses, this represents a very real problem. The computer encourages us to teach students more and more advanced topics about which they have less and less understanding.

Many teachers now believe that a spreadsheet provides a better educational environment in which to teach statistics at an elementary level. The spreadsheet can be made much more transparent to the student, allowing them to look inside the black box. In some instances students can even construct the spreadsheet themselves, thereby appreciating the steps involved in arriving at the final result. Spreadsheets lend themselves more readily to experimentation. Students can ask those "What if .... ?" questions which they are afraid to ask in today's large classes.

Modern spreadsheets have extremely powerful (and colourful!) graphics capabilities which may be used to provide illuminating illustrations of complex processes. Pre-programmed macros can be used to lead students through a programmed learning experience.

This paper will describe the author's experiences in using spreadsheets to teach simple descriptive statistics, probability distributions, regression and analysis of variance. Live demonstrations of the teaching materials developed may be possible, subject to the availability of the necessary computer equipment.

PACKAGE ADSTAT FOR TEACHING OF DATA ANALYSIS ON PC

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The analysis of experimental data obtained from technical laboratories is obviously based on very strong assumptions (independence, normality, etc.) leading to classical straight- forward computations. In practice these assumptions have not been often acceptable and classical methods then lead to incorrect results. For correct statistical analysis of practical data and teaching of data analysis at techical universities the ADSTAT package has been build.

The ADSTAT uses the data based and exploratory methods for estimation of data statistical pecularities and a lot of methods for testing assumptions about data, models and used method.

It is suitable for interactive model building based on data and user's knowledge about the problem.

ADSTAT consists of relatively independent modules, each of them containing several methods concerning to one problem. Modules use a spread-sheet like data editor with some special functions (filling and nonlinear transformation of data blocks). Modules are controlled by combination of pull down menu and user panes.

Results can be saved and printed while graphs can be viewed, zoomed and copied on a printer.

In basic version the ADSTAT contains following modules

1. Univariate data (suitable for basic statistical analysis and exploration especially for small and moderate data sets)
2. Analysis of variance (suitable for one and two way screening or for analysis of interlaboratory experiments).
3. Multivariate data (suitable for exploration of dependecies in multivariate samples or for basic analysis of multivariate data).
4. Linear regression (suitable for linear and linearized regression models building).
5. Nonlinear regression (suitable for creating and analysis of nonlinear regression type models).
6. Probability models (suitable for construction and parameter estimation in parametric univariate probability models).
7. Calibration (suitable for complex treatment of linear and nonlinear calibration tasks).
8. Complex evaluation of variants (suitable for quality evaluation and discrimination between variants based on chosen set of properties).

This package will be continuously build up by addition of new modules , to meet the practical demands of users.

The role of microcomputer in teaching statistics at universities

Alice Yu-Wen Tam
University of Georgia

This paper reports a description of students' perceptions and reactions about the incooperation of computerized data analysis in the Reseach Methods and Statistics course curricula at the University of Georgia. The Department of Educational Psychology at the University of Georgia experimented the teaching of computerized data analysis by teaching the Statistical Analysis System (SAS) as a part of the Research Methods and Statistics curricula during the 1993-94 school year. The majority of students was graduate students, with very few undergraduate students enrolled in the course sequence. Appropriate analysis procedures were taught along with the statistical concepts and formulas taught in the courses. About one hour was devoted to lectures and hands-on computer assistance every two weeks. At the end of each academic quarter, a questionnaire was distributed to every student to ask for his/her feelings about the SAS sessions and suggestions to improve those sessions. Preliminary results indicated a positive attitude toward learning computerized data analysis. Students reported the relevance and importance to learn computer statistical analysis software. Many students requested more time to be devoted to lectures and computer lab assistance.

Stochastical Modelling of Epidemics with a Spreadsheet Programm

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Introduction

Mathematical models play an important role in epidemiology, because they can give insight into the dynamics of an epidemic and allow for predicting the effect of changing conditions (e.g. treatments, immunisation, ecology) on incidence and prevalence. The classical statistical approach to epidemiological modelling is to write down a system of stochastical differential equations, which can then be discussed. Unfortunately, this approach requires a deeper understanding of the underlying mathematical theory than can be expected from students (and even epidemiologists).

Methods

In the present paper, it will be demonstrated, that commonly available spreadsheet programs (Lotus, Excel, etc.) provide a widely available tool for a flexible and transparent approach, where an student can implement even complicated statistical models without the requirement of extensive experience in dealing with stochastical differential equations. It will also be demonstrated, how this approach can be used to display intermediate results and thus to gain more insight into the nature of the epidemic.

Results

The proposed methodology can be used to give students insight into the non-linear relationships that typically determine the spread of a disease when it is introduced into a population or the social or environmental conditions are changing. It is also easy to see for the student, that the variation due to the stochastic nature of such systems can cause substantial variation in the prediction (and even extinction of the disease in some cases).

Applications

The proposed methodology can be easily adopted to different areas of applications. Here we are demonstrating how this methodology can be used to model (1) the spread of HIV under different cultural settings and (2) the life cycle of schistosomiasis and the possible impact of different control regimes (mulluscicides, chemotherapy, behavioural changes).

Experiences

The modelling technique has successfully been applied in a series of courses for post-grade students and lecturers in Egypt and is currently being used to evaluate control strategies for the spread of schistosomiasis.

Conclusions

Spreadsheet programs have been among the. first programms becoming widely accepted even among people with no experience in programming. With the advent of personal computers with more memory and faster processors ('work stations') these programs can now also be used to compute models with hundreds or even thousends of rows in 'real-time'. This offers the possibility modelling epidemics within a spreadsheet. Since the approach offers very transparent solutions (all intermediate results can be visualized) it is a useful tool for teaching purposes.

Teaching Statistics to Physicians by SPEAKEASY

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SPEAKEASY is a very easy to learn (and cheap) mathematical and statistical package, generally used by reserach laboratories of bank institutes and official statistical boards.
It was not supposed to be used as a tool for teaching statistics. This is a great advantage when one decides to use it as a support for teaching both to non statisticians and to students of the high school or their teachers during special training courses, beacause of its flexibility.
My experience in teaching statistics to medical students and teachers of the high school is particularly encouraging and some of the materials and examples developed in these frameworks have been used in writing a book on the topics related to statistics in medicine, edited by Springer Verlag in 1990.
In the present paper some of the most interesting examples will be presented and discussed, together with new ones which can be used particularly for training courses for teachers of the high school.

Teaching Density Estimation Using Bootstrap and MINITAB

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Key Words: Ban width; Histogram; Kernel; Simulation; Teaching.

Abstract

This article is designed to promote the study of density estimation at the undergraduate level. It describes the construction of the histogram as an estimate of the population density function, and illustrates how the histogram can be implemented using bootstrap techniques. The basic idea of nonparametric density estimation is introduced. This topic, once considered difficult to teach at the undergraduate level because of its extensive computations, is now accessible through improved computer technolology and a variety of statistical packages, such as MINITAB and SAS. Several Monte-Carlo simulations are examined and MINITAB measures are used to illustrate the ease of performing some simulation of density estimation procedures that were once reserved for graduate study.

These techniques enable students to deal with interesting and challenging problems which include the mixing of distributions, robustness, and the problem of bimodal. This is seen as necessary considering the need to revise the undergraduate curriculum in statistics to include such topics as bootstrapping, jackknifing, density estimation, and bayesian analysis. This article also introduces a refinement for the smoothing parameter and more accurate methods for finding an optimal value ban width.

AN APPROACH WHICH COMBINES TEACHING STATISTICS WITH SOME BASIC NOTIONS OF COMPUTING

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At the beginning of any statistical elementary course you are taught how the mean (say: m) or standard deviation (say: s) should be calculated. It is, however, not clear for the moment what kind of applications these values can have. Some authors fill this gap by introducing Tchebyshev's inequality or concluding that for a normal distribution about 70% of the population has values in the interval (m-s, m+s). We introduce the notions of mean and standard deviation because they are technically necessary to graphically represent data with an area type graph, available in any professional spreadsheet: standardization must be performed previously and as a consequence m and s must be calculated. To predict future values, eg. of prosperity, regression analysis and sorts in database can be performed and these operations are suggested to be performed by the student under our guidance.

All data processing operations can be done using commercial spreadsheets, like EXCEL (Microsoft) and QUATTRO (Borland) for IBM PC.

The Statistics Curriculum for Social Sciences Students.

in a Developing Country.

Peter Fridjhon

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Johannesburg.

The Statistics curriculum of courses in Psychology, Sociology and Education as represented by the some of the more popular texts in the developed countries makes many assumptions about the students experience. The and environment of the student in the emerging countries may be markedly different to those in the first world. This situation is very noticeable in a college or university that is a mixture of both groups.

The instructor of such a course is faced with problem of what preliminary material the student has encountered, and the general life experiences of the student. The material includes Mathematical knowledge, exposure to computers, experience with calculators, exposure to research designs and exposure to some of research questions in the general discipline.

One of the problems of teaching social sciences statistics is its perceived lack of relevance. One method is to combine research methodology and psychometrics in larger research design and analysis course.

The paper will explore the problems in the designing and teaching of of such a course and will provide details and discussion of its implementation.

Some Experiences in the Teaching of Statistics for the Social Sciences in Mexico

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Abstract

The purpose of this paper is to present the Mexican experience in the teaching of Statistics, at the University level, for the Social Sciences and related fields. The emphasis is on lecturing to students of Economics, Sociology, Political Sciences, Business Administration, and Accounting, among others.
It describes some programs in which Statistics is currently taught in Mexican universities. The main idea is to share the ongoing discussions -mainly in our Department of Statistics at the Instituto Tecnologico Autonomo de Mexico, ITAM, -about the objectives, contents, bibliography and level of knowledge that the students must have.
A first topic is to present some issues concerning the usefulness of Statistics in the Social Sciences. We discuss what type of problems does it help to solve, what kind of data is available and which are the main techniques that are necessary for a social scientist.
A second theme is what are the conditions in the job market in a developing country like Mexico and why is Statistics necessary. We explain the role of statistical evidence in the decision making process and its importance for the various fields considered. We discuss the importance of showing the students some examples of practical situations in the real world where statistical tools can be applied.
We next describe which are, from the point of view of our experience, the actual and future statistical requirements for a typical student.
Next we review the question whether all students require the same level of Statistics. Is it more important to understand the general concepts and to be able to communicate with a Statistician or is it necessary to teach in detail the various statistical techniques? Should the emphasis be placed on applications or on theoretical concepts?
Finally, we conclude with a presentation of what, in our experience, should be a well balanced course in Statistics (Introductory, Intermediate or Advanced) that is taught at ITAM. We point out the difficulties that we have encountered and the advances that we have made in the teaching of this subject during the past 50 years.

Visual statistical thinking: integrating words and images

James Clayson
American University of Paris

The teaching of modern statistics offers a wonderful opportunity to combine visual and verbal modes of perception. When the mix is judicious, students achieve a deeper, and more synthetic, understanding of this technical discipline than they can from either graphical or textual approaches alone. When the mix is not right – because it relies primarily on visual imagery – students may actually learn less than before these computer graphics were invented

In this paper I will present two examples of "judicious" mixing of words and graphics that I have found helpful in introducing liberal arts students to statistical ideas. First, I describe a collection of word-based, pattern-finding heuristics that encourage students to develop their own skill at exploratory data analysis. And second, I show how an innovative use of computer graphics can help even beginning students understand such a difficult theoretical concept as singular-value decomposition.

I think my approach succeeds because it ignores the conventional wisdom that exploratory data analysis should be separated from statistical theory in teaching introductory statistics. Instead, I view the whole learning experience as an exploratory exercise whose success is measured by the student's ability to integrate both visual and textual components into a single structure.

We should not be so dazzled by the bright lights of computer-generated displays that we fail to appreciate the importance of talking through ideas and giving names to things – the traditional teaching method – as an essential underpinning for achieving visual thinking about statistics. Getting the mix right is the teacher's responsibility.

From elementary statistics to generalized regression modelling: on the choice and implementation of teaching strategies [1]

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March 1994

Postgraduate and research education requires to an increasing extent, especially in the social sciences, acquinting the students with extensions of the standard linear model such as generalized linear and nonlinear (regression) models. Advances in statistical theory and computing practice regarding these models and increased sophistication in substantive empirical research conflict with very limited amount of time usually devoted to teaching statistical subjects at the undergraduate and postgraduate level.

It is argued in this paper that suitable design of the first course in statistics and data analysis can considerably facilitate the transition from elementary statistical methods to the methodology of generalized regression modelling taught as an eventual second course. Following aspects of such (re)desing of a first course are discussed: (a) notation; (b) conceptual foundations; (3) minimal probabilistic and mathematical prerequisites; (4) use of examples and exercises, (5) choice of a computer package as a background calculating and modelling tool.

A discussion concerning the contents of an eventual second course capitalizing on the contents and style of a first course in statistics is subsequently given.

Special attention is paid to eradicating conceptual incompatibilities between traditional desing, style and teaching practice of the first course in statistics, and generalized regression modelling, and to emphasizing the didactic aspects of the unity of the methods of inference (ML based on iterative weighted least squares) and testing (analysis of deviance) characteristic of wide class of models related to response variables in the class of exponential dispersion (and related) families.

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[1] Abstract of a contributed paper accepted for presentation at the 4th International Conference on Teaching Statistics, July 25-30, Marrakech, Morocco.

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UNIVERSIDAD NACIONAL DE ROSARIO
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Importance of latent path modelling with partial least squares. Developing a new programme of Econometrics for future statisticians at Rosario's National University, Argentina.

Author: Elda Gallese.

This paper was made in collaboration with two collegues and I'm specifically developing the part of latent path modelling with partial least squares in the subject Econometrics, that is giving as an optional subject to student of the last year of the career of Statistics.

Within the reformulation of the programme of Econometrics it was added the teaching of this method with partial least squares, that was developed by Professor H.Wald to resolve problems of high complexity and with some variables not observed in a direct way, but just through its indexes.

This year we have included the use of the software package written by Jean Berns Lohomoller. Also included this year the discussion of the application of this model by the Planification Secretary of the Province of Santa Fe, Argentina, to mesure quality of urban life.

Teaching Statistics in the Universities of Bangladesh : Constraints and Future Challenges

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abstract

This paper considers the current state of teaching of Statistics in Universities of Bangladesh. The main purpose of teaching statistics is the development of applicable skills. Unlike many other developing countries the demand for statistical skill and knowledge in Bangladesh is growing because of its need for inverstigations in other disciplines. In this context, this paper examines the problem of teaching statistics in term of physical facilities, curriculum development, teaching methods and materials, text books and tries to indentify the strength and weakness of current statistical education in the Universities of Bangladesh.

As the basic trainers in statistical education, University teachers of statistics have a crucial role to play in the continuous development. Detailed examination of the available information suggests that there is a lack of system of training teachers in Statistics ; skill in statistical training is not systematically fostered either in training of trainers, or in matters of research or practical applications. There is a communication gap between the needs of the country and the teaching of statistics in Bangladesh coupled with lack of proper planning to absorb graduates in statistics. Widening of this gap and lack of frequent contacts between the academic world and the world of applications and practice are hampering the development of statistical education and training. The implications of this are discussed in terms of the propoer utilization of statistics in the process of development. Future needs are identified and discussed for the development and effective implementation of statistical education in the Universities of Bangladesh. Suggestions are also made about refresher courses for statistical practioners, and for teaching of statistics in other disciplines.

I. CHACKO
IBADAN University - Nigeria

Over a Decade of Teaching Statistics to Postgraduate Students in Education

In one of the universities in Nigeria, all postgraduate students in Education are expected to offer and pass a course in Basic Statistics. This is to provide them with the know how to be sound researchers in their fields. At the same time, majority of these students have little or no knowledge of basic mathematics and at least 50% of them, had been out of school for over ten years, with an age range of 25 to 55. The class is very heterogenous in nature with a wide range in aptitude in mathematics, which makes it difficult for the lecturer to handle.

As a lecturer for the course, over the last 12 years, I have been trying various approaches to make the course easier for the students. These approaches include filling the gaps based on a test on prerequisite knowledge, giving hypothetical problems to which students are to seek solutions and discuss these in class, gathering data on the students enrolled for the course and analysing and interpreting these as the course progress, and students gathering data on postgraduate students in the Faculty of Education, analysing these at the various stages of the course.

Out of the various approaches, the students seemed to have benefited most from the last one, in terms of the problems involved in gathering data with out any clear notion about the research questions to be answered. This made them to look at the problem at hand critically, formulate the questions to be answered, determine the statistical techniques that could be used and the sort of data to be gathered for the purpose. Learning from their mistakes, made them more critical and more interested in the procedure which was observed in their participation in the class, in their performance, as well as in their attitude to the course.

Indu. Chacko.

ABSTRACT

by Statistics Education Committee of Japan Statistical Society

" On Statistical Education in Japanese Universities "

With the rapid progress of social informatization, there is an urgent need to improve the statistical education system in Japanese universities. Therefore we have investigated the statistical curricula of Japanese universities (460 universities which cover 94% of the total) in 1991 and reported the analytical results for these three years at annual meeting of the Japan Statistical Society. We treated the case of national and public universities the first year, the case of private universities the second year and the case of all universities the third year. In addition to these, a special study was executed for medical schools. The studies are along with following lines,

1) Statistics on the proportion of lectures that related to staistics in general(liberal arts) education programs (during the first and second years of university studies) and comparative studies of the proportions between national and private universities.
2) Statistics on the proportion of lectures that related to statistics in specialized education programs (during the third and fourth years)and comparative studies of the ratios between national and private universities.
3) The distributions of the names of lecture courses related to statistics and their comparative studies among departments.
4) Some considerations on classification of departments and comparative studies of the results between national and private universities.

Now our committee tackles three main problems. The first concerns the consistencies of statistics education through the school education (from primary to university)in which the official instruction guide problems are also included. The second problem relates to the cooperation between staistics and computer science departments in the course of developing the remarkable software packages now available. As a third program we consider now to arrange the systems of statistics education for a modern industrial paradigm shift. We intend to comment on these problems based on reference to the results of our research.

Statistical Training in Zimbabwe : Proposals for Expansion

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ABSTRACT

The Statistics Department at the University of Zimbabwe opened its doors for business in March 1989. Undergraduate and some post-graduate programmes are offered and, in addition, the department offers service courses to students in Engineering, Agricultural Economics, Veterinary Science and Food Science.

It is essential that the Department constantly aims to update and upgrade its approaches to training useful statisticians. The statistical needs of Zimbabwe since the inception of the economic reform programmes in 1991 are changing daily, highlighted in the following areas:

-expansion of industry
-financial and commercial bodies in the international arena
-increasing agricultural activity
-growth of epidemics
-awareness of environmental issues
-Government Statistical offices needs

In this paper we seek to explore ways and means of maintaining a high standard of statistical training under sometimes adverse conditions.

We explore curriculum issues for undergraduate students, focussing on aiming to provide them with a broad enough overview of uses of statistics in Zimbabwe today, so as to render them employable, whilst ensuring their knowledge gained is in fact substantial enough.

We propose teaching methods that aim to encourage students, at all levels, to become critical statisticians, able to identify, and to appreciate relevant information and to communicate efficiently with users of statistics.

Effective training of potential future staff is discussed in the light of acute present staff shortages in particular areas.

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Développement d'un nouveau programme d'Econometrie pour des futurs statisticiens à l'Université Nationale de Rosario. L'utilisation des modèles dynamiques pour les projections de population".

Auteur: Nora Lac Prugent

L'emphase de ce travail est mise sur le problème de l'éducation de la statistique dans un pays en développement. A partir des données de recensements disponibles, nous avons étudié le comportement de la population de la ville de Rosario, siège de l'Université Nationale de Rosario, en utilisant la loi logistique. Cette méthode de projection rapide et peu coûteuse pourrait être utilisée dans des villes analogues à celle étudiée. Nous avons le désir de donner des outils méthodologiques pour dérouler n'importe quel sujet aux statisticiens de l'année 2000.

Computer Assisted Teaching of Biostatistics at the Medical University of Szeged

Dr. Krisztina Boda
Department of Medical Informatics of the Albert Szent-Györgyi Medical University

Abstract

"Computer Assisted Biometrics" has been taught to pharmaceutical students since 1993 as a new subject at Albert Szent-Györgyi Medical University, Szeged. Biometrics is also a compulsory course in the SzOTE Ph.D. program. Lessons are given in two PC laboratories set up by the project "Supply and Installation of Computer Teaching Laboratories" of the Szeged University Association. This project was financed from a loan of the World Bank as a part of the "Human Resources Development Project". This paper gives an overview of the experiences of the first two years of teaching. The staff of the Department of Medical Informatics is experienced in using statistical methods to evaluate clinical data.

The aim of the course: The course in biometrics is designed to equip students with the basic statistical knowledge used in solution biometrical problems in pharmacy and medicine. Another purpose is to gain in modelling and interpreting results using computer programs. This course is also a study in computer techniques, so it may be the base of every subject where computers are used.

Methods: The lecture gives theoretical concepts and mathematical basis. The students study evaluation of experimental data trough manual calculations and by using computer programs (STATGRAPHICS 5.0, SPSS for Windows 6.0) in the practical sessions.

Topics: Elementary concepts, mathematical bases (probability); sampling, theoretical and sample characteristics and their relations, distributions; descriptive statistics; estimation ; testing hypotheses; one and two sample tests; analysis of variance; regression and correlation; nonparametric methods.

Results: in spite of early scepticism from students, this whole system of teaching became popular among them.

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The Problems of Continuing Statistical Education in Medicine - Croatian Experience

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The problem of teaching statistics to non-mathematicians is always very difficult to resolve. The same happens with the statistical education in medicine.

Usually, initial course is taught at the first academic year with only 30 hours of lectures and seminars. The mathematical background of the students starting medical studies is rather poor, so little is to be done with statistical theory. Due to that reason, as well as the nature of their studies, the applied statistics in medicine is the most appropriate course to be taught.

The other problem with the applied statistics is that the student at the first academic year can't understand the examples taken from medical experiments and tests, since he hasn't been acquainted enough with the fundamentals in medicine. It is intended that the student at the higher stage of medical education is able to use statistical methods, but professors from other courses are supposed to use statistical methods during their lectures. It doesn't happen very often, so students usually forget the initial course in statistical methods in medicine. It is clearly seen that there are many problems using statistical methods when they do their final graduate thesis.

To overcome these difficulties there are some statistical courses for graduate students. The intention is to refresh and update their statistical education, since it is quite impossible to read the most recent papers in medicine without the understanding of statistical methods. These courses are usually connected with data analysis and information systems. Special attention is paid when graduate students do their master thesis, since the application of statistical methods is compulsory.

HOLISTIC APROACH TO TEACHING CLINICAL TRIALS

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A Clinical Trials course (five 3-hour sessions) was conducted for Epidemiology and Biostatistics students in the Graduate School of Health Sciences, New York Medical College. Required reading materials were: detailed outline; a current article on a controlled trial from NEJM with letters contrasting clinical significance; articles on bias, power analyses, and alternative designs; Trial Assessment Procedure Scale (TAPS) from NIMH; and bibliography. Didactic approach was framework for team efforts; teams of four students met for a half hour each session to reconstruct sections of 'protocol' from which the published trial could have evolved. Groups submitted drafts of protocol sections, and presented them at the last class for evaluation by peers and professor. Skills developed include critical reading of medical research article for content and important omissions, identification of trial limitations and analytic thinking to modify protocol and avoid bias in future studies, deductive reasoning, development of biostatistical considerations section, team management, oral presentation, integration of trial components, critique of peer reports by creative suggestion of alternative features.

TEACHING STATISTICS TO MEDICAL UNDERGRADUATES

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The structure of a short course in Statistics for Physiotherapy and Occupational Therapy undergraduates at the University of Cape Town is discussed. Teaching statistics to such students offers a particular challenge as they are generally intimidated by numbers and have little or no computing experience. Part of the final year requirements for these students is the planning, execution and analysis of a study within their discipline and the course is designed to provide them with the statistical skills that are needed for this. The aim is to equip the students with the practical expertise needed to analyse their own data and a conceptual understanding of the statistical methodologies involved. Data entry, data cleaning, summary statistics and graphical displays, estimation and hypothesis testing, correlation and regression analysis are covered, with ongoing practical application to data from a questionnaire administered to the students themselves.

ABSTRACT

TEACHING BIOSTATISTICS IN MEDICAL SCIENCES UNIVERSITIES OF IRAN: HOW SHOULD WE APPROACH THE FUTURE?

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Biostatistics as an essential part of the modern life has become an academic tradition in the developed world universities in recent decades. The history of teaching biostatistics in some medical schools in Iran dates back to 1970s. The needs to teach and practise this discipline in the medical section has continuously grown up during the past decade, although its role in raising the standards of medical researches has not been yet completely appreciated. There is still a very long way to go in order to make this strikingly important subject known to its potential clients and the administration and authorities.

Present curricula require medical and health sciences students to take a 2-3 credit biostatistics course during their studies, but there is still some frustration and uncertainties about its success. The frustration is born of a number of reasons-including the nature of the students and limitations on the courses-and the uncertainties are related to immediate experiences in teaching and current statistical quality in medical journals among other aspects. The same applies to graduate courses in biostatistics with a wider angle. Intermediate and advanced courses in Biostatistics are taught not only to MSc students in the area of biostatistics but also to epidemiology, human nutrition and some other health and basic medical sciences. No evaluations have been made on the effectiveness, efficacy and adequacy of these courses so far. Insufficient qualified staff in biostatistics and lack of efficient tools of teaching and learning such as computer facilities and statistical software have made this subject much boring to its clients. The sweetness and pleasant feature of the subject has not yet correctly been comprehended by the students and the medical professions.

This paper intends to examine biostatistical education in medical and health sciences at different levels thoroughly. Various strategic questions are raised:What do doctors need to know about biostatistics? When and how should medical and health students be taught biostatistics? When and by whom should the teaching of biostatistics be carried out? What was the outcome of the teaching in practice? What main revision are needed to raise the quality of MSc programme in biostatistics? How should biostatisticians be involved in medical research? What short-term and long-term strategies are to be taken in order to overcome the existing shortages? The paper finds general practical solutions to these problems providing the readers an experience from Iran.

A entire evaluation is attempted to find a practical response to the question of how should we approach the future. The number of biostatisticians needed at all levels are then estimated and ways to train them are proposed. Possibilities of establishing a BSc course and feasibility of running a collaborative PhD programme in the area of biostatistics are discussed in some detail given the potential human resources in Iran.

The concept of biostatistics clinic and statistical rota are elaborated duly to establish a consultancy system and recover the medical research standard illnesses and deficiencies. The paper further presents a guideline to make biostatistics as an enjoyable, practical, sensible and lively discipline.

The paper concludes that biostatistics should be an integral part of any medical and health curricula as is approved by the supreme council of cultural planning of Iran but a content analysis is to be made for continuous dynamic revisions. Medical statisticians should be involved in any bio-medical researches and their vital roles in raising the standards of the researches should be appreciated. A mass production programme is needed to train medical statisticians (biostatisticians) such that the minimum standard of biostatistical education is preserved.

AN EXPERIENCE OF TECHING STATISTICS IN MEDICAL SCHOOL OF MILAN UNIVERSITY

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Usually the practical solving of a problem is a very good incentive for learning. This kind of learning is conditioned by a sort of evaluation to measure the student's performance or student's skill. Knowledge of statistical methodology topics has also been stimulated to look for solutions to real problems. For this reason a new experience has been tried out to teach descriptive statistics. The aims of this experience were studends should improved their skill:
- to write and to present a brief report;
- to summarise a data set by graphical and numerical methods;
- to work in group.

Some 400 students in their first year of Medical School in Milan University were asked to prepare within 20 days, a poster describing a newborn's data set. Students were followed by 2 professors and 2 tutors, the latter could be consulted over a fixed time of about 5 hours per week in addition to ordinary lessons.

Each student's group (4 to 6 students) received a dossier with:
- bibliography about the topic;
- information about each of 7 variables collected for each subject;
- data set of 200 babies;
- some partial results (i.e.: Σx, Σx^2) to aid the student, to calculate position and dispersion measures;
- features of the poster (the group have to choose a title).

Computer assistance was not specifically requested to do the job.
At the presentation of the poster both skill of the group's description and poster qualities were assessed by the teachers using an appropriately structured questionnaire. Teachers gave positive judgement about all the work presented. The only criticism to this experience is that some students showed a low capacity of performing calculations of description statistics at the final examen. Pheraps this was due to job allocation within the group.

Each student was invited to fill in a questionnaire about different aspects of this experience before being aware of the evaluation.
Data collected (161 females and 94 males) have been studied by multiple correspondance analysis. On the whole a positive judgement on this experience was expressed by 63% of students. Difficulties pointed out were:
- problems of working in a group firstly due to lack at space and secondly incompatibility about meeting time among group's people (about 80% of students).
- Lack of time to make poster because this job was extra to regular lessons (about 30%)

In brief we belive that most of the students achieved a prefixed goal from this experience even if with some problems.

Quercus - An Interactive Tutoring System for Biostatistics.

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With the increased use of statistical software packages as teaching aids it has become apparent that for many students difficulty in using the software acts as a barrier to learning subject matter. A consortium of statistics departments from Strathclyde, Stirling, Heriot-Watt and Edinburgh is engaged in a project to develop a CAL package (Quercus) to tutor the students in the effective use of statistical software to analyse biological data.

The principal requirements for Quercus were that it should be flexible and interactive. It was written as a series of modules each of which provides the students with information, examples, feedback and supplies help when problems arise. Quercus was created using a commercial authoring package AuthorWare Professional®.

Quercus applications have the facility to track the users progress through the application. Report files are written detailing movement within and between sections, responses, response times, use of help facilities etc. A sample of 16 student volunteers were monitored in this way and the data together with information from questionnaires and interviews were used to assess the effectiveness of Quercus as a teaching aid.

TOWARDS A RATIONAL STATISTICS CURRICULUM FOR MANAGERS AND OTHER PROFESSIONALS

Paper submitted to the Fourth International Conference on Teaching Statistics, Marrakech, 25-30 July 1994

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Keywords
Statistics education; Management education; Syllabus design; Bootstrapping; Statistical process control.

Abstract

Statistical concepts and techniques are undoubtedly useful for management, and, for this reason, statistics is taught on most degree courses in business and management, and on short courses on, for example, statistical process control or experimental design. Despite this, the evidence suggests that the discipline of statistics is relatively under-used, misused, misunderstood and feared. (Similar comments apply to the use of statistics in medicine and other professions.)

The syllabuses for such courses are often set largely by tradition (particularly in universities). This paper proposes that the best way of resolving the problem of the "user-friendliness" of statistics is by a radical redesign of the syllabuses - so that people learn what is actually useful to them in the context in which they will use statistics.

The paper suggests some criteria for developing and evaluating practical statistics syllabuses for managers and other professionals. The usual criteria - such as whether the concepts and techniques in the syllabus yield correct and useful answers - need to be supplemented by additional criteria such as error resistance (are users likely to make errors in implementing the techniques?), user confidence, user enjoyment (techniques which yield no pleasure may fall into disuse for this reason alone), user effort (are they hard to learn about?), and transparency and "interpretability" of results. (These criteria reflect practical usefulness more directly than conventional course objectives like: "The student will be able to perform a t-test.") The paper proposes a hierarchical tree incorporating the relevant criteria.

This analysis is unlikely to lead to clear conclusions about the optimum syllabus. It is, however, likely to discourage the adoption of clearly unsuitable syllabuses (as is often the custom), and to encourage the development of new syllabuses which score well on the important criteria. Much of the content of many traditional syllabuses - including the standard deviation as a measure of spread, the use of the normal distribution, and the standard approaches to confidence intervals and significance tests - are, the paper argues, unsuitable for mathematically unsophisticated potential users; instead the paper argues in favour of methods based more directly on empirical data such as bootstrapping and non-parametric concepts.

This will be illustrated by comparing a syllabus for statistical process control charts based on empirical methods such as bootstrapping, with a conventional syllabus comprising mean charts, range charts, p charts, and so on.

A change process:
From mechanistic to realistic statistics education in a faculty of management and organisation

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The origins of the faculty of Management and Organisation ly in the faculties of economics, social sciences and law. As a consequence, a large part of the statistics education was given by educators with an econometric background. This background frequently leads to education that could be characterized with the word 'mechanistic' (Lange (19..), a loose description of mechanistic is: definition-theorem-proof-a lot of exercises).

When students start their studies at the faculty they usually have a limited mathematical/statistical background. Frequently this background can be characterized with the word 'realistic' (Lange (19..), a loose description of realistic is: learning mathematics/statistics through, with and from problems derived from reality).

During 1993/1994 the curriculum with respect to statistics, mathematics and methodology has been changed for first year students. These changes tend to 'realistic'. In the paper presentation a description of this change with respect to statistics is given. The change process will be described on the following topics: 1) a culture shock for the econometric educators; 2) the achieved results (for students and educators); 3) a comparison of old and new exams; 4) the results of the new and the old program compared in a research methods course at the end of the first year. The method to describe the change process could be characterized as a multi-method approach.

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An Approach to the Teaching of Statistics to

Business and Commerce Students.

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A course of statistics taught to accounting and commerce students is in general an adaptation of a pure statistics course. This type of course is usually taught by statisticians as a penance. Thus the approach is one of tradition and "it's a job that must be done". But does the traditional approach fulfil the requirements of these students?

It is perhaps the order of presentation that is at fault. Most "Statistics for Business" texts, for example Hoel and Jessen's text - Basic Statistics for Business and Economics (Second Edition) - seem to follow the order of presentation of the parallel mathematical statistics text. Thus the tradition of trying convert commercially orientated students into statisticians continues.

What is needed is a course that is designed to fulfil the needs of these students, a course that emphasizes the practical aspects and the understanding of statistics. Such a course would not let them flounder in the morass of tradition. They must be given an intuitive and applicative base rather than the traditional mathematical statistical grounding.

This course should follow an approach that teaches the practical aspects of statistics. An understanding of concepts and terms must be reached before the more mathematical work is introduced. This means that these courses should have a different order of presentation. Firstly the students should be taught descriptive statistics, and this should include the traditional topics as well as correlation, regression, index numbers and time series. Secondly this should be followed by the traditional topics of probability, random variables, probability distributions - both discrete and continuous, sampling and inference. Finally now the student can return to some of the original topics and fill in the spaces - for example estimation in regression.

This paper provides details of such a course and discusses its implementation.

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STATISTICS IN BUSINESS SCHOOLS: A CONTENT ANALYSIS

In order to differentiate the orientation of statistics courses in business schools from those offered at mathematics and statistics departments, most introductory textbooks in statistics emphasize a conceptual rather than a mathematical content. This is usually done by supplying a number of examples and providing discussion of the use of some popular computer packages. However, except for the elimination of derivation of formulae, the content and the organizational structure of most textbooks offered to business students are similar to those used by other students. In addition, the instructional method used in business/management schools are quite traditional with no significant departure from those used in department of mathematics and statistics. As a result, students of business/management schools usually do not relate the course content to their future practice and develop a distaste for statistics. Based on the result of a survey, a course description which emphasizes statistical thinking, avoids mathematical explanations and stresses the use of statistics in business is developed. Instructional methods and strategies for effective teaching will also be discussed.

TEACHING EXECUTIVES STATISTICS : A Comparison With Traditional Undergraduate and Graduate Students

by
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For six years, the author was the Director of Concordia University's Executive MBA Program. This program is designed to allow working executives with at least 5 years of managerial experience) the opportunity to earn an MBA degree in two years by attending classes all day on alternate Fridays and Saturdays.

Techniques that are effective for teaching statistics to one category of students are not always effective for the other. As Director of this program, as well as a professor responsible for teaching statistics to these students, the author will dicuss the fundamental differences between teaching experienced executives statistics (average age is approx 38 years old) as compared to teaching younger less experienced students.

LE PROJET D'UNE NOUVELLE ECOLE DE STATISTIQUE : L'ENSAI

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L'office national de la Statistique français, l'INSEE, crée une nouvelle Ecole pour répondre aux besoins actuels de l'économie nationale et internationale.

Au cours des dernières années, il est apparu nettement que le marché de l'emploi réclamait des personnes se situant à l'interface de l'organisation des sources d'informations complexes et de leur traitement statistique. De là naquit l'idée de créer l'Ecole Nationale de la Statistique et de l'Analyse de l'Information qui donnera une double compétence statistique et informatique (au sens de la gestion de données).

Ces bases étant jetées, une vaste réflexion s'est engagée sur le programme de cours obligatoires, le programme de cours à options, l'adaptation aux débouchés pressentis, les poids respectifs de la Statistique, de l'Informatique, la politique d'ouverture sur le monde professionnel, l'insertion dans le système d'enseignement supérieur français et les publics visés, la communication externe pour présenter l'Ecole.

Au cours de l'exposé les caractéristiques retenues pour l'ENSAI seront présentées.

TEACHING BUSINESS STATISTICS IN THE COUNTRIES IN TRANSITION

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In socialistic countries the business statistics was practically neglected. When their political system collapsed and market economy accepted, the business statistics was expected to be taught at the academic level and more widly used in practice. Its implementation , in most cases, has been carried out slowly and often inadequately. The teaching has usually been the slight modification of traditional economic statistics. The present situation is largerly due to the shortage of competent teachers and, so, this statistics does not have a wider application in practice. Where it is used, it is mainly by nonstatisticians.

In the developed countries, over the past few decades, the teaching of business statistics has been very much improved and some new methods and technology introduced. The reexamination of this teaching is a constant process in order to adjust it to students and practice. This was discussed about more broadly at the second and the third conferences of ICOTS in 1986 and 1990.

In order to overcome the lagging of teaching business statistics in the countries in transition, it is necessary to make a thoughtful and organized effort in which the experience and contribution of the developed countries would be of great help to bridge the gap. As the former socialistic countries are unequally developed , the period in which the gap , if any, is to be overcome, depends on the level of development.

There are two aspects to be considered in this matter. Firstly, the implementation and improvement of business statistics through teaching which, understandably enough, requires competent teachers. Since the majority of the countries in transition has not yet created the conditions to form academic statisticians of this profile, it would be useful to offer scholarships for the specialisation, post-graduate and doctoral studies in the developed countries. Secondly, nonstatisticians in business should be adequately trained in statistics. It is of concern to managers and all other people who have to use it in business.

In this context, a problem is raised relative to the text books on business statistics. Surely enough, in time adequate text books will be published, but before they appear it would be reasonable and didactic to translate some modern text book from one of the world's languages into the national language. Besides, adequate equipment should be applied in teaching, as video devices and PC-s. Some existing package programmes ought to be used as PACE or STATLEV (1), or develop some specific ones for this purpose.

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Probability: who needs it?

by

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Abstract

In most statistics teaching, some probability theory is regarded as essential. In most elementary statistics texts (for third level students), elementary probability is introduced early, typically using motivating examples which have little or nothing to do with statistics. Later, the ideas involved are used in an attempt to elucidate problems of statistical inference. Frequently in practice, however, the probability ideas have not been well understood and so the attempt referred to is doomed to failure.

In this paper, it is argued that ideas of statistical inference are best introduced via data and the need to make sense of statistical variation. In particular, the key idea of repeated sampling, central to sampling distributions, can be introduced realistically through process control data. Probability, as the mathematical model for statistical variation, can be introduced in this context and the basic ideas of elementary probability elucidated through statistical examples. Illustrative examples are presented. This approach reinforces the importance of statistical thinking and avoids the unnecessary domination of statistics teaching by mathematical thinking.

ENGAGING DEEPER LEVEL LEARNING SKILLS IN STATISTICS

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An objective of tertiary education is to enable and to encourage the student to master course content by an integration of the material into the life experience and relevant activities of the student.

For services courses in Statistics, this objective is a considerable challenge. There is likely to be little intrinsic motivation for the student. At best achievement motivation will operate for a subset of students, but in the main where students take the course as a prerequisite to another specialization, it is our experience that only extrinsic factors motivate student participation and learning.

It is suggested that the levels of motivation described are associated with choices for generally deep, strategic and surface approaches to learning, and hence study in the corresponding courses.

An intervention to engage students in an explicit self-examination of their own learning styles in order to facilitate changed learning behaviour is described. The intervention comprises the use of a booklet entitled Learning Statistics which seeks to introduce students to a view of the relationship between intrinsic motivation and deeper learning, and to the issue of taking control of their own implicit learning behaviours.

In the context of enabling easier access to University experience without compromising exit standards, these issues are highly relevant in the South African milieu. Many African students have been exposed to qualitatively inferior schooling environments and oppurtunities, whose effects Universities must address.

ABSTRACT: J I DE WET

NON ALGEBRAïC STATISTICAL COMMUNICATION

A statistician often needs to communicate with people with a lack of statistical knowledge and/or with little or no mathematical training.

This people may be students of service courses in statistics which is usually students of disciplines such as sociology, psychology and even medical students. On the other hand the people may be researchers or clients from industry seeking statistical advice from the statistician.

Statisticians to my experience tend to communicate in a statistical way, that is use terminology known to him but unknown to the client and thus creating a problem of proper communication. Mutual understanding is important for effective communication.

The attitude of the community towards the science of statistics often is determined by people (non statisticians) who had previous experience in communicating with statisticians in such a way that they had been scared away.

It is the purpose of this talk to highlight a few general elementary topics/terms in statistics with respect to the non–algebraïc presentation thereof in order to improve the communication between the statistician and his clients.

A GENERAL PROPOSAL FOR TEACHING UNDERGRADUATE STATISTICS SERVICE COURSES.

OJEDA M. M.*
SAHAI H.**

ABSTRACT

In teaching statistics for students majoring in a field other than statistics the practical value of concepts and procedures is very important. If statistical methods are presented as merely arithmetical procedures involving manipulative skills, using a cookbook approach, then students do not perceive the role of statistics in real world contexts. If we expect that an undergraduate statistics service course should prepare students to be able to make adequate applications of statistical methods, in their future professional activities, then it is necessary to consider the training based on: (1) identification of statistical problems in the context of the discipline; (2) formulation of statistical objetives (description, estimation, testing hypotheses or modeling of causal relations); and (3) problem solving using a project-based approach. In this paper, we present general guidelines for designing statistics service courses for different disciplines. We outline general objetives, pedagogical approach, organization of classroom activities, and implementation of projects in the context of the course. Our proposal is fairly general, but it is possible to consider time constraint, area of application, other sequel courses, and the institutional restrictions in the design of the course. An example of a biostatistics course is discussed for introducing personal views about problems encountered in designing courses using this approach.

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Students Perceptions of the Use of Statistics in the Real World

by

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In this paper, we investigate the different student perceptions of statistics as it applies to the real world. A survey instrument is developed, samples of students are identified and requested to complete a questionnaire. The questionnaire is aiming at understanding the different factors affecting the perceptions of applied statistics. Several misconceptions of the field are revealed and strategies to correct them are proposed. Business students will especially be targeted because of the increasing importance of Statistics in a society where Total Quality Management is becoming the way of the future.

What does the Arithmetic Mean mean?

(Teaching Central Values by Loss Functions)

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Almost every one knows how to calculate the Arithmetic Mean, but the meaning of this Mean is not obvious. In every-day life we use statistical concepts in an intuitive way and this creates a misconception of the formal statistical meaning. This gap between intuition and formal concepts complicates the teaching of basic statistics to students, particularly non-statisticians. Therefore a special strategy for teaching these concepts is required.

During my experience in teaching Statistics to non-statisticians from different backgrounds (students of sociology, social work, political Sciences, medical sciences and others), I have developed methods for combining the intuitive conceptualization with the formal concept. The paper offers an example of teaching the subject of **Central Values** by **Loss Function approach**, providing an answer to the problem induced by the gap between intuition and formal conceptualization. Using examples from the "real world", with graphical representation, makes it easier for students to understand the required substance.

AN ALTERNATIVE INTRODUCTION TO THE POISSON DISTRIBUTION

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ABSTRACT

In the typical first level statistics course, the Poisson distribution is commonly introduced as a limiting form of the binomial distribution. The students are helped to consider the effect of allowing n, the number of trials, to become very large at the same time as p, the probability of a 'success' in a single trial, becomes very small in such a way that their product remains constant. This conventional approach presupposes that the students can readily visualise a real world situation in which the binomial model is appropriate, and requires them to imagine what it might mean to allow $n\to\infty$ and $p\to 0$ while $np=\lambda$. For what real world situations is this an appropriate model? This is often difficult for the average student to see until after the derivation of the Poisson distribution, when the instructor can, with considerable ease, refer to several such situations appropriate for the Poisson model (e.g. radio-active decay, mass production process, accident statistics, and so on). A radically different starting point is afforded by modelling techniques based on probabilistic ideas that have been used to generate, by a process of continued sub-division, large numbers of polygons. One particular technique which has aroused interest recently is intended to simulate biological growth by starting from simple rules for random cell division (Cowan, 1989; Cowan and Morris, 1988; Mecke, 1989). This approach has the distinct advantage that it presents students with few conceptual difficulties regarding the understanding of the real world situation and an appropriate model. This paper describes how such a biological modelling technique, originally applied to random cell division in a plane, may be adapted and used as an alternative and effective way of introducing the Poisson distribution in first level courses.

L'ENSEIGNEMENT DES FAMILLES DE DISTRIBUTIONS DISCRÈTES DE PEARSON À TRAVERS UNE MÉTHODOLOGIE CONSTRUCTIVE. APPLICATION À UN CAS PARTICULIER.

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Nous présentons une méthode qui permet aux élèves de connaître les distributions, non seulement d'une facon isolée sinon comme quelque chose qui appartient à des familles déterminés générées par une méthode constructive -comme la famille de Pearson, oú sont inclués les distributions discrètes les plus habituelles - et l'étude de ses propriétés dû à cette appartenance. Pour sa illustration, nous proposons une expression exponentielle des coefficients de l'équation en différences au lieu de l'usuelle polynômique, ainsi que la construction et l'étude des propriétés de la distribution résultante. C'est pour cela qu'un élève de Calcul des Probabilités peut s'introduir dans le champ d'étude des familles de probabilité d'une façon constructive et cela lui permet de comprendre l'importance des familles de distributions.

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Making Statistical Tables More Meaningful to Students of Applied Statistics

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Students with little probability background find the standard statistical tables (normal, t, χ^2 and F variables) a source of puzzlement. They wonder where the entries come from and what they mean. My experience has been that such students can best comprehend entries of the standard normal tables if they think of them as positive and negative errors with a mean of zero and, preferably, a standard deviation of one. Normal tables entries fit such a description. Entries of the t(n) tables can also be thought of as errors with a mean of zero for n>1 and a variance of n/(n-2) for n>2. To preserve a unit standard deviation, we should tabulate $\sqrt{1-(2/n)}$ times the entries of the t(n) tables. Students can try out some values. At any rate, entries of both the standard normal and the t(n) variables are errors incurred in estimating 0 (meaning they have a mean of zero).

As for entries of the $\chi^2(n)$ tables with a mean of n and a variance of 2n, dividing each entry by n we get values which are possibly erroneous estimates of 1 (meaning they have a mean of one). For n=10, e.g., the two numbers (c,C)=(0.394, 1.831) give a 90% confidence interval for 1. Thus, $(0.394\ \sigma^2, 1.831\ \sigma^2)$ is a 90% confidence interval for σ^2. Subtracting 1 from both sides of the adjusted entries, we get the relative errors involved in estimating 1. For n=10, the relative errors are (-0.606, 0.831). Students can compare the entries of the χ^2 tables with those computed from entries of the normal tables for large n by the formula $n+z\sqrt{2n}$, where z is the standard normal .

Entries of the F(m,n) tables are almost already in the form of possibly erroneous estimates of 1, since EF(m,n)=n/(n-2) for n>2. Multiplying entries by (1-2/n) and subtracting one we get the relative errors. Taking the variance of the F(m,n) variable into consideration, students can compare entries of the F tables with those computed from entries of the normal tables for large m and n by the formula: $n[1+z\sqrt{2(m+n-2)/m(n-4)}]/(n-2)$. The checking is easier for $m = n-6$ which reduces the formula to : $n\ [\ 1+2z\ /\ \sqrt{n-6}\ ]\ /\ (n-4)$, n>6 .

Reference: any statistics textbook with tables .

The Role of Nonparametric Methods in Teaching Statistics

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Introduction

Traditionally, teaching statistics has been based on concepts that need the central limit theorem to be justifiable. Examples are the well-known t-test and the standard deviation. Even the arithmetic average, when applied to non-Gaussian data (which is rather the rule than the exception) is difficult to be interpreted, unless the data is measured in monetary units. The central limit theorem, however, is difficult to be understood by students with a limited background of mathematics and its application requires the use of tables, because the integral of the Gaussian density has no closed form solution.

Methods

With the advent of more powerful computers and a more general methodology, statistics based on ranks have become more attractive. Thus box-and-whiskers plots are competing against mean plus/minus standard deviation, the sign- and U-test against the (paired and unpaired) t-test, and so on. One of the advantages of this approach is that (at least for small samples) the distribution of the test statistics (e.g. the binomial distribution) can be computed without the need of mathematical theory and applied without the need of obscure tables.

Results

In this new strategy of teaching, all the basic concepts of statistics (confidence limits, tests, errors of first and second kind, level and power etc.) can be taught using examples where nonparametric statistical methods are applied. In all these examples, the mathematics is restricted to elementary arithmetic operations (sum, difference, multiplication, division), so that nothing is hidden from the student as 'to be believed, because it is too difficult to be understood'. The Gaussian distribution, although still important, is identified to be not a characteristic of the data, but a large sample approximation based on the central limit theorem, which, when introduced at this stage of teaching, can at least be motivated by comparison with the binomial distribution.

Applications

Once the statistical concepts have been introduced without implicitly making assumptions on the distribution of the data, the role of such assumptions becomes more obvious to the student. Thus the student will be prepared for the increasingly frequent criticism of methods based on the linear model in modern scientific journals. He will be able to argue more reasonable about the choice of methods, e.g. the t-tests, because he does not have the impression, that it is necessarily 'normal' for data to have a Gaussian distribution.

Experiences

The strategy has successfully been applied in teaching medical students at Tübingen and in a series of courses for post-grade students and lecturers in Egypt, where it has also been implemented in courses for teaching statistics at the undergraduate level.

Conclusions

Although statistics is in fact based on mathematics, one of the most fundamental principles of mathematics, namely that the student should be able to deduce every result, has been violated, because the central limit theorem seemed to be at the same time too important to be postponed and too difficult to be proven. The new strategy of teaching statistics, however, is based on deductive reasoning, which has turned out to be an invaluable experiences, especially where learning is traditionally bases on memorising rather than reasoning.

Five Figures Descriptive Summary Measures

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abstract

Given a set of data, it would be wised to apply an Exploratory Data Analysis (EDA) first in order to extract a valuable information available in the data. Features such as the location of the body of the data, the shape of its distribution, should get them clear first at the beginning before a further analysis of the data. A five figures summary measures which usually sufficient to describe the above features of the data will be highlighted. Some very handy techniques of obtaining such figures will also be given in this paper.

ALGORITHMS IN STATISTICAL MODELLING. THREE STATE TRUNCATED ABSORVENT MARKOVIAN PROCESS.

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- ABSTRACT

The paper considers the stochastic nature of real world and underlines the importance of teaching statistical modelling.

The lack of realism of simple deteministic models versus the complexity of more realistic stochastic models is discussed. The importance of efficient algorithms to deal with moderate complexity models is considered.

The case of three state truncated absorvent Markovian process is analysed and a stochastic model is established to describe the relevant statistical proprieties of such process. An efficient algorithm is developed to solve the model and some results are derived.Confrontation of results versus simulated figures is donne in view to test the fitness of the model.

- KEY WORDS: Stochastic; model; algorithm.

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Developing a new programme of Econometrics for future statis ticians at Rosario's National University, Argentina. Explora tory Data Analysis.

Author: Liliana Severino.

This paper was made in collaboration with two collegues and I'm specifically de veloping the part of exploratory data analysis.

It was giving in Econometrics an optional subject of the last year of the career of Statistics.

I will show here our experience in introducing new statistical methods in teaching statistics to future statisticians, in particular Exploratory Data Analysis using several software packages. It was shown as a previous step of modelling or as a explicative tool as it is used in the case of studying the electric energy consumers.

STUDENT'S UNDERSTANDING OF THE LOGIC OF HYPOTHESIS TESTING

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Significance testing is one of the most controversial subjets in research (Morrison and Henkel, 1970) and also one of the most misunderstood topics in the learning of statistics (Falk, 1986; in press). In this paper we present the results of a theoretical and experimental study concerning the understanding of university students about the logic of statistical testing. The theoretical study discuss epistemological issues concerning Fisher's and Neyman-Pearson's approach to hypothesis testing and their relationship to the problem of induction in experimental sciences.

The experimental sample was constituted of 436 student in 7 different university major. Some of these student had a theoretical-oriented course in statistics as, for example, mathematics students and the others had â practical-oriented course in statistics as, for example, psychology. The item presented in this paper is part of a larger questionnaire, including 20 items and refers to the kind of proof provided by the result of a test of hypothesis. As a consequence of the analysis of the arguments of these students we identify three main conceptions: a) the test of hypothesis as a decision rule which provides a criteria to accept one of the hypotheses; b) the test of hypothesis as a mathematical proof of the truth of one of the hypothesis and c) the test of hypothesis as a inductive procedure which allows us to compute the "a posteriori" probability of the null hypothesis.

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TITLE: Assessing Understanding of Probabilistic Concepts

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ABSTRACT

Educators and other professionals see the potential that graphics, modeling, and multimedia software offer students to reach their potential in understanding abstract statistical concepts. Programs that integrate design activities into the curriculum find they encourage achieving clearly identified, high-priority educational objectives-including interdisciplinary study; student collaboration; hands-on applied learning; and multiple forms of assessment. Recognizing that designing is a natural and necessary part of study in many different fields, colleges and university are providing students in business, archaeology, and law, as well as engineering and architecture, with access to graphics software tools.

Educators are discovering that designing solutions to problems using today's computer modeling software provides students with precisely the learning experiences advocated by the latest pedagogical research. By engaging students in project work, they're practicing problem-solving, they're sharpening their critical thinking skills, and they're learning to work collaboratively. Statistical graphics software has the potential to really enrich the curriculum.

The focus of this paper will examine the ways students come to represent their understanding of probabilistic concepts with the use of visualization tools. Students in doctoral programs in statistical methods were asked several assessment items on probabilistic concepts in multiple forms, i.e, objective and alternative forms by using authentic situations and concept maps. Results from the process component of the project reveals the manner in which the students used the graphic tools which encouraged exploration of many possible solutions to a problem. The visualization of key concepts and their relationship mapping produced a graphic form that allowed other students to evaluate alternate representations to the same topic. Using the computer ability to capture that process has made this all much easier to do. The students were using technology to explore issues relating to probabilistic areas and decisions regarding hypothesis testing situations.

Abstract

Factors Influencing Student Performance In Introductory Statistics at the University Level

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The introductory statistics course taught as a service course by the Mathematics Department at most universities is unarguably one of the most, if not the most, feared courses taught on campus.

Students come to this course from a great variety of area disciplines and these students have extremely varied mathematics backgrounds. Only a very few of the students are mathematics majors. At Southern Utah University a large block of students (about 50%) come from the College of Business, but many social science majors, life and physical science majors and even some elementary education majors enroll in the course. The great diversity in the students' mathematics backgrounds also makes it a difficult course to teach: at SUU about 10% have had only up through Intermediate Algebra (the prerequisite), while twice as many have had at least some Calculus. The largest group (about 50%) list College Algebra as their most advanced background course.

Cutting across these diverse groups is a common problem: the need to repeat the course. Over the several years about 25% of the students enrolling in Intro. to Statistics have found it necessary to repeat the course because of poor performance or dropping out before completing the course.

This paper presents the findings of a study directed at determining the factors that influence student performance in statistics at the university level: major, sex, math background, learning style, etc. The study has been carried out over a period of two years and involves about 150 university students.

INTUITIVE PROBABILITY CONCEPTS IN SOUTH AFRICAN ADOLESCENTS

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ABSTRACT

Probability has not been a formal part of any South African curriculum until relatively recently. In 1992 a syllabus was introduced which required that probability be taught to children in Grade 9 (14-15 years of age). Research in progress uses a test adapted from Green (1982) in the UK to investigate the understanding of probability and chance concepts among Grade 9 children in the Witwatersrand and Transkei areas of South Africa. In order to ascertain differences that may exist between rural, township and urban school children in their naive understanding of the concepts involved, schools from such areas were included in the sample even though some of them had not adopted the new syllabus. The test has been administered to 14 volunteer schools in the Witwatersrand area and 5 in the Umtata region of Transkei. Analysis of data from the sample of approximately 1200 children indicates that their level of understanding is not markedly different from that of children from the same age group in the UK. The performance of children who re-wrote the test after tuition showed no significant improvement, although the reasons provided in open-ended questions were generally more meaningful. This paper provides details of the performance of the children in the sample and discusses the understanding and misconceptions revealed in the light of the children's experiences.

Statistical Inference Laboratory

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Summary

Many students find it hard to understand the role of chance in inferential statistics. A few examples:
- they mix up population parameters and their estimators,
- they derive 'estimators' which depend on the unknown parameter,
- they don't understand the stochastic character of a statistic.

In order to improve their comprehension of inferential statistics a computer program 'Sila' (Statistical Inference Laboratory) was created. The program simulates the process of estimation, testing hypotheses and constructing confidence intervals. The student has to specify the following characteristics:
- the number of independent populations, their type of probability distribution and for each parameter either its value or the qualification 'unknown',
- the kind of inference (estimation, testing hypotheses or confidence intervals),
- the parameter(function) of interest,
- (the size of) the samples corresponding to each population,
- the statistic.

The student either enters a complete sample or a random sample is drawn.

Subsequently the (interval) estimates are displayed. In the case of a testing problem the p-value, the test statistic's distribution and the power function is shown for arbitrary values of the parameters.

In fact there are two modes of operation: either the user supplies a problem or the problem is predefined and chosen from a file. In the first case the user is free to choose all its characteristics whereas in the second case each choice has to be in accordance with the predefined characteristics.

The program will be shown and the experience with its use by students will be reported.

Students' Learning on The Stem-and-leaf Display

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The purpose of this study was to understand whether the stem-and-leaf display is easy to be read by students, whether the students can make a stem-and-leaf display after they have been taught the procedure, and whether they can answer related statistical questions. Moreover, I wanted to know how clear, how interesting, how difficult, and how appropriate the content of the stem-and-leaf display is.

Two tests and a questionnaire were taken as techniques for collecting data. The students of Grade 14 were the subjects of the study. The important findings of the tests are as follows:

(1) Students had no difficulties in reading and making the stem-and-leaf display.
(2) About a quarter of the students had troubles in finding the median by only counting.
(3) A few students made mistakes in calculating the arithmetic mean by using a calculator.
(4) Students had a good performance in making a frequency distribution table to represent a stem-and-leaf display.

There were other findings from the questionnaires about the reactions of the Grade 14 students on the stem-and-leaf display:

(1) The degree of students' memorization on the stem-and-leaf display was average. Although the difference of the negative, moderate, and positive levels was not significant if #\ = 0.05, the difference of the five levels (very unclear, unclear, average, clear, and very clear) was significant if #\ = 0.01.
(2) Most students' learning interest on the stem-and-leaf display was average but inclined to be poor. Moreover, the difference of the three levels (less interesting, average, and more interesting) or the five levels (very uninteresting, uninteresting, average, interesting, and very interesting) was significant if #\ = 0.005.
(3) Most students thought that learning the stem-and-leaf display was easy. The difference of the three levels (more difficult, moderate, and easier) or five levels (very difficult, difficult, moderate, easy, and very easy) was significant if #\ = 0.001.
(4) Most students thought that the stem-and-leaf display was inappropriate for them to learn. The difference of the three levels (negative, neutral, and positive levels) or five levels (very negative, negative, neutral, positive, and very positive levels) was significant if #\ = 0.05.

ANALYSIS ON PSEUDOENSEMBLES: A NEW PHILOSOPHY AND METHODOLOGY OF INDUCTIVE STATISTICS

Vladimir L. Koliadin

Several new approaches to statistical data analysis have been developed during last decade: bootstrap, data-based simulation, data-corruption methods. Despite the successful application of the new methods to real problems, their status within the traditional statistical theory remains unclear. These approaches, having been normally analyzed within the conceptual frame of the classical statistics, are usually considered as some auxiliary methods.

The central idea of the paper is that these non-traditional methods are the first forerunners of a new philosophy and methodology of inductive inference. The paper is an attempt to specify the basic ideas and underlying logical principles of this new statistical philosophy, which is called here the Analysis on Pseudoensembles (AP), and to compare it with that of the classical statistics.

A general view at the nature of statistical inference is proposed. According to this view, all the practical problems of statistical analysis may be divided into two categories. Firstly, the problems where the concept of statistical ensemble has clear prototype in reality. Secondly, the problems where the ensemble has no such a prototype: the ensemble here is rather a product of our imagination which we need to make the classical statistical theory applicable. The AP is a statistical philosophy and methodology for dealing with the second class of the problems.

The spectrum of practical problems, where AP-approach is much more relevant than that of classical statistics, is wide. The observed adherence to the classical style of statistical thinking is rather a consequence of some inertia of mind, maintained by statistical education and traditions, than a result of sober analysis of the nature of real problems.

From an utilitarian viewpoint, both AP-philosophy and AP-methodology are much more simple to initial understanding and teaching. Another obvious advantage, which is significant in practical work, is flexibility in the choice of test statistics: it is not necessary to make wearisome analytical work to calculate the distribution of the test statistic, or to make the statistic distribution-free.

Several examples of problems and relevant AP-methods for their solutions are provided to illustrate basic ideas of the AP-approach.

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A propos des règles normatives pour les jugements en probabilité

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Résumé

Dans cette communication, nous étudierons les fondements des règles normatives qui sont utilisées comme base pour évaluer le raisonnement humain dans des situations probabilistes. Nous montrerons que ces règles sont basées sur des connaissances qu'on ne peut espérer atteindre par des expérimentations concrètes de situations aléatoires ou par le développement intellectuel normal ou encore par une formation sur la théorie des probabilités. On verra qu'il est essentiellement impossible de prouver que les règles normatives, de ce domaine, ont un fondement dans la réalité pas plus qu'il n'est possible de prouver que les misconceptions sont, en fait, des misconceptions. Le mieux que l'on puisse faire, en regard des règles normatives, c'est de montrer qu'elles sont consistantes avec les données provenant d'expérimentations systématiques ou qu'elles sont des généralisations de résultats dont le propre fondement est expérimental.

Une telle vision peut mener à comprendre la difficulté que les humains ont à se débarrasser de leurs conceptions erronées, qu'ils soient assistés ou non. Elle peut aussi modifier profondément les interprétations que l'on donne aux résultats d'investigation dans ce domaine, la définition des investigations et la façon de traiter au plan didactique, le problème des conceptions erronées.

Concernant ce dernier point, le fait que la théorie mathématique des probabilités ne soit d'aucune utilité pour résoudre le problème des misconceptions et que les perspectives offertes par l'expérimentation concrète ne soient guère meilleures nous a mené à considérer une approche didactique basée sur la simulation. En dépit du problème épistémologique que pose la relation entre la réalité des processus aléatoires et leur modélisation sur ordinateur, nous croyons qu'il est possible de construire des environnements de simulation qui puissent favoriser la déstabilisation des modèles mentaux en probabilité et aider dans la construction de modèles plus adéquats pour raisonner dans ce domaine. Nous présenterons un tel environnement lors de notre communication.

THE ART OF COUNTING –
Materials for Teaching and Learning Combinatorics

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Combinatorics is a subject that is taught in senior secondary school and also in university courses in statistics and probability. A thorough knowledge of combinatorics is essential for future statisticians, and a basic understanding is desirable for anyone who uses statistical methods. Yet it is a subject that students find hard to grasp and that teachers often have difficulty presenting.

The important ideas in introductory combinatorics are the basic counting principle, permutations and combinations. Everyone who teaches the subject realises that students often have trouble with the subtleties of these basic concepts and the language in which they are couched.

One of the problems in teaching combinatorics is to select simple, interesting and clear examples. These should point out the distinction between selection with and without replacement and between ordered and unordered selection. Linguistic or cultural interpretations can often cause a problem to be ambiguous. Our favourite example is the question: 'In how many ways can eight gifts be shared between four people?' This question has at least 12 different answers depending on how it is interpreted!

We have analysed the problems involved in teaching and learning introductory combinatorics and with a team of people used our findings to prepare teaching materials: video, print and computer-based. Video can be used to present the basic ideas in a realistic, applied setting. It can be backed up by the more traditional print materials, illustrated by a chapter from a textbook we are writing. Finally, a computer disk can combine the written and visual approach with an interactive style of working.

We will describe our approach to teaching combinatorics, present illustrations from our teaching materials and discuss the reactions of users, both teachers and learners.

APPROCHE EPISTEMOLOGIQUE DE LA COMPLEXITE DES GRAPHIQUES STATISTIQUES

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Les graphiques statistiques – comme tout moyen de transmission de connaissances – nécessitent un apprentissage, ce qui est fait depuis longtemps en géographie et depuis une dizaine d'années en mathématiques au collège en France.

Dès que les graphiques commencèrent à devenir courants dans les publications scientifiques, la question se posa d'en faire une utilisation judicieuse. En particulier, l'Association Internationale de Statistique s'en préoccupa dès son 3ème congrès en 1857.

La complexité d'un graphique peut être comprise dans le sens de difficulté de lecture et d'interprétation, mais aussi dans le sens de degré de mémorisation du phénomène permis par la représentation graphique. Des études portant par exemple sur l'efficacité comparée des diagrammes circulaires et à bandes ont été effectuées depuis le début du siècle ([1], [2], cf. aussi [3] p. 393), et sont toujours en cours (Jelinski A., [4], pp. 39–56).

Un graphique étant la codification d'un phénomène, sa complexité – réelle ou perçue – dépend du contexte culturel dans lequel il est conçu et de celui dans lequel il est lu. Comme pour d'autres notions de mathématiques, on peut alors aborder cette notion de complexité par une approche historique basée sur l'hypothèse que les représentations graphiques les plus faciles à comprendre et à interpréter sont celles qui ont émergé en premier.

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Proposition d'une communication libre pour ICOTS IV
Résumé de la communication

Notre intervention a pour objectif de dégager un ensemble de questions sur l'apport éventuel de l'activité d'interprétation des représentations graphiques, pour l'apprentissage du raisonnement statistique.

Un survol d'un ensemble de travaux antérieurs sera fait dans le but de mettre en évidence l'importance du problème posé, de situer nos intérêts et menera à la définition des mots clés que nous utilisons:

- représentation graphique/ Modélisation
- représentation graphique statistique
- raisonnement /raisonnement statistique
- lecture vs interprétation d'une représentation graphique

Nous étudierons ensuite, certaines relations possibles entre les différentes activités et processus définies, notamment la relation entre l'interprétation et le raisonnement. Les relations entre la représentation graphique et le raisonnement et entre la représentation graphique et l'interprétation seront aussi abordées.

Nous nous intéressons aussi aux questions sur les éléments graphiques qui bloquent l'interprétation des représentations graphiques et s'opposent au raisonnement statistique.

Nous traitons enfin, quelques exemples de représentations graphiques:

- l'histogramme
- le nuage de point
- les profiles, les étoiles et les faces de Chernoff

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Application de la statistique et de l'analyse des données dans le domaine de la santé

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Résumé :

Sur la base de trois enquêtes réalisées dans le Maroc oriental à propos du diabète, de l'hypertension et de l'utilisation de la phytothérapie comme traitement, on montre l'intérêt de la statistique et de l'analyse des données comme moyens de description, d'analyse et d'aide à la prise des décisions.

On discute aussi l'intérêt pédagogique que représente le traitement statistique des données médicales dans l'assimilation des concepts théoriques.

Sujet: 4.Enseignement de la Statistique par la pratique et des projets.

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Sur la distribution du minimum d´une série aléatoire, du point de vue pratique.

Resumé: Le nombre suffisamment grand d´applications pratiques de la théorie des valeurs extrêmes dans le domaine de la génie justifie ce travail. En particulier la distribution du minimum est souvent utilisée dans l´hydraulique dans l´étude des niveaux minimums des réservoires, dans la génie civile dans les problèmes de résistance des matériaux, dans la théorie de la fiabilité, etc.
Celle-ci constitue aujourd´hui un domaine d´applications important de méthodes probabilistes que intéressent à nombreux ingénieurs, raison par laquelle on a choisi d´introduire ici la notion de la distribution du minimum de n v. a. indépendantes en liaison avec la fiabilité d´un système.

En suite on va étudier le comportement asymptotique du minimum par une méthode pratique, en utilisant la simulation et des méthodes graphiques. On simule alors des échantillons aléatoires de tailles différentes à partir d´une population initiale. On a choisi dans ce travail la distribution Normal. On obtient les valeurs du minimum de chaque échantillon; on répéte ça un nombre k de fois suffisamment grand et on passe à analiser la distribution des k valeurs des minimums ainsi obtenus.

On a alors construit les histogrammes des minimums des échantillons simulées pour les différentes tailles choisies. D´après l´analyse des histogrammes on peut noter que quand la taille de l´échantillon augmente la distribution du minimum est clairement assymétrique négative. On a tracé encore des graphiques de probabilités en utilisant la distribution Normal et on peut vérifier que, pour n grand, l´alignement n´est pas net œ que nous permet de conclure que le modèle Normal n´est pas convenable.

Par contre, si on utilise dans le graphique de probabilité la distribution de Gumbel des minimums on remarque que l´alignement est plus net.

On arrive alors, par une méthode pratique, à s´approcher de la vraie distribution asymptotique du minimum, car on sait que, dans le cas de la population initiale être Normal, la distribution limite du minimum est la loi de Gumbel.

Ce travail c´est seulement un example des plusieurs qu´on peut utiliser pour permettre aux étudiants-ingénieurs de s´initier et d´effectuer des traitements simples de modèles s´appliquant aux cas de problèmes courants. Aprés ça c´est plus facile de compléter l´étude avec les développements théoriques nécessaires.

Use of Study Strategies in Statistical Methods Classes

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Stephen Olejnik
Brady Allen
University of Georgia

Students who enroll in introductory statistical methods classes at a university are generally upper division or graduate students. These students have generally been very successful in their disciplines but they often find it difficult to learn statistical methods. Students frequently complain that they have studied long hours but are not achieving the level of success that they feel they deserve. In frustration they ask their instructor what am I doing wrong?

Often, after listening to the students, instructors find it difficult to offer specific solutions. Increased study time is often not the solution. Students may be spending a great deal of time already and perhaps, because of other responsibilities and commitments, there simply is no more time to give. The solution may be the use of more effective and efficient study strategies.

The purpose of the present study was to investigate the use of study strategies and their relationships with classroom performance, attitude toward statistics, and test anxiety. To conduct this study a multi-method approach was taken. Quantative measures were obtained on the first day of class. Students in a first course in statistical methods were asked to complete a test anxiety inventory, an attitude toward statistics questionnaire, and a study strategy inventory. Additional quantitative measures were obtained throughout the ten week quarter. In addition to the actual achievement scores on each of the three in-class exams, students were asked to predict how well they thought they would do before looking at the test items and again after they answered the test questions. Finally, as students completed each item on the test, they were asked to indicate their level of confidence in answering each item correctly. Thus quatitative measures of actual performance and measures of preparedness are available for each student throughout the quarter.

Two types of qualitative data were also collected throughout the quarter. Before each exam, students were asked to write a description of the strategies they used to learn the course material. Thus a written record of student approaches to studying statistical methods is available. A second qualitative data source was obtained through telephone interviews recorded by a graduate research assistant with the students following the second exam.

Instructors of statistical methods should be concerned not only with the course content but also in providing guidance to students in the most effective and efficient methods for learning this material. The results of this study will provide empirical data to support study strategy recommendations instructors of statistical methods may provide their students.

Attitudes Towards Statistics

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In our daily practice of teaching introductory statistics to undergraduate and graduate students we have repeatedly observed that simple intellectual differences among students often do not adequately account for differences in their mastery of the concepts. Factors related to attitude and anxiety seem to be highly related to diferences in students' understanding in many instances.

Students from two introductory statistics classes participated in the study. One class consisted of undergraduate students from a four year community college. The second class consisted of primarily graduate students enrolled in an educational statistics class at a major research university. Responses to the attitude surveys and the open-ended questions were labeled with an identification code that was selected by the participants and that was not known to either the research or the instructor while data was being collected. This allowed for anonymous responses by the students and allowed the research to match qualitative and quantitative responses for individual students.

The Survey of Attitudes Toward Statistics (SATS) was used as a quantitative measure of students' attitudes. The SATS is a 30 item Likert-type instrument that provides subscale values for Affect, Cognitive Competence, Value, and Difficulty. Thew SATS was administered on the first day of the course and again at the end of the course. Demographic data was also gathered for each student.

Students provided qualitative data by responding to open-ended questions at the beginning, end, and at selected times during the course. These questions related to the students' expectation for the course, what information had been used in forming these expectations, whether or not they believed their attitudes toward the course changed during their enrollment, and what if anything contributed to that change. In addition to producing rich textual information, the students; responses provided a validity check on the results obtained from the quantitative instrument. Three student volunteers were selected from a group of students who admitted to having statistics anxiety to serve as case studies. The self-reported statistics anxious students participated in interviews during the course and after its completion.

Results of the study revealed differences in attitude responses between students at the different institutions with students from the graduate class reporting a more positive attitude at the end of the course, while the undergraduate class reported a less positive attitude. In many instances students' written response to the question relating to attitude change were inconsistent with attitude change as assessed by the survey instrument. Similar results concerning the convergence and divergence of the two approaches form the basis of the paper.

Student Development of a Philosophy of Empirical Research

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When we teach research design, statistical methods, and data analysis techniques, we often find ourselves and our students mired in the details and particulars of design, methods, and/or techniques. As teachers, we fall into such a "trap" with ease. It is with ease because when we teach various aspects of design, methods, and techniques, we expect students to master such aspects, and we examine student mastery of these aspects. We often feel comfortable in teaching and examining students on such particulars; the comfort comes, in part, from supposed objectivity of such particulars. We teach an objective form of things because, perhaps, that is the way many textbook authors present them, and that is what many students expect in statistical methods class discussion and in course quizzes, tests, and examinations.

Objective as we may want to be in our teaching and testing, it is currently proposed that more emphasis be placed on the subjective nature of empirical research. This emphasis can be continued and repeated throughout one course and throughout a sequence of courses. An increased emphasis on subjectivity may very well lead a student to developing a personal point of view, a perspective, or an orientation to empirical research. Developing such in the (statistical) minds of students is indeed a challenge. Developing a point of view, perspective, or orientation might be attempted through some kind of statistics "instructional structure." The structure proposed herein is three dimensional:

(1) Look at your data,
(2) Consider nontraditional analyses, and
(3) Use intuition, common sense, reasonableness, and judgment.

Such a structure needs to be nurtured with nearly day-to-day regularity. This is not a perspective students have encountered in the past, nor is it one with which many are initially comfortable. Students typically relate statistical methods with numerical information which they see is near pure objectivity, cut-and-dried steps, and definitive answers. This attitude needs to be revamped. But just how might this revamping be accomplished? Abstracted discussions of some situations are now given that exemplify the above three dimensions.

Look at your data. When inspecting a data set, what does one look for? The conclusions one can draw from an inspection are varied and potentially quite informative. For example: missing data, score distribution form, and aberrant observations. In addition to simply eye-balling the raw data, other views of a data set may be taken through simple statistical descriptives (Max, C_{75}, C_{50}, C_{25}, Min) and tabular and graphical displays (e.g., stem-and-leaf plots and scattergrams).

Nontraditional analyses. A few examples are: focused analyses as opposed to omnibus analyses; comparing group proportions (above a cut-off, for example) as opposed to comparing group means; and data distribution comparisons as opposed to specific statistic comparisons. The research perspective advocated is that of a deeper study of the research question(s).

Intuition, etc. The fruitful use of intuition, common sense, reasonableness, and judgment comes with practice, experience, knowledge, and guidance.

The Use of Resampling Methods in Statistics Instruction

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ABSTRACT

In a multiple regression analysis the squared multiple correlation is tested for significance from zero. Researchers may believe that on a subsequent replication the squared multiple correlation would also be significantly different from zero and be "close" in magnitude to the one from the first sample. However information on how "close" replications are to the first sample is not available from the significance test on the null hypothesis but from the confidence interval on the population squared multiple correlation. These confidence intervals are not generally available. So do researchers (or students) have an intuitive notion of the sampling variability and hence an intuitive confidence interval for the squared multiple correlation? Are these intuitive confidence intervals shorter or longer than those from the actual sampling distribution of the squared multiple correlation? If people are exposed to the sampling variability via a sampling experiment, does this affect their intuitive confidence intervals? What is the effect of sample size? These questions were addressed in a study of 57 fourth year honours students in a multivariate methods course. Briefly, those students whose estimates of the 90% confidence interval were larger than that from the actual sampling distribution at pretest significantly reduced their estimates after exposure to the sampling experiment. Those students with smaller confidence intervals at pretest significantly increased their estimates at posttest. Appropriately students increased their estimates of the confidence interval with decreasing sample size but their estimates were too large for smaller sample sizes. These results are discussed in terms of the use of sampling experiments and resampling methods for teaching people about sampling variability especially for statistics, such as the squared multiple correlation, where formulas for confidence intervals are not available.

Instructional Strategies in Statistics Courses that Emphasize Data Analysis

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Applied statistics courses in the social and behavioral sciences provide instruction in statistical methods for data analysis to students who display enormous variation in mathematical skill and background. The easy availability of powerful computing tools, such as SPSS/PC+, has placed sophisticated data analysis at the disposal of these students, but, at the same time, presents an increasingly difficult challenge to the instructor. The topic explored in this paper concerns a framework for the development of instructional strategies within an environment characterized by student diversity and computational sophistication.

The proper application of the techniques of applied statistics rests upon the understanding of a set of elementary core concepts. A basic premise in designing instruction for a highly diverse population of students is that these understandings can be achieved at varying levels of mathematical sophistication. Those of us trained in mathematics tend to assume that the most appropriate expression of these concepts is by means of mathematical formulae along with appropriate definitions and assumptions. However, this abstract mathematical understanding is inaccessible to many (if not most) students. Despite this, all students can be expected to achieve understanding of these core concepts at the level of verbalization. On the other hand, students with more formal training in mathematics can be expected to make the translation of these core concepts into abstract, mathematical terms. For example, the verbalization, "distance from the mean in standard deviation units," accurately describes the notion of the z-score, although only a student with adequate algebra skills can successfully translate this verbalization into a mathematical formula. In applied statistics, the verbalization represents a more important instructional outcome that the formula.

Consider the notion of variability. This is a fundamental abstraction that is central to most (if not all) statistical analysis. Yet the concept of quantifying variability represents a relatively high-level abstraction and traditional computational exercises based on computing sums of squares, variances and related quantities display no obvious understanding of this core concept. Similarly, the related notion of measuring relative standing in a distribution by means of a z-score is not only abstract but, in some ways, counter-intuitive. For example, a z-score of +1.0 only has meaning relative to a distribution and is fundamentally unlike physical measurements that have absolute interpretations.

In summary, this paper examines the interplay between computation, abstraction and understanding in the context of applied statistics courses in which sophisticated data analysis is routinely available.

ACHIEVING PROCESS IMPROVEMENTS: A Case Study in the Utilisation of Total Quality Management within a College of Further Education

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Abstract

This paper considers the central tenets of Total Quality Management, the crucial role of a team driven impetus to process improvement, an approach to quality decision making and its associated measurement techniques and delivers a case study of the efficacy of a team driven focus to the attainment of continuous process improvement in a College of Further Education in the UK.

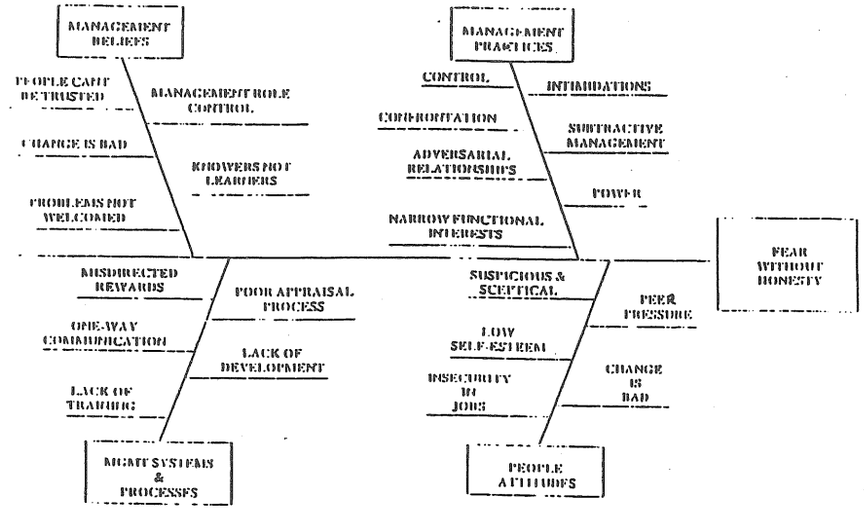
Introduction

All philosophies differ in the detailed prescriptions which they offer, but all can be said to contain certain common elements. This commonality may be depicted as follows:

- **a challenge to the status quo**: a critique of the past and present
- **a set of values**
- **a vehicle for change**
- **the delineation of a futur desired state**

Such a schema facilitates both a comparison between differing philosophies and an analysis of any one philosophy; it is in this latter form that the scheme will be used. When specifically applied to the approach to management designated by the term "Total Quality Management", the schema reveals the emergence of the following scenario:

A challenge to the status quo: Lowe and McBean (1) are not alone in representing the deficiencies of current management practice in both the manufacturing and service sectors of Western economies. (2) They choose to do so through a detailed analysis of four key managerial indicators, namely, management beliefs, management practices, management systems and processes and people attitudes:



A set of values: the services sector, in general, and the educational area, in particular, is favoured by the work of Parasuraman et al [3]. They provide a comprehensive coverage of the expectations that customers may entertain of any service, including education, and of the values which they expect that service to exhibit:

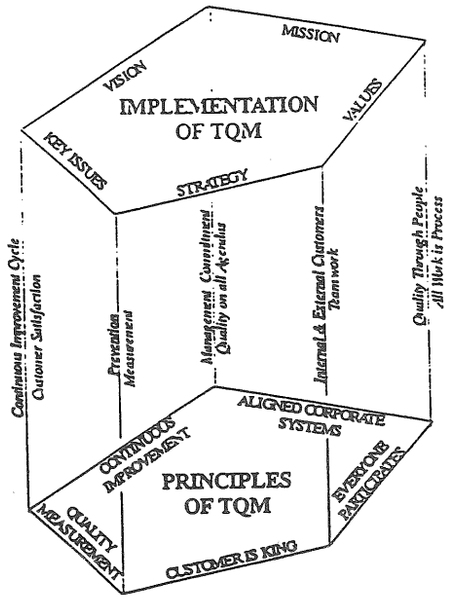
- **access**: involves approachability and ease of contact
- **communication**: means keeping the customers informed in language which they can understand and listening to them
- **competence**: means possession by the organisation's personnel of the required skills and knowledge to perform the service
- **courtesy**: includes politeness, respect, consideration and friendliness of the organisation's personnel
- **reliability**: involves consistency of performance and dependability
- **responsiveness**: involves the willingness, readiness and timeliness of employees to provide service
- **security**: is freedom from danger, risk and doubt
- **tangibles**: include the physical evidence of the quality of service provision
- **understanding/knowing the customer**: involves making the effort to understand the customer's needs and expectations.

All of the above can be said to be values which, if manifested by an organisation's personnel, will serve to meet the needs and expectations of customers in the service area of which education constitutes a significant element.

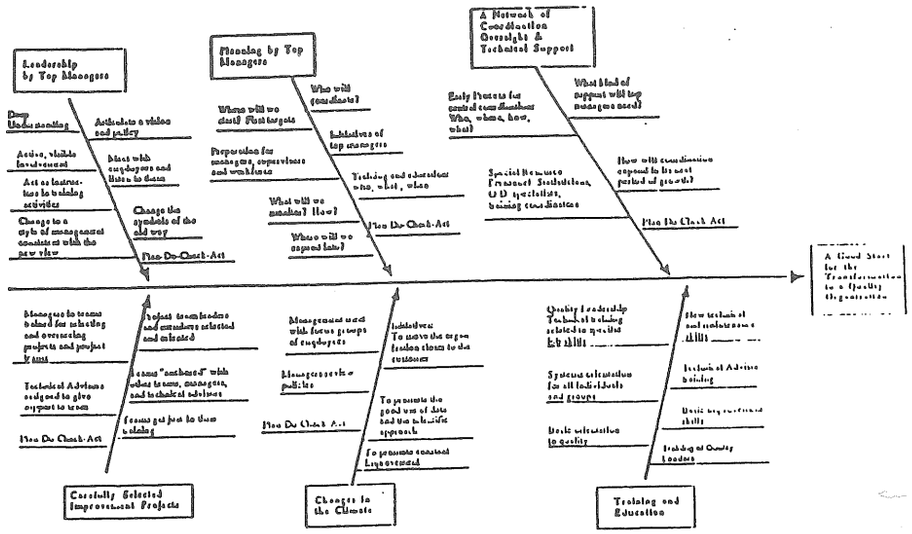
A vehicle for change: TQM, through its effective implementation, is perceived as the vehicle of change which will sweep away the old management practices characteristic of the status quo and herald the dawn of a new area. Whilst the "Quality Gurus" might differ somewhat in their prescriptions for the implementation of TQM, there is sufficient of a consensus for it to be possible to discern a number of agreed features of TQM as a vehicle for change:

- **the customer is king**: TQM "..... start(s) with the customer's requirements and end(s) successfully only when the customer is satisfied with the way the product or service of the enterprise meets those requirements" [4].
- **everyone participates in TQM**: not just the senior and middle managers in the organisation and its first line supervisors but the entire workforce and, more recently, "..... subcontractors, distribution systems and affiliated companies" [5].
- **quality measurement is essential**: "Quality measurement for each area of activity must be established where they don't exist and reviewed where they do" [6].
- **align corporate systems to support quality**: where "..... existing systems and corporate structures ..... are found inappropriate for meeting cross functioning goals ..... necessary changes (must be made)" [7].
- **constantly strive for quality improvement**: "Improve constantly and forever the system of production and service, to improve quality and productivity, and thus to constantly decrease costs" [8].

The work of Kanji and Asher reveals four principles of TQM, as opposed to the five given above, and it is their contention that each of their four principles has associated with it two concepts [9]. If the Kanji/Asher model is developed to take account of this addition, the following model emerges:



- a future desired state: the goal which is being sought, through the critique of the status quo, the espousing of values which are customer focused and through rigorous and effective implementation of TQM as the vehicle of change, can be graphically displayed as follows:

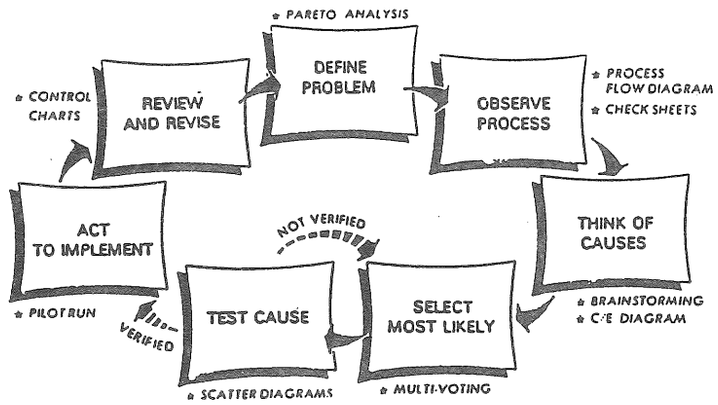


There is widespread acceptance of the role of teams in all Total Quality Management initiatives and of the central thrust which they impact to each and every total quality improvement project. Many writers and practitioners have emphasised the crucial part to be played by teams in pursuit of the goal of continuous quality improvement. Berg notes that, "It is becoming increasingly evident that the success of future quality efforts will depend to a large extent upon the ability to create cohesive teams ....." (10). Similarly, Shannon observes that, "Success in the 1990s will necessitate that rare combination of quality leadership ..... and project teams ..... that are involved in making decisions"(11). Stavinskas has no doubt but that, "Quality teams have been used extensively as a method of improving quality" (12). Whilst for Musselwhite and Moran, "Self-directed work teams drive quality improvement effort into every fibre of the organisation"(13). The consensus encompasses specific recognition that teams are not instituted merely to facilitate the manufacturing or service delivery processes but are created as vehicle of change through which problems of poor quality are detected, prevented and solved; thus permitting the never ending spiral of continuous quality improvement to be successfully commenced.

What is often less clear is the precise role to be played by teams in the attainment of the primary objective of Total Quality Management, namely, continuous quality improvement. This role is perceived as being the ability to:

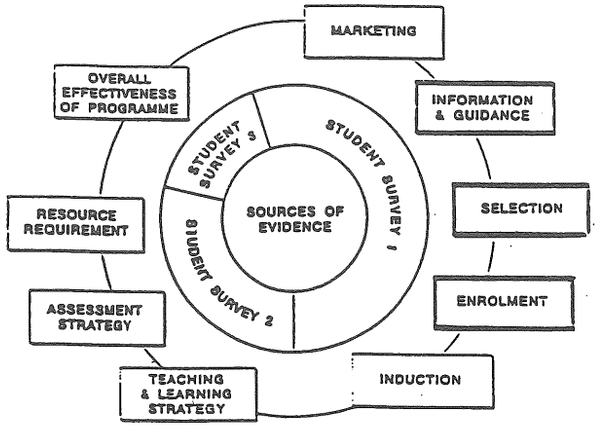
- analyse symptoms
- establish causes
- generate remedies
- test the chosen remedy under operating conditions
- monitor the chosen remedy
- report on the quality improvement gained and held

Whilst these infra-structural features are imperative to the generation of teams in credit rather than in debit, the quality decision making process is of particular significance and importance for it links the tenets of rational decision making with the measurements required by Total Quality Management: (14)



The case study which follows is derived from a UK College of Further Education (15). More especially, it relates to the largest faculty within that college, measured in terms of the number of students and academic staff, which ran six separate professional and undergraduate courses each of which, at the outset of the quality improvement exercise, had its own discrete enquiry through enrolment processes. This generated a bureaucratic nightmare.

The quality improvement team's first task was to assess existing empirical evidence:



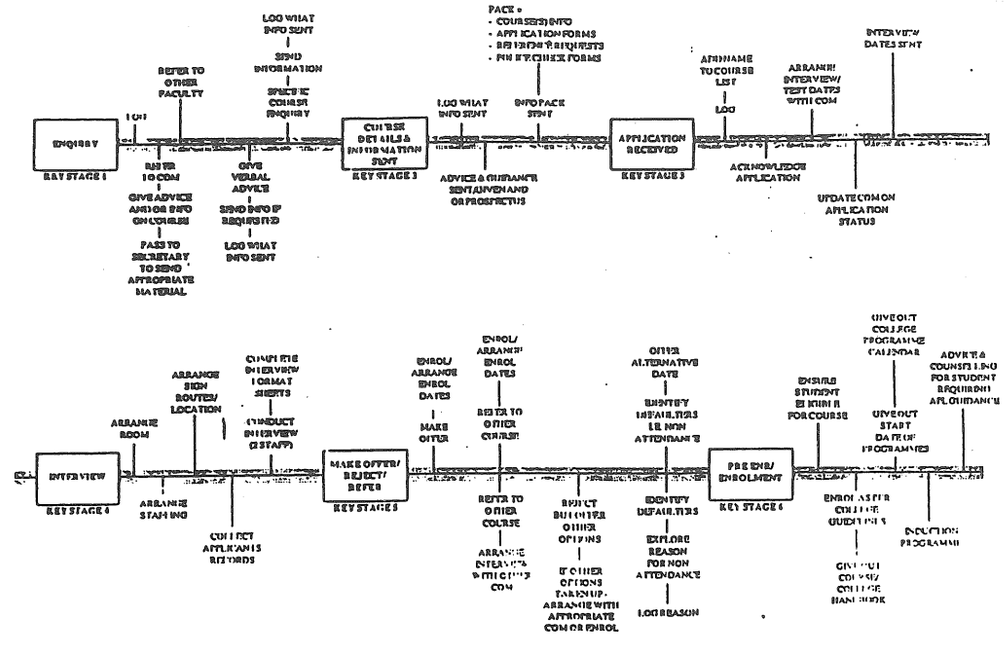
This revealed a loss of potential students to competitor colleges because applicants were often kept waiting for a period of up to six months from the date of their initial enquiry for admittance to a course before receiving any response from the faculty. At the same time the faculty was being encouraged by senior management to increase its student intake by 40% in the next academic year.

The cross functional quality improvement team sought to standardise the enquiry/enrolment process across its six courses by using "key stage" indicators:

Enquiry ---------- Course Details & Information Sent ---------- Application ---------- Interview ---------- Accept/ Reject/ Refer

Enrol ----------

Finally, the team sought to delineate the precursors for action for each key stage so as to ensure a rapid response to potential students through a standardised and measurable process:



The result was that the enquiry/enrolment process was reduced from a worst case 6 month time span to a norm of 7 working days. Later monitoring of the new processes revealed that the previous student dissatisfaction with the enquiry/enrolment process had fallen from 69.2% to 1.3% and savings in staff time were estimated at slightly in excess of 61 hours per week.

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Assessment and Attitude: Significant Factors in a Major University's Quality Improvement Process

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Abstract

Assessment and attitude are key factors responsible for Auburn University's quality improvement progress case after case. Assessment is central to the quality improvement process which provides a sound strategy for data-based decisions that can be documented and measured. Equally important, a positive attitude enhances the probability that improvements will become a part of the university culture, and, most importantly, makes the journey a pleasant one.

Introduction

Leadership focused on continuous quality improvement in institutions of higher education has been neglected for decades. Continuing public concern for accountability and responsibility, operating expenses that seemingly defy all traditional cost containment efforts, spiraling tuition, decaying infrastructures, decline of student performance in standardized and professional licensing exams, and an increasingly competitive marketplace are explicit examples which verify this long-term neglect.[1] Boards of trustees or regents, employers, parents, and students are the stakeholders who fund higher education; and the general public is increasingly concerned about access to higher education as a means toward employment and economic security.[2] David Yankelovich, a noted policy analyst, reported that 88 percent of the general public feel that "a high school diploma is no longer enough to qualify for a well paying job and 73 percent agree that having a college degree is very important to getting a job and advancing in one's career."[3] Many advocates and critics of higher education believe that these constituent groups are bringing an educated consumer orientation to their assessment of higher education, and this consumer orientation has had a direct impact on the outcome assessment movement in higher education.[4] "Today's

students expect of colleges and universities what they demand elsewhere: better service, lower costs, higher quality, and a mix of products that satisfy their own sense of what a good education ought to provide. They want the enterprises that serve them to be efficient--not for efficiency's sake, but because efficiency promotes the flexibility and adaptability they seek in the marketplace."[5] These concerns are causing many university leaders to move the issue of assessment and quality improvement to a level of priority and to search for more effective ways to manage the business of higher education.

The total quality management movement in higher education is exploding. In a 1993 survey sponsored by the American Society for Quality Control (ASQC), for example, 139 universities reported successes gained through applying TQM principles, and 50 percent of these universities have established quality councils, offices, or centers to coordinate their quality improvement activities.[6] Total quality management is a more effective way to conduct business and requires an attitude of commitment and the fundamental belief to *do it right the first time*. This process results in continuous improvement by understanding and perfecting the system by which the organization is operating. Deming cautioned that emphasis should always focus on analyzing and improving the system because 94 percent of an organization's quality problems lie within the system, not with individuals.[7] By involving everyone in the organization, each person is a significant part of the improvement process and takes pride in his or her contribution to improving the system.[8]

Regardless of whether the quality management process designed is based on the work of Deming, Juran, Drucker, Scholtes, or other quality management advocates, there are several basic stages of development that must be followed by any organization interested in moving into the quality improvement process. As Auburn University initiated basic total quality principles, the following four stages assured the success of this continuous improvement process: (1) Preparing to Initiate Continuous Quality Improvement; (2) Getting to Know TQM; (3) Scheme for Assessment and Continuous Improvement; and, (4) Leading a Dynamic Team.

Stage One: Preparing to Initiate Continuous Quality Improvement. It is imperative to understand who comprise the stakeholders in a university environment and how these stakeholders interface as one smooth operation: employees, funders, and customers. *Employees'* major concerns are having a job that is meaningful, feeling involved and empowered, and feeling that their ideas are sought out and used. They want fair wages and want to feel pride in what they do. They also want to work for an organization that is socially responsible: an organization in which the leaders address cultural diversity, are good corporate citizens of the world, operate under a sound system of ethics, and are respectful of each other and the environment. *Funders* are the taxpayers and all their agents who are promoting productivity, efficiency, effectiveness, and fair return on investment. *Customers* in general want quality products and services, which is the reason for interacting with any organization.[9]

Stage Two: Getting to Know TQM. In order to make a professional commitment to any quality improvement management system, a knowledge-base of specific principles and best practices must be acquired by every individual team member. This learning investment is mandatory because it provides the "nuts and bolts" which ultimately hold the system together. Each of Deming's 14 principles for management, Juran's quality trilogy, Crosby's absolutes of quality management, Drucker's management philosophy, and many other management "best practices" were studied carefully as the Auburn University Economic Development Institute (EDI) quality management system evolved over a seven-year period.[10] These principles and best practices are powerful axioms based on assumptions that individuals want to do their best, and it is management's job to enable them to do so by constantly improving the system in which they work.[11]

Stage Three: Scheme for Assessment and Continuous Improvement. Assessment is the centerpiece of continuous improvement and should focus on questions which provoke data-collecting that can be used to "alter teaching methods, curriculum development, and administrative policies. Assessment has all the attributes of a process that yields never-ending improvement."[12] The continuous planning and evaluation process shown in Figure

1 is the most important aspect of this stage because it clearly identifies the total process from the vision and mission of the university to daily self-appraisal of each individual in the

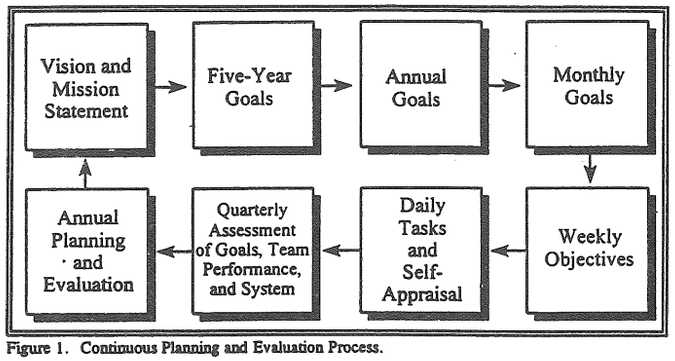


Figure 1. Continuous Planning and Evaluation Process.

system. Involvement of all staff is critical because it assures two-way communication, higher performance, and the confidence to suggest new job dimensions and responsibilities. This continuous, seamless strategy is the driving force behind the continuous improvement cycle. Once the *scheme for assessment and continuous improvement* is implemented, the ongoing commitment to quality gradually becomes the basic operating concept of the organization. Perhaps the most practical way to evaluate this management strategy is best described by the Shewhart Cycle which consists of four steps as illustrated in Figure 2.

- Step One: Plan - Document and establish measurable objectives.
- Step Two: Do - Execute the plan and collect required data and information.
- Step Three: Check - Analyze data qualitatively and quantitatively.
- Step Four: Act - Obtain corrective action and assess future on regular basis.

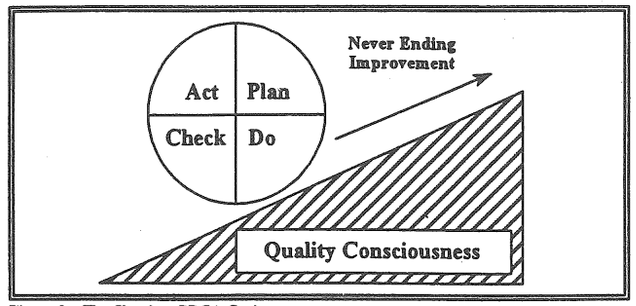


Figure 2. The Shewhart PDCA Cycle.

When each step has been completed, the cycle is either standardized or adjusted as a result of outcome appraisal.[13] As explained by Deming earlier, this cyclical process allows problems and solutions to be focused on the system rather than on the individual.

Stage Four: Leading a Dynamic Team. What constitutes good leadership has been the subject of debate for many centuries.[14,15,16,17] "Things can be manipulated, quantified, measured, and calculated; people can't. You manage things, and you lead people."[18] Stage four requires creating and maintaining an environment which empowers a team and encourages reasonable risks. Deming defined a leader as one responsible for transforming the organization through knowledge, personality, and persuasive power.[19]

Effective team leaders have a vision for the future, explicit goals, measurable objectives, and data-based assessment techniques. These leaders demonstrate through action how to make the vision become a reality. Leading the total organization is based on the assumption that everything is changing, while continuous improvement manages the dynamics of that change. The leader of a dynamic team encourages all members to assume more responsibility, communicate more effectively, act creatively, be innovative, and work smarter.[20] Recognition and reward for this level performance is a requirement and has a direct impact on an individual's attitude toward day-to-day improvement.

Afterword

As universities position themselves to enter the 21st Century, the ability to compete for funding, students, and faculty will sharpen. The reality that increasing costs, accountability, and a service orientation are critical parts of this competitive puzzle is serious, yet motivating. "If one [university] doesn't deliver on its promises, students just pack up and move down the block."[21] Consequently, university leaders world-wide are searching for better ways to manage and improve quality. Since universities are the brain-trust of our society, they are critical to economic prosperity. As educational leaders, we all have the challenge and responsibility to educate and graduate quality undergraduate and graduate students. Until the academic dimensions of higher education are central to the assessment and quality improvement process, university leaders will continue to have difficulty answering definitively, what kind of job are we doing?"

Total quality management is fundamentally an improved way to conduct business and is proving necessary for the well-being of America.[22] A positive attitude coupled with reliable assessment techniques are significant factors which contribute to higher quality, lower costs, and rapid response. Total quality management is not a new program or a popular fad; it is not even a new way of organizational thinking. It involves a solid balance of management and organizational development tools and practices, each of which has merits in its own right. Specifically, it requires intensive planning, extensive customer feedback, detailed work process and assessment, enhanced participatory management and employee empowerment, and reforms in human resources management practices, from compensation and appraisal to training and development."[23] Hill and Taylor summarized the potential benefits for total quality management to higher education well: (1) continuous and sustained organizational improvement; (2) increased levels of external satisfaction; (3) tangible and significant cost savings of approximately five-to-ten percent of operating costs; (4) focus on the importance of interdisciplinary teams with faculty and administration; (5) new way of managing the organization which promotes organization-wide congruence, accountability, and involvement; and, (6) improvements in employee morale, commitment,

and motivation.[24] Although quality is the cornerstone to this process, the opportunity to make work more satisfying and rewarding is probably the strongest and most lasting reason for the growing and sustained interest in total quality management.[25]

Endnotes

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Total Quality in Education and the European Quality Model

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0 Abstract

The necessity to deal with quality and quality concepts like TQM is seen more and more clearly by industry throughout the world. But what about other "organisations" and "institutions" as for example the entire public sector or educational institutions?
The following paper discusses the relevance of Total Quality concepts for the special sector of higher education institutions, respectively universities. After describing first experiences in the USA the European Quality Model will be used for developing a self-appraisal Model for Higher Education institutions.

I Introduction: TQM and Higher Education - Does that fit?

Throughout Europe, companies are realising that it is necessary or even inevitable to deal with quality or quality concepts in a much more extensive way than they did before. But other organisations and institutions like the entire public sector, healthcare and educational institutions, do they need concepts like TQM?
Yes, of course they do. In face of the need for cost reduction everywhere, these fields with operating expenses, that seem to defy all traditional costing systems are coming more and more into public concern. Consequently, the question is asked "Is there a better way to manage the public sector or higher education?"
This article tries to prove - for the special sector of higher education, respectively for universities - that TQM may be a better way to get things done.
In fact, the idea of "TQM in Higher Education" is not new. A survey carried out by Oregon State University in 1990 showed, that by this time 25 universities and similar institutions of higher education in the United States were involved in some way with the TQM process, although the

survey did not represent all institutions possibly involved.[1] The spectrum of TQM implementation thereby extended from administrative to academic areas, from TQM consultation to research in TQM and its use in instruction.

Some might say, that the States can't be used as a model for Europe and Germany in particular, because of totally differing education systems. Certainly, it is true that the education systems in the United States and Europe - even within Europe - are different. For example, some countries have publicly financed non-profit universities while others have private colleges and universities. This might have an impact on the motivation to change and cost savings.

But is this the right way to argue? As a matter of fact, all of the higher education institutions - public or private - are or at least will be within a short time faced with the necessity of improving their "service" and by this reducing costs. So the question is not "Yes or No?" but "When?".

In the following, some "special features" of universities and their organisation will be reflected and put in the TQM context.

II Universities as subjects of TQM

When comparing a university to a company as regards TQM, what's different?[2]

A company exists to serve its shareholders. And it serves its shareholders best, when it serves its external customers (in the broadest sense) best.

The customer-supplier-relationships in a university or college are of another kind. Taking into account the primary purpose of a university, one important group of "customers" are the students. Though, they do not stand outside of the institution - they are a part of it. And they are not only customers, but products and in some way shareholders (at least at private colleges and universities) at the same time. As a matter of fact, especially non-profit universities can exist without serving their customers best resp. without "producing" successful graduates. But in the

1 see: Coate, Edwin L.: Implementing Total Quality Management in a University Setting, publication of Oregon State University, 1990, p. 4

2 concerning this subject, see also Baggett, M.: Demythologising Quality Improvement for Faculty, in: Harris, J.W., Baggett, M: Quality Quest in the Academic Process, Birmingham, Alabama, pp. 95-100

end, the institution's success depends on the success of its graduates and this makes the goal of "serving customers" even more important than in normal companies.

As far as the structure of a university is concerned, it must be said that it is in some respect different but at the same time similar to a company. A university can be differentiated into two main departments: Administration and the academic area, both interrelated in some way. The administration area can simply be compared to a service company with all its typical features. This is to say that the same instruments and methods may be applied, that have been working in businesses throughout the world for many years by now.

The more complicated area appears to be that of academics. While on the one hand the "Freedom of Research and Teaching" reveals flexibility and self-management, the university constitutions with their complexity, inflexibility and hierarchical structure (in Germany: Senate, Faculties, Professors) seem to be serious obstacles. This problem can't be solved at once - the question is, whether these difficulties make an improvement of the academic "process" impossible or not. As - to stay in Germany - with the reunification belt-tightening is the rule in the whole public and educational sector, all institutions including the universities must follow the same slogan: "Do more with less". The comparison to the "business world" again leads to a fundamental rule: "Better processes are the key to cost reduction and better products". And this has been validated by industry. In Germany, a first step in the right direction has been initiated with the current "reform of studying structures" and the measures agreed in this context.

While principal questions like those stated above are still on the list in Europe, a survey by Goal/QPC, carried out in the United States in 1991 shows, that the US-Americans (again?) have gone further.[3]

A survey among 22 public and private universities and colleges was designed to describe the state of the art of TQM in higher education in the United States. One of the questions included attitude scales to measure the importance of the seven criteria of the Malcolm Baldrige

3 for details, see: Seymour, D., Casey, C.: TQM in Higher Education: A critical Assessment, Goal/QPC Application Report, Methuen, Massachusetts, 1991

National Quality Award (MBNQA).[4] Without discussing the results more detailed, some basic findings in regard to the European attempts are:

- All of the Baldrige Criteria are in principle applicable to a university or college.
- All of the criteria are highly important for the success of a higher-education-institution and a great deal of emphasis should be placed on them. (see fig. 1, solid line)
- The "what is"-line (fig. 1, dotted line) shows, that the participants in the survey have not yet reached "what should be". In fact, this is not such a problem; at least they know, where they want to go to.

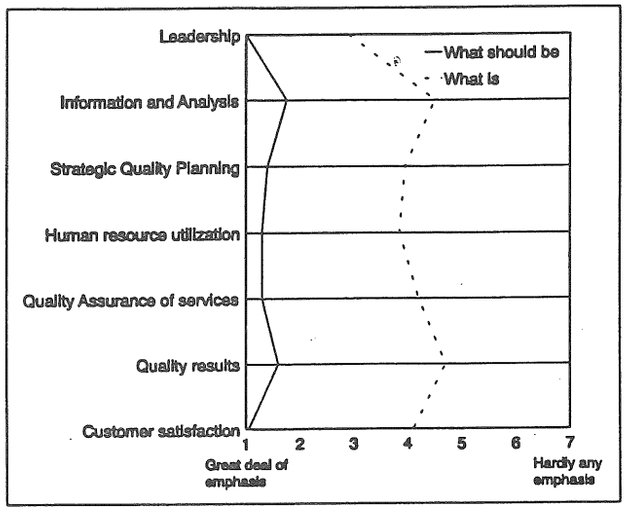


Fig. 1: Baldrige Criteria responses (means)

III The European Quality Award 1994

In order to show the framework, in which higher education activities in Europe may be put, the following pages contain an introduction to the European Quality Award (EQA), which is the counterpart of the above stated MBNQA.

4 see: Seymour, D.,..., p. 17

The Award is managed by EFQM and supported by the European Commission and the European Organisation for Quality (EOQ). To receive the Award, a company must demonstrate that its approach to Total Quality Management made a significant contribution to satisfy the expectations of customers, employees and others with an interest in the company. For companies, the recipients of the EQA serve as practical models of TQM. In 1992, the Award was won by Rank Xerox and in 1993 it was won by Milliken European Division.

The criteria model (figure two) should represent a "model" company excelling the European Marketplace in the Nineties, irrespective of its size or business.

In detail, the criteria model consists of nine main criteria, structured in two groups: The "Enablers" and the "Results" group.

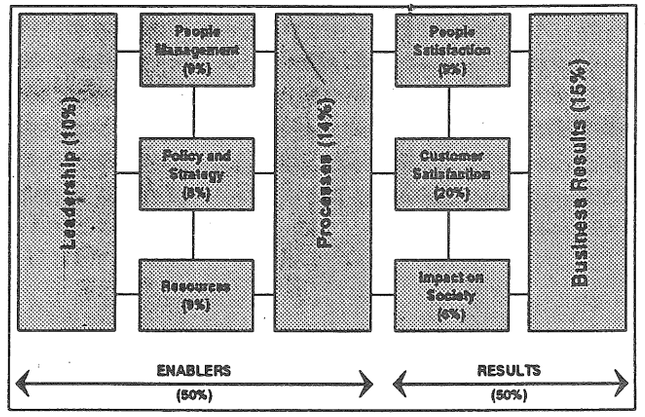


Fig. 2: European Quality Award: The European TQM Model

The applications of the companies for the EQA are based on a Self-Appraisal carried out by the companies.

The aim of "The European Model for Self-Appraisal"[5] is to simplify the Self-Appraisal process by clarifying the criteria of the EQA with examples and aspects, that could be addressed in the relevant context.

5 European Foundation for Quality Management (Ed.): Total Quality Management - The European Model for Self-Appraisal 1994, Eindhoven, Holland

In the following chapter, this Self-Appraisal Model will be in some way redefined showing on the one hand, **that** the European Quality Award criteria may be applied to universities and on the other hand, **how** the "Processes" criterion as an example can be operationalised in order to fit the university setting.

IV "A European Model for Self-Appraisal in Higher Education Institutions"

Combining the knowledge about universities, TQM and the European Quality Award, the authors will now show for the criterion "processes", that the European Quality Award criteria are indeed suitable for a university.

True, especially for publicly sponsored universities, the practicability and feasibility have to be seen against the background of legal conditions. This implicates for example the special relevance of the voluntary nature of an engagement of German civil servants ("Beamte"). Though, this is not a question of "to do or not to do", but a matter of motivation.

The structure of the model is absolutely equal to that of the "original" - "European Model for Self-Appraisal", 1994 edition. Those paragraphs printed in *Italic* are even cited from this brochure without any changes.

Processes

The management of all the value-adding activities within the organisation.

How processes are identified and if necessary revised to ensure continuous improvement of the organisation's business.

One well-established perception is, that a university and the term of "process" may not fit. The main emphasis in the context of this criterion "processes" will therefore be put on listing processes in a university, differentiated between administrative and academic processes. True. some of the processes are interfunctional and could be assigned to both of the areas and this fact is not questioned at all.

Having identified these processes, their management and measurement is exactly the same as for "normal" business processes. That is why the paragraphs b., c. and e. have not been changed as regards the "original" Self-Appraisal model of the EQA.

a. *How processes critical to the success of the organisation are identified.* Areas to address could include how:
   - critical processes are defined: what processes are currently on the list
   - the method of identification is conducted
   - interface issues are resolved
   - "impact on the business" is evaluated.

Critical processes in administration could include:

- registration procedures
- physical maintenance
- payroll
- Student outcomes assessment (BAFöG)
- recruiting
- student exam administration
- admissions
- canteen management
- library management
- computing services/ network operating

Further processes in administration could include:

- mail distribution
- printing/copying services
- materials - acquisition/ purchasing
- financial aid
- grounds care
- student housing procedures
- recreational services
- trash removal
- hazardous waste elimination
- conference and guest services
- electronic equipment services (TV, Video, Audio)
- paper flow reduction
- office space allocation
- minority initiatives
- motor pool services

Critical processes in the academic area could include:

- curriculum development
- teaching and advising
- research
- academic recruitment and hiring
- student exam preparation, realisation and evaluation
- faculty development
- precollege programs
- industry grants gaining
- post-graduate study development
- interdisciplinary program development
- long range planning

Further processes in the academic area could include:

- faculty recognition and awards	- graduate career planning and placement
- promotion	- international programs: promotion, facilitation, assessment, improvement
- faculty retirement and benefits	- placing student teachers
- industry-academic contact seminars	

b. How the organisation systematically manages its processes. (...)

c. How process performance measurement are used. (...)

d. How the organisation stimulates innovation and creativity in process improvement. Areas to address could include how:

- new disciplines of design, new technology, new curricula and programs are discovered and utilised
- the creative talents of the university's people and students are brought to bear

e. How the organisation implements process changes. (...)

V Conclusion

Can Total Quality Management concepts work in a university setting? The answer is yes. True, a university is "something different" from a "normal" business, but that has not too much impact on the applicability of TQM. When looking at the Self-Appraisal model of the "European Quality Award", which is one of the most comprehensive TQM models in the world, the authors have shown, that the criteria and sub-criteria may fit universities as well as companies. Numerous examples for one of the appraisal subjects have been presented, demonstrating possibilities and aspects of TQM in a higher education institution with both, the academic area and the administration area being involved.

Summing up, the result of the article is not different from what Daniel Seymour and Casey Collett found in their Higher Education Study in the United States: "... the conclusion of this study must be, that the operating principles of Total Quality Management could have a dramatic impact on the way our institutions operate."[6]

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6 Seymour, D., ..., p. 28

TOTAL QUALITY IN EDUCATION

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Abstract

When discussing Total Quality in education we have to start with some definitions. Without clear definitions it is difficult to identify the problems, assumptions and barriers of Total Quality Management (TQM).

TQM is a vision which any educational organisation can achieve through long-term planning and implementing total quality plans. For the fulfilment of the TQM vision, an organisation can adopt the following definition of TQM:

> **It is an educational culture characterised by increased customer satisfaction through continuous improvements, in which all employees and students actively participate.**

In this paper authors will be discussing the role of Total Quality Management in Education.

The TQM Pyramid

The most common barrier against TQM in educational institutions is the outdated management pyramid used by the organisations. Like Jan Carlzon, we firmly believe in abolishing outdated management pyramids and building a new management pyramid, thereby developing the vision and meeting the challenges inherent in the TQM process.

As can be seen from Figure 1, our new TQM pyramid has **a foundation** and **4 sides**. The five components which characterise TQM are:

1. Management's commitment (leadership)
2. Focus on the customer and the employee
3. Focus on facts
4. Continuous improvements (KAIZEN)
5. Everybody's participation.

These five components will be discussed in greater detail in the following pages.

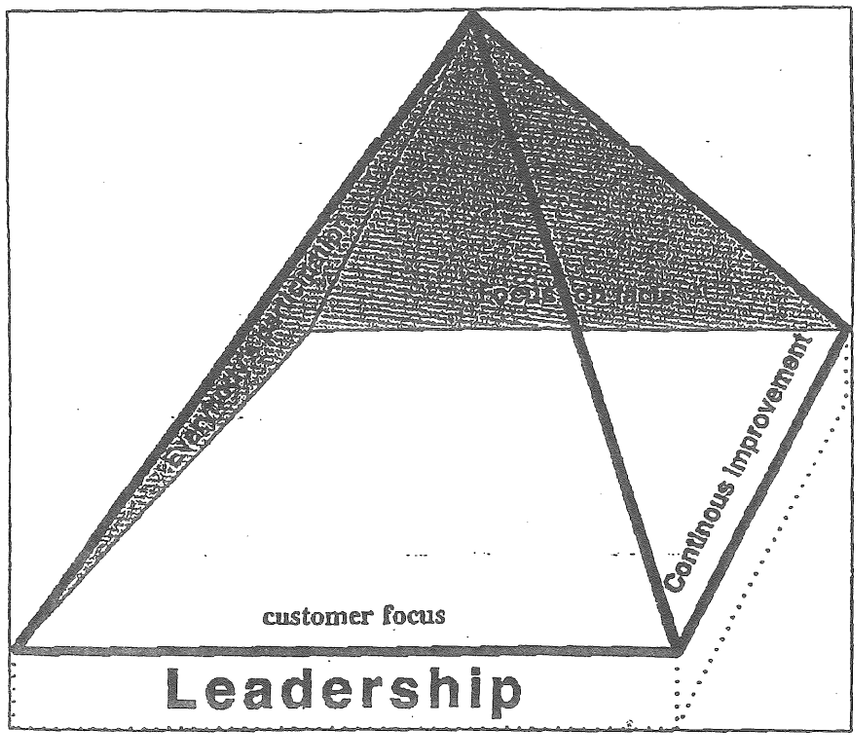


Figure 1: The TQM Pyramid

Management's Commitment

Leadership is the foundation of TQM and without the foundation it is impossible to implement TQM in an educational institution. We believe that a vital task for any management is to **outline quality goals, quality policies, and quality plans in accordance with the 4 sides of the TQM pyramid** (Fig 1). Top management must review the institution's quality goals and policies, and if necessary reformulate them so that they conform to the components of TQM pyramid. It is important that these goals and policies should be clear and meaningful to all employees and all students of the educational institution. It is also extremely important that the **quality goals** send signals to employees and students about the principal task of the institution, in order to satisfy its external customers.

The institution's **quality policies** must provide the employees and students with detailed information about how to achieve the set goal. Further, the quality policies must also conform to the five components of the TQM pyramid.

Quality goals and quality policies must be followed by meaningful action plans. Past experience indicates that firms ought to concentrate both on short-term plans (1-year plans) and long-term plans and adopt an annual **quality audit** for the development of T.Q.M. We believe that the annual quality audit is an essential part of the TQM vision. Only through active participation in the quality audit top management of an educational institution can acquire the necessary insight into the institution's quality problems. The quality audit gives top management the opportunity to put a number of important points to departmental managers e.g:

1. Identification of customer.
2. Customer's requirements and expectations.
3. Customer satisfaction.
4. Customer's perception of services.
5. Collection of information.

This information allow top management to check whether employees of the educational institutions are in fact seriously trying to fulfil their firm's quality goals. By actively participating in the annual quality audit, top management shows that they have understood the TQM message. Such active participation by top management also makes their commitment highly visible and will have a valuable effect throughout the organisation.

An important fact to be remembered in relation to TQM is that it is easy to suggest that "TQM requires management's commitment", but in reality it is not so easy to explain how management should tackle the problem of implementation of TQM.

In order to manage TQM Deming has formulated fourteen points for the managers. His point number 14 presents a 7 step plan for implementing TQM. We believe that the 7 step plan is also valid for educational institutions. In brief, these 7 steps are:

1. Management must agree about goals, conditions, and obstacles to the introduction of TQM.
2. Management must have the courage to break with tradition.
3. In building up a new "quality organisation", management must appoint a manager for quality improvements who has direct access to top management.
4. Management must, as quickly as possible, build up an organisation to advise on the carrying out of continuous improvements throughout the educational institution.

5. Management must explain to employees why changes are necessary, and that they will involve everybody in the organisation.
6. Management must explain that every activity and every job has its own customers and suppliers.
7. Management must ensure that every employee in the educational institution participates actively in a team.

It can be said that the above steps implicitly include all five components of the TQM pyramid.

Focus on the Customer and the Employee

Focus on the customer deals with the problem of identifying the different customers and their expectations. The customers are internal as well as external customers. Internal customers are the students and the employees, and the external customers are the society and the different organisations where the graduates continue their career.

Focusing on the customer, and the customer's requirements and expectations, is neither new nor revolutionary. However, one of the new messages in TQM is:

> **In addition to focusing on external customers and their expectations and demands, it is necessary to focus on so-called internal customer and supplier relations.**

Before you can satisfy external customers, however, you must first eliminate some of the obstacles to the internal customers, and create the conditions necessary for them to produce and deliver quality. One such obstacle that must be eliminated in an organisation is the fear of the individual.

At the same time, improvements ought to be process-oriented. Any educational organisation can be defined as a series of connected processes, of which employees and students are a part and therefore the management interested in quality must start by looking at the processes. This is one of the reasons why the foundation of the TQM pyramid is called "management's commitment".

In order to produce and deliver quality, employees and students need to know what the internal and external customers expect of them. When the employees and the students have this information they will be able to start improving the processes. Although the internal customers and internal processes are important, nevertheless, one must not lose

sight of the fact that the main purpose of focusing on internal customers is to create satisfied external customers.

Focus on Facts

Focus on facts deals with measurements. There are 2 main types of measurements:

1. Internal measurements,
2. External measurements.

Internal measurements consist of measurements from the key processes and the measurements of internal customer satisfaction. External measurements consist of measurements of external customer satisfaction.

Knowledge of customers' experiences of products and services is essential for creating customer satisfaction. More and more organisations are therefore setting up a system for the continuous measurement, collection, and reporting of quality facts. Here we will briefly describe the 3 main groups of measurements. They are:

1. External customers' satisfaction (CSI = Customer Satisfaction Index).
2. Internal customers' satisfaction (ESI = Employee Satisfaction Index and SSI = Student Satisfaction Index).
3. Other quality measurements of the educational institution's internal processes, often called "quality check points" and "quality control points".

Focus on the customer and the employee are cornerstones of TQM. It is only natural, therefore, that employee satisfaction, student satisfaction and customer satisfaction are included as quality goals for an educational institution.

Satisfied customers, satisfied employees and satisfied students are prerequisites for Total Quality. But satisfaction is not enough. There is also a need for controlling the results of the most important internal processes and checking the conditions of the educational processes on which the institution is built around. The former type of measurements may be called "quality control points" and the latter may be called "quality check points".

We have suggested earlier that an educational institution can be described as a collection of connected processes with an input to subsequent processes (the internal customers) or an output to external customers. We can measure the quality of the result of any process, in order to ascertain whether we are satisfied with a particular result. To measure the quality of a process, we also have to establish a **"quality control point"**.

TQM, as mentioned in this paper, is process-oriented, which means that management, employees and students must be aware of the problems in the internal processes, and, in particular, the reasons for these problems.

In his famous book "Kaizen", Imai (1986) recommends quality control points and so-called **"quality check points"**. Imai also calls quality control points "R criteria" (= result criteria), and quality check points "P criteria" (= process criteria), indicating the difference between quality control points and quality check points.

While a quality control point measures a given process result, a quality check point measures the state of the process. Of the many different states that can be measured, it is important to choose one, or a few, which can be expected to have an effect on the result. Process characteristics, which are expected to influence the results of the process, are the potential quality check points. Clearly, a quality control point for one process can be seen as a quality check point for another process.

We believe that there is plenty of scope for defining quality measures and establishing quality control/quality check points throughout an educational institution. Such measures are important in connection with continuous improvements.

Continuous Improvements

The importance of continuous improvements has been illustrated by Imai where he has presented an interesting and a singular definition of quality. He has simply defined **quality as everything which can be improved**, which is an extreme view from Western thinking of quality. However, the interesting point here is that the Japanese see a very close connection between quality and the concept of improvement.

The purpose of achieving higher quality, both internally and externally, is to make the internal processes "leaner", which in turn will prevent defects in the internal processes and lead to lower costs. External quality improvements are aimed at the customer to increase external customer's satisfaction. Both types of improvements are closely connected with top management's understanding of the company's annual quality audit. The quality audit should be an integral part of the educational institution's culture where all employees actively participate in the quality improvement process.

In our experience the development of ideas for quality improvements is one of the most valuable investments an organisation make to provide their biggest return on

resources. We believe that educational institutions have a lot of opportunities for quality improvements which should be utilised.

Education and training is only one, albeit necessary, condition for the involvement of an educational institution's employees and students. It is far from sufficient, however. Continuous improvements also require **"leadership"**, which is part of the TQM pyramid.

Everybody's Participation

As previously mentioned, TQM is process-oriented. Here external customers, as well as the internal customers (including the students), are all part of the educational institution's processes. Therefore the customers, together with their requirements and expectations, must be identified in all the processes. Following identification the next step will be to plan how these requirements and expectations can be fulfilled. This requires detailed feedback from the customers, so that their experiences and problems can be associated in all processes. Here the feedback is a condition for the continuous improvement of the educational institution and for this to be effective everybody should participate.

However to encourage everybody to participate it requires education and motivation of both management, employees and students. The top management of the educational institution must get involved in as many education and training activities as possible. In our view, the active participation of top management in the annual quality audit is an important part of these activities and their commitment will quickly filter down throughout the organisation.

In general department managers will influence middle managers, who will then influence their subordinates, and so on down the hierarchy. Deming's 7th step of his plan to implement TQM will be a natural consequence of the diffusion of the quality message.

Work teams are an important and indispensable part of the firm's quality organisation, and Japanese experiences (see Lillrank, 1988) show that it may be necessary to establish a parallel quality organisation in order to make sure that work teams start making improvements immediately,

For the realisation of the TQM vision in any organisation including educational institutions, management must accept the condition **"that it will help" to involve all employees and the students.** A further condition is that management also invest in the education and training of all employees and students at all levels in :

1. Identifying failures and problems.
2. Finding the causes of failures and problems.

3. Prevention, i.e. preventing the causes of failures and problems.
4. Start again.

There is a crying need for massive educational and training programmes to equip management, students and employees with both the knowledge and skills to develop the above quality improvement process continuously.

After they have received the necessary education, employees and the students can begin training. The best form of training is to use the techniques on the problems they have identified. This provides the best opportunity to the people to embark on the quality journey.

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L'enseignement de la statistique du Primaire à l'Université.

D. DACUNHA-CASTELLE

Université Paris-Sud - Orsay

L'enseignement de la statistique et de manière beaucoup plus générale la formation au traitement des données numériques ou symboliques (recueil, examen critique, présentation, manipulations, interprétations) est certainement l'un des points faibles de la plupart des cursus de mathématiques et au-delà de bien des cursus disciplinaires. Introduit à doses variables, souvent considéré comme un pensum incontournable redondant, formaliste et mal formalisé le travail sur les données n'a ni le statut ni des cursus convenables. Les raisons pour repenser l'enseignement sur ce sujet sont fortes, en particulier :

1 - Dans tous les pays, y compris dans certains pays du Sud, l'accumulation des données numériques par voie de presse ou de télévision est un fait de société.

2 - L'économisme triomphant des sociétés modernes laisse le citoyen désarmé, handicapé pour faire entendre sa voix s'il ne peut analyser ce qu'est un taux, une variation de taux, un tableau à double entrée. Tous les pouvoirs politiques manipulent en permanence, sans une éthique claire, ces données. Le pouvoir bancaire dans les sociétés développées use pour sa publicité d'un langage pour le moins équivoque, qui masque bien des réalités.

3 - Plus qu'autrefois, les élèves des enseignements professionnels doivent maîtriser parfaitement certains éléments.

4 - Laisser aux seules personnes passées par une formation de gestion ou d'économie la maîtrise de ces outils simples est particulièrement dangereux. Le plus alarmant est de voir des maîtres es-sciences incapables d'interpréter rapidement un tableau de données en situation d'hypothèses simples.

Il faut donc construire des progressions du cursus de mathématiques sur ce sujet, mais si les mathématiques jouent un rôle central, le succès implique impérativement du travail à travers les autres disciplines, on peut dire sans exclusive.

Je me propose d'expliciter très précisément la situation en France, à partir des cursus et des pratiques dès l'Ecole Primaire jusqu'à l'Université en intégrant bien sûr des problèmes très divers et essentiels comme :

- L'usage de l'outil informatique , spécialement des calculatrices...
- La formation des maîtres...
- La nature des examens...

PROBLEMES DE L'ENSEIGNEMENT DE LA STATISTIQUE ET DE LA PROBABILITE DANS LE CURSUS DE L'ENSEIGNEMENT SECONDAIRE.

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On pose parfois la question: est-il vraiment nécessaire d'introduire des éléments de probabilité et de statistique dans le cursus de l'enseignement secondaire? Pour l'auteur de cet exposé, il n'y a pas de doute. D'un côté, les éléments de la probabilité et de la statistique représentent un événement assez important dans la culture contemporaine et ne pas les révéler signifie dissimuler aux yeux de la jeunesse une des plus grandes réalisations de l'esprit humain. Par ailleurs, ce qui n'est pas moins important, est que sans la connaissance des bases de la probabilité et de la statistique il est difficile de comprendre certaines notions indispensables en physique, biologie, chimie, économie, médecine, sociologie etc. D'autant plus que le domaine d'application des méthodes statistiques s'étend de plus en plus en embrassant tous les côtés de l'activité humaine. Si autrefois la probabilité et la statistique étaient utilisées seulement en mathématique, physique et technique, on se rend compte aujourd'hui que les modèles normal, lognormal, exponentiel, de Poisson, binormal, de Pareto etc. ont pénétré dans les sciences sociales et humaines. Donc des notions comme le hasard et la probabilité, la moyenne et la variance, la population et le temps moyen de vie, et les résultats fondamentaux de statistique comme la loi des grands nombres ainsi que le théorème limite central entrent très naturellement dans le langage des écoles secondaires. La statistique permet d'une part de construire de bons modèles mathématiques dans les études, par exemple, d'évolution dans le temps d'une population dont tous les individus se reproduisent, meurent et agissent les uns sur les autres et d'autre part de mieux expliquer les lois de Mendel, la désintégration des atomes radioactifs, la propagation des épidémics etc. Le but de l'auteur est de montrer que les notions de probabilité et de statistique sont très simples et concrètes si on les représente en utilisant notre intuition, comme le faisaient Fermat, Pascal, Leibnitz, etc. On peut expliquer la simple nature des notions statistiques sans perdre leur strict sens mathématique.

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PRESENTATION DU DIDACTICIEL:"TECHNIQUES DE LA STATISTIQUE"

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Didacticiel réalisé par le CNAM (Conservatoire National des Arts et Métiers), centre régional du Languedoc Roussillon et chaire d'Analyse des Données du CNAM Paris,en association avec l'Unité de Biométrie ENSA M./INRA/Université Montpellier II

Le didacticiel "Techniques de la Statistique" est une collection de six modules indépendants:

- STATISTIQUE DESCRIPTIVE
- AJUSTEMENT LINEAIRE
- DENOMBREMENTS ET PROBABILITES
- VARIABLES ALEATOIRES
- ECHANTILLONNAGE
- TESTS

Il s'agit de six modules EAO de type tutoriel, autonomes les uns par rapport aux autres, et utilisables sur micro-ordinateur de type A.T., sous DOS ou WINDOWS.

A ce jour, le module "AJUSTEMENT LINEAIRE" est diffusé par STUD-I, les modules "DENOMBREMENTS ET PROBABILITES" et "VARIABLES ALEATOIRES", dont le scénario a été validé par un comité de pilotage, sont en cours de réalisation informatique, les autres modules sont en cours de rédaction.

Ces modules recouvrent le programme d'enseignement "Techniques de la Statistique" du CNAM, utilisé en formation professionnelle, et s'adressent aussi à de nombreuses catégories d'étudiants dont le cursus comporte une initiation à la statistique: sciences économiques, médecine, pharmacie, DEUG B, IUT, BTS...

Le didacticiel peut être utilisé en complément d'un enseignement traditionnel, pour l'enseignement à distance, ou comme outil d'autoformation, par des personnes utilisant les statistiques dans leur activité professionnelle.
Le module "AJUSTEMENT LINEAIRE" est actuellement utilisé par des étudiants du CNAM, dans le cadre de l'enseignement à distance.

Chaque module comprend une présentation, une partie "procédure", où les notions nouvelles sont introduites peu à peu de façon interactive, un résumé et des exercices. On y fait un usage intensif des graphiques, des simulations, et des analyses de réponse.

La conception de ce didacticiel a fait l'objet d'un mémoire d'ingénieur CNAM:
VERDOIRE E.:*Enseignement assisté par ordinateur du cours "Techniques de la Statistique AO"*, mémoire ingénieur CNAM, Montpellier, 1990.

The Role of Statistical Societies in Education

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1. Introduction

Statistical societies listed in the International Statistical Institute's Directory were solicited for information pertaining to their specific roles in education and public awareness. Many societies responded with a range of detail, a summary of which is incorporated into the text below. Activities generated by the responding societies tended to focus on Workshops and/or Short Courses, and High School and University Education with concerns centered on a variety of issues such as curriculum, training of teachers, and related issues. In some instances presecondary education was included. We look at these in turn. Then we attempt to address some more general issues which we gather under a heading called Philosophy, perhaps an inappropriate misnomer but one that is intended to convey a flavor of what educational issues, in which societies should perhaps be involved, and how this might be achieved.

2. Workshops and Short Courses

All societies are engaged in the business of conducting meetings or conferences on a regular basis be that annually or biennially, and in some cases there are two or more meetings per year. The initial, and often still the prime motivation behind these endeavors is the dissemination of new research results or their application. While in a broad sense the sharing of such material can also be viewed as education (of the latest

cutting edge work), we shall not include this particular aspect herein.

An increasing and broadening trend among societies is to conduct Workshop and/or Short Courses in conjunction with the traditional meetings. These take a variety of forms. At one extreme is the model such as that of the American Statistical Association, which has its Short Course program preceding, and quite distinct from the so-called Regular Meeting, even to the extent of there being a separate registration fee structure involved. Similar workshops include those held by the South African Statistical Association, Eurostat's Training of European Statisticians, the Indian Society of Agricultural Statistics, the International Society of Clinical Biostatistics, Regions of the Biometric Society, Statisticians in the Pharmaceutical Industry, and the Philippine Statistical Association. At the other extreme is the model exemplified by the Inter-American Statistical Institute which runs a Seminar and School simultaneously, with the Seminar occupying one half day and the School on the other half day for each day throughout a week. Each segment has a specific and complementary topic. Thus, for example in 1993 at its Session in Brazil, the School on Regression had the same lecturer throughout; and the Seminar on Biostatistics, taking a different aspect each day, featured a leading expert giving an overview of the topic and review of major developments in the area. Both of these two components necessarily are classified as education. The opportunity to present one's own current research results, though still present, assumed a subsidiary role.

That particular Brazil Conference had an additional feature in that the major speakers came from a co-sponsoring society (in this case the American Statistical Association). The resultant cross-fertilization of ideas and interactive contacts typified much of what has frequently been suggested and sought by representatives of statistical societies at recent ISI Sessions as they have explored avenues for scientific exchanges. In a similar vein, there are the European Courses in Advanced Statistics,

week-long programs of instruction on specific topics held biennally and supported by a consortium of statistical societies from Europe (with Belgium, France, Germany, Italy and the Netherlands forming the initial membership, along with other countries who are subsequently declaring their interest). Likewise, there is the Centro Interamericano de Ensenanza de Estadistica which serves the member states of the Organization of American States by providing, among other things, training and instruction through courses, workshops and seminars to regional members involved in statistics as well as providing guidance and help where appropriate to the national universities. The Finish Statistical Society arranges seminars on education of statistics in schools. Some societies, such as the Philippine Statistical Association, the New Zealand Statistical Association, the Psychometric Society and the Austrian Statistical Society, have conducted entire meetings focussed on some aspect of education. This contrasts with a frequent feature of including sessions specifically targeted at educational issues as part of the scientific programs of regular meetings.

3. Educational Institutions

Involvement of statistical societies in educational institutions, be these universities or teritary education, high schools or secondary education, or in few instances even lower level or primary education, has assumed a variety of forms some of which we will attempt to summarize here. The first topic falls under the rubric called curricula. Many societies are involved to varying degrees in the setting of curricula that include statistics. At one extreme, many societies can empathize with the example of the Finnish Statistical Society as it continues to strive for statistics to be an independent subject at schools, with in their opinion not enough success to date though senior secondary students can learn about statistics as part of their mathematics curricula. At the other extreme, many of us are doubtless excited by the New Zealand Statistical Association's success with the 1992 major document Mathematics in the New Zealand

Curriculum containing a statistics strand throughout all levels of school education (ages 5 to 18 years); this Association also has succeeded in obtaining a voice on the national curriculum structures body. Likewise, the Statistical Society of Australia as a part of the Australian Mathematical Sciences Council has been successful in including statistics and probability as one of five strands in a National Mathematics Statement; also "chance and data" are often introduced in primary school curricula. The Italian Statistical Society has two publications of relevance, specifically, the SIS-Bullettino which provides a forum for the discussion of problems relating to the teaching of statistics, and the SIS-Formazione which focusses on course material as well as teaching aids. The Psychometric Society has recently completed a survey of colleges and universities throughout the United States enquiring about the types of measurement and quantitative programs offered.

While some societies such as the Italian Statistical Society play an active role in the setting of university curricula and course content for statistics, the Institute of Mathematical Statistics (for one; presumably there are others) was a major player in the actual establishment of statistics departments and the alternative option of programs in statistics within departments of mathematics (in the United States). These developments were subsequent to a resolution of that Institute and based on suggestions and ideas succintly delineated by Hotelling (1940) in his treatise on the teaching of statistics. Although this was written more than fifty years ago, many of the general principles expressed then apply equally today even though some of the specifics will perforce have different (modern) counterparts. How important this was to the actual establishment of departments would be difficult to gauge. Certainly, from the mid-1940's to about the mid-1960's there was considerable growth along these lines in the United States (with a similar growth in many other countries, though operating under a different time frame), and so it might seem that Hotelling's words of wisdom were

at least contributing factors. However, it must also be said that departments of statistics and most especially programs and laboratories were being formed prior to 1940 (the first being the Department of Biostatistics at Columbia University established by Pearl and Reed with attention focussed on medical statistics and related fields).

Monitoring the quality and content of courses and programs to some degree seems to be an implied activity. The New Zealand Statistical Association already makes submissions to the relevant government agencies on process issues such as examinations and scaling in student assessment and their effect on the real curriculum, gender equity, and in providing teachers with professional development opportunities. Some statistical societies or agencies have engaged in the (external) review of programs in statistics at tertiary level institutions, usually by recommending or appointing members to carry out the review. A related issue is accreditation which will be addressed briefly in the next section.

Turning to the training and/or education of teachers at the secondary level and even some at the primary school level, we report that the South African Statistical Association has established Teachers Centres in all major regions of the country, where school teachers receive extra training on some specialised topics under the guidance of an instructor appointed by the Association. The Statistical Society of Australia, the Royal Statistical Society and the Italian Statistical Society run workshops for the education of teachers. Little direct information on this specific activity was provided by the responding societies; however, it is my belief that such training is attracting increasing attention.

By far the largest undertaking on teacher training is that conducted by the American Statistical Association through its Quantitative Literacy Programs. This was developed initially under the leadership of Richard Scheaffer (see Scheaffer, 1989),

and has grown to the extent that the association appointed a Director of Education, a position currently occupied by Kathryn Rowe. Since both these individuals are speaking at length elsewhere as part of ICOTS4, for completeness we restrict ourselves here to some brief summary remarks drawn from an overview leaflet provided by the American Statistical Association. "The American Statistical Association ... in collaboration with [the National Council of Teachers of Mathematics] has over the past decade produced a series of quantitative literacy [QL] projects ... the development of four QL series booklets ... on which to base quantitative literacy curriculum; ... created, tested, and fielded Quantitative Literacy Workshops for middle and high school teachers (now independent and highly successful, these 5-day summer workshops have trained 3,000 teachers in locations from Hawaii to Maine to Puerto Rico across the country; seven [were] scheduled for 1993); ... developing a data driven curriculum strand for the high school mathematics .. and ... now in development, takes [QL] into the elementary school curriculum. ASA's plan for future projects includes QL initiativves in science and social science curriculums and development of assessment tools." Also, all "project materials are written by teams of classroom teachers, other mathematics educators, and statisticians, and all are field-tested in classrooms". This has resulted in a long list of related publications. In addition, these is a regular newsletter **Statistics Teacher Network** distributed to 5,500 secondary mathematics teachers.

As an alternative to the insertion of statistics directly into school curriculam, there are several other creative ways of drawing attention to the importance of statistics and its role in the everyday would. The Polish Statistical Association, as one of its statutory tasks, supports, sponsors and cooperates in organizing Concise Statistical Yearbook competitions for secondary school students, including the financing of prizes for students, teachers, and schools (see Kordos, 1993). The New Zealand Statistical

Association provides statistical expertise in judging at the annual science fairs for secondary schools. In 1992, the Philippine Statistical Association held its First Statistics Quiz as a cooperative endeavor with several industries. Teacher bursaries to enable teachers to improve their own expertise in statistical education have been established by the Royal Statistical Society. Finally, the Spanish Statistical Society has translated the volume **Statistics: A Guide to the Unknown**, Tanur et al. (1978) into spanish.

Last, but most certainly not least, is the the Statistical Professorial Chair at the University of the Philippines Statistical Center, set up by the Philippine Statistical Society with an appropriate monetary donation. Furthermore, an Endowment Fund has been created; the earnings of the fund are to be used to fund research and training activities of the Association.

4. Philosophy

In the previous sections, brief sketches of specific activities undertaken by societies currently and/or in the past have been presented. In this section, attention is drawn to some issues with which societies may wish to be concerned. There are other debates to which we may be drawn reluctantly, or gladly, but which have an urgency because of outside pressures. Trying to adjust to external forces imposed upon us is never as satisfactory, nor as satisfying, as when we are able to contribute meaning fully to the deliberations. Therefore, it is important that we anticipate such issues whenever possible and to prepare ourselves appropriately.

One situation demanding of our attention is accreditation. While none of the responding societies mentioned any specific activity on this, it is safe to say that this is an issue looming larger on our horizons. The so-called professional disciplines (e.g. law) have long been subjected to accreditation demands. At the other end of the scale, it is doubtful that disciplines such as those in the humanities and sciences (e.g.,

art, history, biology) are, as disciplines, accredited. Where does statistics fit? If viewed as a part of mathematics, it probably fits with the latter category. Or, are we an accrediting type discipline? It is not possible to answer that question here. As a harbinger of things to come, recently, Jaschik (1993) in interpreting proposed regulations issued by the United States Department of Education expressed the opinion that "... [t]he regulations ... would require accrediting agencies to make much more detailed evaluations of the colleges they monitor. Agencies would be required to assess the quality and appropriateness of a college's curriculum, the quality of the faculty ....". Whether or not statistical societies become accreditting agencies (for statistics programs) or whether this should be left to government agencies to set the policies is open to debate, and is for individual societies to decide. However, if societies do broach it, they should be aware it is a potentially devisive issue. Therefore, there is a need to tread carefully, and for societies to become fully informed of the pros and cons on all sides of the argument (and there are many sides!) before setting their policy position. As a final comment, accreditation is not to be confused with certification (of the working statistician; also a potentially devisive issue but one outside the purview of this discussion as it is not directly concerned with education *per se*); Senn (1993) presents a brief but balanced perspective on the topic.

Another issue revolves around the quality of instruction. Some universities have employed the so-called student evaluations (of their instructors, possibly also of courses) for at least two decades. For all the energy that has been expended locally on improving or modifying questionaries and procedures in an effect to obtain valid ratings, it is still generally accepted that current evaluations are at best an imperfect measure, and indeed only one measure, of instructional quality. [There is no solace either in Eley and Thomson's (1993) conclusion that "the reliability of student ratings is often higher than that of peer ratings".] Furthermore, there can be a vast difference

between "good evaluations" and "good teachers". No doubt all of us know of instructors who consistently receive good student evaluations but whom we would be hesitant to ascribe the descriptor of being "a good teacher". It is usually agreed that students are not qualified to assess the instructor's expertise in an area; nor can they know if old or current, or more generally, appropriately selected, material is being taught. Likewise, among other devices employed, entertaining instructors who give easy grades typically earn for themselves better evaluations. However, there are other students together with parents, taxpayers and university administrators seeking excellence in teaching, and in many localities this excellence is now being demanded. Thus, the question as to how this is to be accomplished must be addressed, but not before questions as to how this is to be assessed properly have been resolved. Given that as a profession statisticians are in the business of the measurement and quantification of information and given that education as an entity has existed a long time, it is perhaps surprising that we have not long ago developed procedures (perhaps in consort with specialists in education) which by now would stand as robust, valid, respected and universally accepted measures of instruction. As far as I could ascertain, such measures have still to be developed. Presumably this presages a debate as to what "exactly" (if that is possible) constitutes instructional excellence and/or effective teaching. While this is outside my area of expertise, one thought is that we are dealing with a multivariable percept with each variate (whose nature is to be determined) weighted according to some criterion to be established. Therefore, the question arises as to the whether or not statistical societies should play a leading role in this development and its subsequent dissemination.

Let us return to the inclusion of statistics as part of overall curriculum requirements. While recognizing that concentrated specialization in a choosen discipline can occur anywhere from early high school to the postbaccalaurate degree level depending

on the country, all students do experience at some stage a broad based curricula designed to provide a general education. For the sake of discussion here, let us consider statistics and its place in an undergraduate eduation curriculum. The general studies core common to such curricula are typically designed to expose the student to a fundamental spectrum of subjects to broaden their vision to the world around them, including the development of their intellectual capacity and the formation of some basic skills. Thus, this core seeks to achieve a balance across the humanities and the sciences, for example. Though it is often not the case as it is played out, the focus should be on fostering a mind of inquiry rather than on an accumulation of facts. In some institutions, statistics is available as an option as part of the mathematical component of this core. When thinking of our discipline as "statistics in research" (as distinct from "research in statistics", which is not under discussion here) together with "statistics in society", it is clear that statistics plays a role very consistent with the philosophical foundations on which this general studies core is built. Therefore, it would seem that to achieve the proper balance not only across or within the sciences but across the entire core, a course in statistics or data analysis should be a mandatory component and not simply one of the mathematics options. My attention was caught by a recent article by Schwartz (1993) exhorting instructors and students to distinguish between scientific truths and pure science. Schwartz is apparently an anthropologist, but he clearly understood the importance of establishing and testing hypotheses, and gathering data, so that with an enquiring mind one seeks to find the truth. Whether or not he has any notion that he is doing so, he is essentially espousing a canon underlying statistics, and further is insisting it has a central and vital role to a basic education. Statistical societies can provide leadership, even if only by establishing guidelines for departments as they work within their institutional structures, to achieve this goal.

Finally, may we reflect upon one poignant response saying effectively that while

that society recognises the importance of making contributions to education and aspires to do so, its own financial exingencies preclude any such luxury at this stage. Those of us who have visited such countries can attest to the difficulties encountered. I myself recently was taken through the once magnificent library of a major university; there seemed to be no journal or text published in the last twenty years or so among its holdings. Yet, in some (mostly western) countries the earlier boom in hiring of statistics faculty is now matched by a large number of retirees many of whom have valuable collections of statistical literature which they would gladly contribute. The International Biometric Society several years ago established a program whereby back issues of its journals were sent to libraries in what are now transition countries and in developing nations. Can, or should, societies become conduits in this process? Or, maybe the ISI itself can offer leadership here. Likewise, there are numerous other avenues which can be explored and/or developed by societies; in reality, the range and nature of the opportunities are manifold and multiplied by our collective experiences. Hopefully, those ideas shared here will lead our imaginations and resolves to further involvements.

Acknowledgements

As indicated at the outset statistical societies were contacted for information for inclusion in this article. Where clearly identifiable, specific references have been cited. Most of the material however came as comments in a covering letter, or in leaflets or other similar documentation. With a few exceptions, societies have been identified in the text with their respective activities. Personal communication comments were generally not directly attributed as it was felt to do so would clutter and disrupt the flow of the text. However, may I hereby acknowledge the following: T. Ackerman, A. W. Ambergen, E. Bader, P. K. Berry, T. Brown, M. Camden, U. Casey, W. Conradie, M. -F. Coumont, J. Z. Forman, R. Franco, I. J. Goddard, E. Keogh, G. Kulldorff, P. Narain, G. Oeuvray, R. Panula, B. Remiche, A. Rizzi, K. Rowe, R. Scheaffer, S. Senn, K. Sharples, A. Smith, J. Tejada, and R. W. Trinidad; all are thanked for their contributions and help. Of course, any extraction and interpretation of their material must remain as my responsibility.

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STATISTICAL EDUCATION IN BANGLADESH

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Statistical education was introduced in Bangladesh in the late forties when the Department of Statistics at Dhaka University was established in 1948 by Professor Qazi Motahar Husain. Professor Husain was born in 1897 [1] and had obtained his Bachelor's degree and Master's degree in Physics. He joined the Department of Physics at Dhaka University in 1921 and later taught in the Department of Mathematics. Professor Husain later obtained his Ph. D. degree in Statistics from Dhaka University. His doctoral thesis was in the area of experimental design.

It may be noted that people like R. A. Fisher (born in 1890) and P. C. Mahalanobis (born 1893) [2] whose degrees were also in Math-Physics and Physics, respectively and who had already made significant fundamental contributions to statistics, had also influenced the thinking of Professor Husain. I was told that Husain and Mahalanobis were good friends and Husain used to go to Calcutta quite often to see Mahalanobis. As was the case with many statisticians in those days, Husain studied statistics on his own without any formal training in statistics.

Professor Husain thus initiated statistical thinking in Bangladesh. After he created the Department of Statistics at Dhaka University in 1948, he

wanted to establish a statistical institute which would provide applied and professional training in statistics. Thus, he created the Institute of Statistical Research and Training at Dhaka University in 1964 to achieve this goal.

Professor Husain had a profound influence on the statistical community of Bangladesh. His goal was to make Bangladeshi students statistically literate. Currently, all the universities including agricultural university, engineering universities offer statistics courses in their programs. Over two thousand two-year, four-year, and master's level colleges have statistics courses and programs. Some simple concepts of probability and statistics are taught at the ninth grade and more statistics courses are offered at the senior high school levels. Thus, statistics courses at various levels are taken by hundreds of thousands of students each year in Bangladesh.

In Bangladesh, the medium of instruction is Bangla (Bengali) except that at the university students understand English and the courses are taught usually using a mixture of English and Bangla languages. However, at the junior and high schools, statistics courses are taught only in Bangla. Hence, statistics texts in Bangla written by Bangladeshi authors are mostly used except at the universities where mostly the standard English textbooks are used. The statistical journals published by universities in Bangladesh are all in English language.

Statisticians in Bangladesh occupy important positions besides teaching. Statisticians have served as vice chancellor (equivalent of university president in the United States) and deans of universities, as cabinet ministers and topmost civil servants in the government. Bangladesh may be among few countries where statisticians got opportunities to be in positions of such high position and authority in both academic and government institutions. Bangladeshi statisticians have also served in various international organiza-

tions.

Most of the offerings of courses in statistics and their emphasis are generally in the area of applied statistics. This is because of the fact that almost all the jobs available there require those kind of statistical background. The main emphasis currently are in the areas of demography, sample survey, design of experiments, economic statistics etc. Mathematical statistics is not popular there since there is hardly any job available in Bangladesh for a mathematical statistician. Most Bangladeshi statisticians who have specialized in mathematical statistics are working outside Bangladesh in teaching positions at universities. Bangladeshi statisticians who are currently pursuing doctoral programs in mathematical statistics plan to go back to teaching in Bangladesh universities. This will strengthen the statistics programs there.

In view of the present lack of emphasis on mathematical statistics, the students at university level hardly take rigorous advance mathematics courses such as real and complex analysis, measure and integration, functional analysis, abstract algebra, or even advance calculus or ordinary and partial differential equations or linear algebra. This really puts the students in a very disadvantageous position when they go abroad for graduate work in statistics. The students who go abroad to pursue graduate studies in statistics thus take a number of courses in advance mathematics to remedy the situation.

During my several visits to Bangladeshi universities, I brought out this fact and advised the universities to include a core mathematics program as part of the graduate and undergraduate programs in statistics. That has not yet been rigorously implemented either in theory or in practice. It is for this reason that not too many statisticians in Bangladesh have pursued any significant research in the realm of mathematical statistics.

Bangladeshi universities have tried to keep up with the changes that took place with the advent of computer instruction. The universities now provide training and instruction using statistical packages such as SAS and SPSS besides other software packages. The statistics departments have PC's equipped with statistical packages, which the students and faculty use quite frequently. Many students are familiar with standard computer languages such as Basic, Fortran, Pascal, and C etc. Thus computer has become an integral part of statistical education.

Bangladesh Statistical Association was formally established about ten years ago. The association serves as a watchdog for the implementation of statistical methods in government and industry and also for the development of statistical curriculum in academic institutions. The members of the association are almost all from universities and government organizations. They hold meetings every two years.

The Statistical Bureau is the main statistical organization of the government. The Bureau is headed by a top civil servant who has academic background in statistics. The Bureau oversees all statistical activities of the government including data collection, surveys and censuses. The Bureau usually is assisted by statistical experts from the United Nations and other international agencies. The government is the biggest employer of statisticians in Bangladesh.

Career as a statistician is among one of the top choices of the students in Bangladesh and hence there is a very stiff competition to enter a statistics degree program at the university level. This is because of the fact that there is high demand of statisticians in Bangladesh.

Bangladeshi statisticians residing in the United States and Canada formed a new statistical association called the North America-Bangladesh Statistical Association (NABSA) in 1989. Once the Constitution of the association is approved and the association is registered, the association will start functioning officially. The goals of the new association are: To develop professional relationship among the Bangladeshi statisticians; To encourage and initiate collaborated research among the Bangladeshi statisticians; To publish a statistical journal; To provide statistical training, consultation, and services related to the improvement of Bangladesh; To develop communications with educational and research institutes in Bangladesh; and To develop funds and resources to help Bangladeshis to pursue research or higher education in statistics or related areas.

It is hoped that as we move to the twenty-first century Bangladeshi universities will further strengthen their mathematical and applied statistics curricula to provide their students a solid foundation of statistical theory and methods. Also, the Bangladesh Statistical Association along with the cooperation of the North America-Bangladesh Statistical Association will play a more active role in further strengthening statistical programs and education in Bangladesh.

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ROLE OF PROFESSIONAL SOCIETIES IN CREATING PUBLIC AWARENESS ABOUT STATISTICS

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If a branch of science is to benefit humanity, an awareness about its implications and potentials has to pervade the society at large. In particular, those who frame, implement and evaluate public policies as well as those who determine the effectiveness and efficiency of development activities have to be provided with an unbiased, objective and impassioned view of this branch of science, before the society and more so the common man derive any benefit out of it. Teaching and research in this branch of science can, no doubt, equip a selected few with a good knowledge of the subject and enable them to use this knowledge to further enrich the subject and/or to apply such knowledge to solve problems facing mankind. These activities confined within the corridors of academic institutions - have to be largely augmented by promotional activities to create 'public awareness' of uses, abuses and misuses of the subject, prevailing as well as likely. Professional societies - branded variously over the ages - can and do play a big note to boost uses, caution against abuses and reduce misuses of the subject.

All this is true for Statistics - a scientific method that runs through different branches of science, aids decision-making based on objective evidences and adds to the efficiency of operations and investigations. Statistics has strong and meaningful interfaces with many professions. Professionals exert a lot of influence on the acceptance and uses of a subject like Statistics. And once these professionals who include, among others, managers of private and public enterprises are duly exposed to the nature and principles of Statistics and are convinced that Statistics can be gainfully employed to serve their long-term interests, public awareness about Statistics and its role in planning, monitoring and evaluating development activities at meta -, macro - and micro levels will receive a big boost.

Professional societies in the fields of Operational Research and Management Science, Quality and Reliability, Cybernetics and Systems Analysis, Computers and Information Technology and similar other subject specialities can significantly contribute to the creation and promotion of public awareness about Statistics through the large clientele of their members and constituents. Properly oriented, these bodies can formulate codes of professional ethics and insist on their observance by members,

thus preventing misuses and abuses of Statistics. This apart, professional bodies in terms of their specialised and applications-oriented training programmes can build up greater competence among the trained to keep abreast of latest developments and current applications of Statistical methods for analysing and solving specific, real-life problems compared to the somewhat regimented and didactic teaching programmes in universities and colleges.

To be effective in this sense, professional societies have to do a lot of rethinking and re-orienting. Sometimes, they have been providing lessons in some topics of great relevance and proven utility in industrial or business situations without properly treating them as statistical methods. In fact, some of the more talked about apparently innovative techniques like the Taguchi methods in the context of Quality Management are nothing but spin-offs of established statistical methods and techniques (like fractional factorial experiments). Similarly, in the field of Operational Research, professional societies do admit in their training programmes persons with different academic backgrounds and engaged in diverse activities - many of whom would not possibly qualify for admission to formal education programmes in Statistics. They also pick up some lessons in Statistics but do not often realise that they need more of statistical methods to estimate optimal solutions to many of the models they discuss, given real life data, before they can properly use their training in Operational Research.

A correspondent in RSS News (February 1994) summarises some prerequsites for pushing Statistics to public through television (BBC) programmes as follows :

We need a 'point of entry' for the programme, for example

- the contribution that Statistical science would make to the direction of the government white paper Realising and Potential : A Strategy for Science, Engineering and Technology, or

- the environmental consequences (wasted material, increased CO_2 emmissions, scrap rate) of over engineering the product to cater for excessive variation.

We need a 'controversial' angle to make people want to watch and stay watching, for instance

- do statements like 'the statistics are misleading' (when people really mean presentation of data) implicate statisticians as 'misleading' scientists and professionals, or

statisticians contribute more than accountants.

We need to address the perceived 'dullness' of our science; i.e. how can we demonstrate visually what we contribute.
We need some simple, exciting and important contributions of statistics to a variety of problems (industrial, medical, social, etc.) which could be put over in a way which would be accessible to the man on the street.

Professional societies in Statistics and kindred subjects have an edge over colleges and universities to fulfil these pre-requisites and to organise public awareness programmes through mass media. They can afford to be unconventional in their approaches, they are usually more efficient and more accountable (to their constituents) than colleges and universities - with little subsidy and protection from the government, and they can enjoin some professional ethics on their members.

Professional societies of engineers, accountants, medical practioners, journalists and similar other people in many countries have been able to mould public opinion about their respective professions, to create and foster public awareness about the necessity and utility of the subjects or branches of knowledge covered by such professions and even to influence the professionals in meeting the expectation of the public. There is no reason why professional bodies of statisticians will not succeed in the mission. They need support and guidance.

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GLIMPSES OF NUMERACY - THE EXPERIENCE OF STATISTICS NEW ZEALAND

Vince Galvin

ABSTRACT

In providing information to different decision makers within the community a central statistical office forms a view of how effectively quantitative information is used.

This paper describes the experience of Statistics New Zealand in attempting to examine how well the process of defining information needs and using data to make decisions works in New Zealand.

INTRODUCTION

For a democracy to function it's members have to be informed. This was expressed eloquently by the then French minister of Education Lionel Jospin in opening the 1989 ISI conference;

"The right to information has become one of the fundamental rights of the twentieth century citizen. In a society where information and the media play a considerable part, your (professional statisticians) action helps safeguard a fundamental human liberty.....The working methods you use are complex, the data you deal with difficult to evaluate. An effort to explain (to the public) is necessary. This effort is required by democracy. All citizens must be in a position where they can understand and assess the policies followed by governments."

How can we decide what sort of statistical effort will achieve this lofty aim? We want at least two things to happen. We want effective compilation and utilisation of statistics to take place in government decision making. We also want everybody to understand enough about this process so that they think they can make informed contributions to public policy debates.

How do we measure are current situation or our progress towards these goals? How many people have to understand how much for things to work well?

This paper will not resolve these questions! It will take the view that a desirable level of public understanding is one that allows for the effect use of statistical work in public policy. Consequently, it will look at the public's statistical literacy in the context of the process by which statistical reasoning is used in making public policy decisions.

I will present the view that the practical course of action is to try and identify the system that identifies statistical needs, allocates resources to statistical collection and uses statistical reasoning in public decision making. Then consideration needs to be given to making an assessment of where it is at risk of breaking down in a way that seriously compromises it's

usefulness and identify priorities for corrective action that can be taken. This will be from the perspective of a National Statistical Office (NSO).

This paper will discuss some of these issues, first by developing a framework for considering them that is largely coloured by our experience in New Zealand and secondly by looking at the way we have approached these activities in New Zealand.

STATISTICS IN PUBLIC POLICY

We can start by describing the sort of contribution statistical work can make to public policy debates. Statistical work gives some idea of the distribution of outcomes that might result from any one situation. It adds to our understanding of phenomena by making some explanations of how the world work more likely and some less likely. In describing how theory and data are combined in understanding events Friedman (1935) commented;

"Observed facts are necessarily finite in number; possible hypotheses, infinite. If there is one hypothesis that is consistent with the available evidence, there are always an infinite number that are.....Additional evidence with which the hypothesis is to be consistent may rule out some of these possibilities; it can never reduce them to a single possibility alone capable of being consistent with the finite evidence"

How much is this sort of knowledge worth to the community in terms of improving public decision making and helping people understand the impact of government policies? The former US Department of Commerce Chief Economist Courtney Slater summarised his observations on the American situation as;

"Respondents must commit valuable resources to providing the information requested. The benefits of participation are diffuse and difficult to identify, but the costs are explicit and resented. Yet focusing only on the costs naively ignores the more serious costs of making inferior public or private policy decisions when inadequate or misleading information must be used. The marginal benefits of good decisions continue to exceed the marginal costs of collecting data....Government collection and publication of statistical information benefit from economies of scale unlikely to be available in the private sector..... only the federal government prepare a continuous record of data protected from the fluctuating interests of individual institutions".

The collection, compilation, analysis and dissemination of statistics is a public process and can only proceed if it's benefits are widely understood. Everyone in the community is a supplier of statistical information and bears the cost of supply to a greater or lesser extent. This also helps explain why an appropriate level of statistics doesn't occur without government involvement. Something that has to be comprehensive to have any meaning will not be in any individuals interest to support alone.

THE PUBLIC PROCESS

In broad terms the sort of 'public system' that I have in mind is:

1) The need for information is identified by government officials and interested community groups.
2) These groups make representations to the government and to the National Statistical Office and these needs are assessed against other requirements.
3) Surveys to obtain information are carried out.
4) Data is the analysed for the purpose of problem assessment and programme development by researchers in various institutions.
5) Statistics which measure the overall state of the nation and to some extent the success of individual government policies are reported to the general public by the media.
6) As a result of this information impressions in the public mind are formed and they vote accordingly.

Different groups have quite different goals and objectives and the statistical skills that are relevant to them are likely to be different. The interesting question is how can they be persuaded to assess the extent to which statistically literacy is critical to their success. The institutional context of decisions they are making also has to be borne in mind. Decisions may have more to do with the incentives faced by the organisation as a whole and it may not be clear as to what contribution statistical analysis can make.

For example the budget-maximising hypotheses of some of the theories of economics of bureaucracies would want to ask whether institutions make different decisions with more data and better statistical tools available to them or would it provide more justification for a course of action that had already been determined by strategic objectives.

The other side of this is that each of these groups will have constraints that serve as barriers to them acquiring and using statistical skills. These are such things as the skills of the organisation or the availability of the resources required to undertake extensive research work.

It is possible to list groups and examine how their objectives and scope for making use of statistical techniques are different. It is also useful to consider what features of their environment might act as barriers to using statistical reasoning.

1. Public Policy Makers

Objectives relevant to statistics that politicians and public officials have in mind are:

a) Identifying 'need' for policy change;
b) Analysing impact of specific programme proposals and forecasting their cost;
c) Evaluating the success of policy changes;
d) Allocating resources within programmes.

More mechanically governments are also interested in the effect that fluctuations in economic indicators have on their cost of borrowing.

There is considerable scope to make intensive use of statistical techniques to successfully complete these sorts of activities. However the inherent difficulties of estimating how people will change their behaviour in response to a change in public policy programmes mean that there is always a concern that there are limits to what statistical analysis can achieve.

Public policy assessment also requires the consideration of value judgements and vested interests. As Bonnen (1989) summarised;

"Thus, every policy decision involves values and prescriptions.....Every policy decision inevitably involves problem solving in a learning process that is iterative and interactive. This is a process in which organised interests are in conflict and which is influenced by existing political institutions, the stakeholding actors, the prior decisions and political commitments that the responsible decision maker(s) have already made.... all of which condition what is possible at any point in time."

However if contemplating these difficulties mean that little serious attempt to use data is made then there is a real risk that in the absence of information policy will tend to gravitate to extremes. We have had some experience of this in New Zealand, particularly in situations where an undesirable outcome exists but because little study of cause and effect relationships have been made different solutions that have assumed radically different causes have been tried without much understanding being developed.

2. Private Companies

There will be an enormous range in the potential for analysis depending on the nature of the business, the size of the industry etc. The main analysis work will be aimed at monitoring the extent of penetration of the available market and by looking at the potential of expanding or changing the business in some way. In this sense they will have the incentive to lobby for more extensive statistics to be collected on their immediate area of concern.

Companies also have a similar interest to government in the way that fluctuations in economic indicators affect their business costs.

In the New Zealand environment of a relatively protected economy that has been subsequently liberalised, the perception that good market analysis is not as critical to success as good lobbying has been something of an obstacle to firms fully exploring the potential of data to make business decisions. The early stages of our efforts to market statistics were full of examples of companies making large cost savings through the simple use of readily available data.

3. Professional Associations

These groups will be looking at ways of measuring the value of their members professional skills. In the areas of statistics and economics Early (1990) points out that "professional societies are customers not only of the actual estimates that we (a National Statistical Office) produce but also of the methods and documentation".

Official statistics is a highly public side of the statistical profession. While many statisticians have no involvement with the NSO, the profile of the statistical profession may depend on the professional standards of the NSO.

4. Community Groups

These will be looking for ways to try and measure how their members are being placed at 'risk' in some sense by the operations of society. They are going to be particularly interested in ways of identifying differences between their members and the rest of society with respect to some key attributes. Their ability to make intensive use of statistical techniques will depend critically on their own size and relevant data being readily available.

In terms of the collection of data these groups can play a critical role in helping persuade their members to provide information if they themselves have been convinced that their members interests are best served in this way. The output of public statistics tends to identify groups to the rest of the community however and so groups that feel 'stigmatised' by their 'statistical profile' may need considerable persuasion to continue to contribute information.

Our experience in a relatively small country is that community groups are often speaking on behalf of a small population that is difficult to locate and study. The effect of this tends to be that any attempts that they make to undertake research are inevitably under funded and result in research that is regarded as low quality. The situation can develop where such groups feel that research has little to offer them and that they are better served by concentrating on other activities.

5. General Public

The general public want information about how the performance of Government in managing economic and social programmes and they want information to help them make a range of their own private investment decisions. Generally they need information presented to them in a way that can be absorbed quickly and easily. A threat to statistics here is the ambiguity perceived in the way statistical information is used. How many people would agree with the proposition that Statistics can prove anything?

To this end, the role of a NSO can never be limited to a dispassionate presentation, but must include a vigorous interest in the association of estimates with inference.

6. The Media

The media is the general public's main source of information. The media's interest in statistics largely comes from the role it may play in the debate of issues of current concern. In portraying statistics the media has the incentive to attach a great deal of importance to the latest figure that has been released so that tonight's news can be made to seem as eventful as possible. This puts the public in danger of being misled when there is some uncertainty about current trends.

More positively the media has the scope to use good statistical reasoning as a way to hold politicians accountable and to demand that satisfactory explanations for decisions are made.

RISKS TO THE PUBLIC SYSTEM

Using the previous section and considering the nature of statistical output a set of the risks that are associated with breakdowns in both the compilation and utilisation of statistics can be compiled. The aim of this activity is to develop this chart to a point where it gives an extensive listing of the types and extent of causes of problems. The sort of risks that our experience leads us to focus on are:

1. Breakdowns in the compilation of Statistics

a) Data is not available on an issue of public concern

i) The need for the information was not anticipated

This might arise from groups of people not having advocates or from their advocates not being in a position to identify their members needs as a result of the sort of processes described above in the community groups sections.

ii) Government wasn't convinced that statistical collection would help policy formation.

This can occur because the Government's advisors don't believe data collection is justified by it's cost or by the belief that it is not possible to get data available on a particular area of public concern when it is needed.

iii) The support for statistical collection wasn't sufficiently organised.

Given that requests from a NSO for greater funding are likely to be seen as self-interest, public statistical activity will only continue as long as either external events such as the governments credit ratings provide a direct demand for them or as long as it is clear to government that there is agreement the information is valuable to a broad group of users. The wide range of customers for statistical outputs suggest that support for public statistical programmes may involve a variety of people and consequently be hard to organise at critical times. Problems of this type can also result in resources being allocated inappropriately within the statistical system.

b) The data available is widely perceived to be inaccurate

i) General public or firms stop supplying data

This might arise from feeling threatened by disclosure of individual information or from the feeling that the data they will supply will be used against them. In terms of the above considerations this can arise from community groups losing confidence in the value of statistical efforts.

The threat that arises from a lack of understanding is people deciding that supplying data is simply a waste of time as nothing worthwhile is ever done with the information.

ii) Poor quality statistical output is produced

There can be a lot of reasons for this but in this context the most relevant considerations are where problems in communicating objectives result in data being collected that cannot be used for it's intended purpose. This of course weakens the case for any further collections, regardless of how compelling a case can be made for them.

2. Breakdowns in utilising statistics

a) A lack of skills to appreciate what analysis can be undertaken

From the perspective of available skills this might arise from government advisors, advocates or firms not having the skills to use data or not being aware of available data.

Particularly relevant in this context is where the way that available information is organised is itself a barrier to easy use. This can easily occur when users have to pull together information from different sources (or different organisations) to get an overview of a topic area.

b) The value of statistical work not being apparent.

In the context of public policy, statistical analysis is carried out by individuals who are agents for someone else. Civil servants are working for politicians who have been elected to make decisions on behalf of the general public. The skills of statistical literacy are means to an end. Most people who have an agent performing skills for them will be more inclined to monitor their agent's outcome than their process. There is a significant risk that if analysis is carried out too 'far away' from the people who are supposed to have benefited from it what has been gained from the analysis will not be communicated.

c) Not having access to available data.

This can result from not having funds to buy available information, not being aware of its existence or being prevented from having data by law or the policy of the agency holding the data.

d) Data being misused

In discussing distinctive features of the output of a CSO in the context of quality management Colledge and March (1991) identified the intrinsically error prone nature of statistical products. This suggests that as the users are often 'not in a position to detect errors by observing the data' the problems with explaining the use of data are considerable. Consequently public discussion of the quality of statistical estimates are unlikely to be able to explain the full complexities of any problems.

There is also the risk of the media presenting data in such a way that the critical point of a current issue is confused or that in allowing a flagrant misuse of information by a public figure to go unchallenged the potential to help people understand their society is missed.

CONSIDERATIONS IN MANAGING IMPROVEMENTS

Clearly some of these risks arise from people not being aware of benefits they are currently receiving from the existence of statistical infrastructure, or not having the skills to take advantage of what information is available. However their are obviously other parts of the legal, political and economic environment that may require attention.

Who is going to assess the current situation and making improvements? In my environment the NSO is a logical place to locate some of this responsibility. Given that a NSO has a finite budget and that many of the things that it perceives as imperfections will be outside it's control it has to decide how what sort of improvements it can make with different allocations of it's resources. In broad terms the NSO has to manage those risks that fall under it's area of responsibility and attempt to exert influence in those areas where it doesn't have authority. Below is a list of the sort of activities that can be undertaken. When considered in the light of the need to make incremental improvements the following questions need addressing:

a) How much information needs to be collected about the current situation?
b) How can the relative importance of each of these risks be assessed?
c) How can the improvement process be supported?

a) Monitoring the Current Situation

The points listed out above are a checklist. The identification of the types of breakdown can be followed by making judgements about their causes. This requires a thorough knowledge of what main decisions are being taken in the different parts of Government.

Once this list is sufficiently developed it could be used as a form of output measure. The number of breakdowns and their causes can be itemised and if efforts to maintain the system have been successful the causes of the breakdowns will change.

b) How can priorities for action be developed?

The theoretical answer is to look at the financial and social costs of the breakdowns that are occurring, decide which of the breakdowns it is possible to do something effective about, and allocate resources accordingly.

In the area of public policy, where the successful application of appropriate techniques leads to better forecasting of programme costs or better targeted programmes estimates can be made of the amounts of money that can be freed up to be used on other activities. However for the most part the challenge is to be continuously developing an

understanding of what sort of decisions statistical analysis can play a significant role in improving so that a value of any missed opportunities can be estimated.

In term of assessing where progress can be made the simplest thing to do is to look out for places where a relatively large group of people (be they clients of a government programme or the general public reliant on media reports) is dependant on the skills or awareness of a relatively small group of people. This will inevitably lead to a sort of balancing act. It will be easiest to look at relationships that involve key users of the statistics system and ensure that these people or organisations are not underestimating the value of good statistical practice. It is more difficult to measure whether the public at large is losing interest in the statistical system and decide what sort of corrective action could be taken.

Looking at the scope for progress also includes developing a view about how changing the level of statistical awareness in one part of the community might drive further changes. For example will a more statistically literate population demand a higher quality of numerical presentation in the media? Will a more numerate media demand a higher standard of explanation of the use of numerical information in public policy making? Most difficult of all, if any of these changes occur how large does the effect have to be before there is any sort of change in the way decisions are made? This is difficult to assess in abstract and will probably depend on the types of relationships different groups have.

c) How can the improvement process be supported?

i) Collecting success stories

Collecting information about where the creative analysis of data has created benefits is a very important task. Decision makers focus more clearly on examples than abstract arguments about possible gains. Our experience is that a few clear cut examples can go a long way. The next step is to decide how widely it is worth spreading the news of success stories.

ii) Identifying key relationships

The NSO has a wide range of relationships to manage with all of the groups identified above. It receives representations from groups that have the incentive and resources to lobby it, and a NSO has to look at what barriers the different parts of it's user community face towards explaining it's needs for information and using them to achieve their goals. The NSO has to make sure that it doesn't get caught only meeting the needs of those users best able to articulate their requirements. This is particularly critical if the effective use of information is becoming a factor in identifying further needs for information. Above all in this context, it is essential that a NSO is able to demonstrate that the system is responsive so that any success in generating interest or participation in the process can have some sort of tangible benefit associated with it.

iii) Identifying areas of possible tension

In some areas the actions taken to control the risks mention above are in tension with each other. The sort of issues that can arise are:

a) The need to make data available for research while preserving assurances of confidentiality.

b) The difficulty in deciding how to weight the competing resource claims of regional and national statistics. Better national data is likely to be of interest to policy makers but most other decision makers will be wanting to know about their more immediate environment.

iv) Identifying what is possible

For us in New Zealand knowing about the work our colleagues in other NSOs around the world have in trying different ways to build relationships with different parts of their user communities often provides us with some 'priors' for how successful some of our own initiatives are likely to be and it provides additional sources of success stories to tell.

THE EXPERIENCE IN NEW ZEALAND

The above discussion may seem very abstract and theoretical. The remainder of this paper will give an overview of the extent to which this notion of managing the risks facing the statistical system has driven our actions and initiatives.

Consistent with the comments made above about the importance of recognising the relevant features of the institutional structures it has to be pointed out that as a small country many New Zealand institutions are relatively small in international terms. This means that they do not have the capacity within organisations to develop the specialist skills needed to do much detailed work analysing data. In practice this means that they are often not experienced in using data and so we have to be very proactive in helping them refine their data needs.

It is also likely that with smaller organisations their are fewer people performing a similar range of tasks and so it is possible to have professional contact with staff undertaking a much wider range of responsibilities in different organisations than may be the case in larger countries. This may mean that we will be more focused on individual relationships, where larger organisations may be more concerned with managerial processes.

The economy-wide events that have posed threats and opportunities to the statistical system (and hence its perception by the public) have been the de-regulation of the economy and the government's move to target social assistance and restructure the way that government programmes are delivered.

1. How we form a view of the process in NZ

What sort of channels do we need to collect information about any parts of the process that might not be working well or that might be changing? Some of our channels are established as part of long-standing practice, some are covered by our legislation and some are initiated by us because we see that there is a risk that an emerging need is not being responded to.

Our main sources of information are:

a) The Marketing of Statistics

A very concrete way of finding out how people value statistical information is discovering what they are prepared to pay for it. From the 1986/87 financial year Statistics New Zealand has had to achieve revenue targets. This has provided us with strong incentives to assess how client needs are changing and develop products and services that keep up with the changes in how data is being used. Analysis of our revenue figures demonstrates that our revenue comes from relatively few customers.

Even despite this concentration the marketing function has made us acutely aware that our information has gone from being something of interest to business to being a causal factor in interest rates and so their business costs.

This says that there are theoretical reasons for thinking that data use of this type should be increasing. One of the exercises that we are carrying out that aims to throw some light on this change is to look at different industries and try to ascertain why we are approached for data by some firms and not others.

b) Public Policy involvement

For the policy agencies of Government are involvement is much more direct. We have a Public Policy support division that co-ordinates our organisations efforts to maintain awareness of the problems that analysts in these agencies are trying to solve. There are always balances to be struck in how far we get involved in trying to provide the statistical tools for this type of work. The lesson that has been learnt from experience is that we have to be proactive and flexible in the way we handle these activities or people stop talking to us.

What we have found that by being the largest group of statisticians employed by government that has a relationship with policy analysts we can point to situations where we were able to identify specific techniques that gave a framework for resolving practical policy assessment issues.

The sort of work that has resulted from this sort of liaison has been the undertaking of surveys, bits of analysis work and participating in inter-departmental initiatives.

c) Statistical Reviews

As part of the Act of parliament that defines the role of Statistics New Zealand the Government Statistician can initiate reviews of the quality of Statistics in any particular area. A review can begin as part of a regular review cycle or in response to a particular concern. The process typically consists of Statistics New Zealand chairing and providing secretariat support to a group of 'expert' users drawn from government and private agencies.

With our Macro-economic statistics it was decided to turn the group into permanent bodies to reflect that this was an area where significant changes were needed and that the effectiveness of our attempts to implement improvements needed to be monitored.

The concept has been carried further with our development of Maori statistics. Discussions with the leaders of the Maori community revealed that we had little notion about what information would be of use to the Maori community in developing it's economic and social resources. The Maori community also had yet to develop it's view on what role statistics could usefully play in it's work. The result was that the group that meets with Statistics New Zealand is involved in a process of working with us to develop frameworks for assessing Maori statistical needs.

d) Census consultation

For any group that is relatively small in the population and is not visible in any administrative collection the five yearly Census represents one of the few chances for the status of their members to be identified in a way that enables the extent of their difficulties to be quantified. Recognising this we initiated a programme of public meetings to try and help such groups identify their needs.

This programme has become more extensive with each Census and we have learnt a great deal about who to approach and how to discuss different issues. These meetings have included many people from the general public coming along to have their say. This tends to reinforce the role that statistical output has in forming an identity. Often what people want to talk about is what they will look like in the data and why that doesn't feel right to them. Consultation with the general community tends to increase interest in the scope of publications and on privacy issues.

e) Feedback from clients on products

The other source of information that we get is from the wide range of people that use our products. This comes from surveys of users of the products, regular unsolicited advice and monitoring discussion of our activity in the media. Some of the impact of this information is described below. We have on a couple of occasions commissioned external agencies to do this type of work for us so that we could ensure that a more frank version of our limitations could be obtained.

f) The effect of Census Advertising

The only time that we get involved in mass media advertising of any sort is in the lead-up to our five-yearly Census. We emphasis the role Census output has in planning the location of hospitals, roads etc. The change that we notice is that around this time we get a 'halo-effect' of increased response rates in our ongoing surveys. While it can be argued that this shows the value of being recognised by respondents, there has to be a positive association with this recognition. The improvement in the response rates suggests that the message in the advertising about the value of good statistics has been widely accepted.

g) The limitations of our picture

The point that is immediately apparent from this discussion is that our knowledge about the statistical skills in the community comes from the descriptions that organisations give us when they are telling us how they do or how they would use statistical information. We are able to develop a good picture of the concerns of these people and their attitude towards the use of data.

What type of risks are we exposed to if we are mainly communicating with existing users? The main difficulty that we face is that if a group in the community does not have identifiable 'leaders' with whom we can start to build a relationship we are in danger of neglecting their needs. Of course, we watch the response rates for our surveys very closely for any sign that our respondents have started to choose not to supply data.

2. How we decide where to put our efforts

In terms of identifying gaps in our statistics the consultation activities described above have served to identify these. Looking at the utilisation of statistics our consideration of the checklist issues above has lead us to taking specific activities that I will describe in the next section. In broad terms some of the main risks that we have identified are:

a) Threats and opportunities in maintaining the relevance and responsiveness of our estimates.

With are recent experience of rapid change it has been judged that the major threat to the statistical system in New Zealand was the need to keep the government aware of the impact that changes in the extent of economic regulation where having on our ability to produce key statistics. In terms of the above discussion it is of critical importance that the actual output of our statistics can be demonstrated to be relevant to the decisions are politicians are trying to make.

b) Lack of data analysis in policy preparation

We have had experience of decisions being taken that were based on assumptions that were clearly inconsistent with available information. This was of the prime motivations for trying to get more direct contact with policy analysts. We have found that one of our

key challenges is to get information to these people in a form that makes it useful to them.

c) Our relationship with the media

This has arisen from us being aware that the main part of our image with the general public is totally dependant on the way that statistical information has been portrayed in the media. As well as the training efforts described below this has meant re-assessing our managerial processes for dealing with the media and developing relationships with people identified as key commentators by the media.

This has also lead us to give a good deal of attention to the way we run our media conferences. We are now very clear about the timing of media releases six months ahead, and in the conferences themselves we give presentations which guide the media representatives in evaluating how the most recent data has modified our understanding of the economy.

The government restructuring described above meant that measures such as our Balance of Payments that used to be based on administrative records of transactions went through a period of volatility as they were swapped to survey based estimates. This caused a different cycle of revisions and provided us with a great challenge in developing a clear view in the minds of the mass media about the causes of what was happening.

d) The challenge in combining data from different sources

Our efforts to restructure our statistical products are described below. It became apparent that one of the major difficulties users had in understanding what was going on in an area of concern was getting all the relevant information together in one place and understanding subtleties in differences in definitions and quality of related statistics. The realisation of the scale of this problem was a driving factor in an internal re-organisation.

3. Activities

a) Product Development

In establishing the public's view of statistics from the feedback from users of our information it is possible to isolate some of their criteria for deciding to get data from us or not. The point about product development from the perspective of understanding the links in the statistical system is that monitoring how usage changes when old products are upgraded or new products introduced can tell you a lot about what the barriers to using information have been.

Some major themes:

i) The attractiveness of analytical measures

People want information that summarises a large amount of material. They want whoever is presenting information to them to do this for them. We often receive

feedback that people want us to do this as they see that we have the data and we are not viewed as having a vested interest in the conclusions This sort of work usually requires making extensive assumptions and our experience in dealing with inquiries is that people find talk of these measures being sensitive to the assumptions frustrating.

An example of this sort of work is the Real Disposable Income Index. This attempts to summarise how wage rises, price rises and changes in taxation and income support programmes have impacted on people in different income deciles. It requires a considerable range of assumptions but it was a popular innovation precisely because it combined information from a number of places to produce a measure of an issue that is of widespread interest.

This sort of difficulty becomes particularly acute when the assumptions are to do with identifying trends. Markets and the political environment are sensitive to suggestions that things are changing and the problems with picking turning points in economic indicators can bring a CSO into the front-line of public debate.

ii) Presenting information that crosses data sets

After feedback from users that bought our regular publications that they wanted all the information about a topic area bought together in one place we began a program of producing publications that drew together relevant data from administrative sources and our own collections.

iii) Attractive Presentation

It won't surprise anyone that our experience with upgrading our press release documents in terms of the quality of their appearance and the clarity (and brevity) of their content have received very enthusiastic responses from users. The last upgrade which saw the introduction of a much higher level of colour and graphical output resulted in unsolicited letters of approval from a large number of members of parliament.

b) Education

In terms of looking at the statistical system any sort of education or training activity we carry out it falls into to broad forms. The first is identifying clearly defined community groups whose level of statistical skills is critical to the functioning of the statistical system. The second type is more in the nature of long term investment.

i) The training of groups

In the first category has been our involvement in preparing material for the training of journalists. Our experience continually reinforces that good relationships with the media and a good level of understanding amongst the media are critical to the effective functioning of the statistical system.

The other initiative that we have undertaken in this area was to run seminars on the use of statistics for community groups. This concern arose from the risk identified above that groups represented by volunteer workers or with small full-time staff would not have the skills to get full value out of the statistical system.

ii) Investment activities

In the category of investment for the future are our activities in dealing with schools. In doing this we have to consider what can we possibly add to a formal theoretical education. Our main activities in this area involve monitoring modifications to those parts of the school curricula that are relevant to the use of social studies and the development of PC databases of aggregate data that are provided to schools cheaply. In both these activities we are attempting to ensure that using data is looked on as a nature part of learning and discussing topics.

c) Public Relations for statistics as a whole

The other activity that can be identified that we play from time to time is to act as the statistical systems public relations manager. The aim of this activity is to prevent statistical practice from getting a bad name so that the risk of public cynicism about the use of statistics is managed. In practice this means giving advice (sometimes publicly) that particular surveys that are being used for public policy purposes do not conform to standards of good survey practice. This is a problem in New Zealand as the companies running surveys are frequently small and so do not have the capacity to employ methodological specialists. This function of speaking out falls to us because we are the largest identifiable statistics organisation in the community.

The other main type of activity that we have to undertake is to guard against the perception that the information that people supply to us good get passed on in a way that would disadvantage them. As well as the technical and managerial systems of confidentiality assurance that are being put in place this means making efforts to distinguish statistical collection activity and agencies swapping data for enforcement purposes in the public mind.

CONCLUDING REMARKS

This paper has tried to give a sense of the difficulty of maintaining the 'public system' that keeps data being collected and analysed for public policy making. In the course of this paper I have discussed identifying some aspects of this system. In particular it is possible to identify different groups and the roles they play in this system. In managing this system the NSO has to continually decide which of these actors is least likely to be able to play their role and how critical this potential failure is to the overall functioning of the system.

What the best way to carry out this assessment will be very different in different countries. In our context it is critical that an attempt is made to collect all the different types of information about these risks together in one place so that scarce resources can be allocated in accordance with a commonly held view of priorities.

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How statistics is taught in the province of Santa Fe at present . Presentation of a proposal for changing .

This work refers to the teaching of statistics now in the primary and secondary levels in private and official schools in the province of Santa Fe (Argentine Republic).

Besides , a project on change that have been proposed for the above mentioned levels will be put forward This project will be applied along with the Federal Law of Education and a presentation of a training course , for teachers and proffessors that will be able to apply and interprete statistics in their respective classes will be made .

As i will a fellowship i need your answer quickly I will pay when i arrive because it´s too expensive to make a bank´s transfer from here and i have no checks in dollar from here .

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INEXPENSIVE DEVICES FOR ENCOURAGING STATISTICAL EXPLORATIONS

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Abstract: *Much attention has been given in recent years to ways in which a computer can be used to help illustrate statistical concepts. In this paper we take a much lower-tech approach to consider how some ordinary objects might also provide useful means for allowing students to generate data and explore statistical techniques. For example, what can we do with a coin -- besides flip it? How can we fix a die so that our students won't notice a difference -- but statistics will? How can we keep students busy for an hour with a single blank sheet of paper?*

Fair Coins? Flipping, Spinning, and Tipping

One of the most common examples of a simple random phenomenon is a coin flip. A "fair" coin is tossed in the air and caught (or allowed to fall to a flat surface). The result is recorded as either "heads" or "tails", depending on which of the coin's two main surfaces is visible. In the standard model, a well-flipped coin should have an equal chance of coming up either heads or tails. Is this really the case in practice?

One can easily design an exercise to have students investigate this question. Simply bring a bag full of coins to class and let each student generate his or her own sample of flips. Although time constraints, and student patience with doing a relatively uninteresting task, might not allow individual students to generate a sufficiently large number of flips to be convinced that P(H)=P(T)=0.50, one can pool the results for the

entire class to obtain a more accurate estimate of the proportions. Along the way, we have an excellent opportunity to illustrate the sampling distribution of a sample proportion by displaying each student's individual estimate. We might also have each student construct a confidence interval, based on his or her individual sample, then display the resulting intervals to see what fraction fail to include 50%.

One drawback to a coin flipping exercise is that students may find it relatively uninteresting and are not at all surprised by the result. They are perfectly willing to believe that the proportion of heads is one half without doing any statistical experimentation. So let's modify the experiment just slightly. Instead of tossing the coin in the air, hold it on edge perpendicular to a flat smooth surface and flick one side, causing it spin rapidly. Eventually, the coin will lose momentum and settle down to fall on one side or the other. It seems as though this should be as random a process as flipping the coin, but the proportion of heads may no longer be 50%. Our classroom experience with U.S. pennies shows that the proportion of heads goes down to about 40%. Comparisons of confidence intervals or hypothesis testing results become more interesting for students when the information they provide is somewhat counterintuitive.

A further assault on student faith in the fair coin can be accomplished by expanding the exercise to include coin tipping. Carefully stand a coin on its edge on a flat surface, then gently tap the surface to cause the coin to tip over. U.S. pennies work fairly well, nickels are easy to stand but require more jarring to tip, while quarters and dimes do not have sufficiently smooth edges to allow standing on edge. Our experience from classroom samples using pennies shows the proportion of tipped heads to be at least 75%. We suspect that the true proportion for carefully

tipped coins may actually be quite a bit higher. Some students get somewhat overzealous in banging the table to make the coins fall so that the "tip" begins to resemble a "flip". However, one industrious group of students arranged 50 pennies to stand *simultaneously* on a glass table top, tapped the table, found 48 tipped to show heads, and brought in photographic evidence to document their results!

Why do tipped pennies appear to show a propensity for falling heads up? Apparently, the edges are angled very slightly to facilitate removal from the mold when the coins are minted. Does this also account for the spinning results? Is the proportion of tipped or spun heads the same for all pennies, or might it vary from penny to penny? Do the age, condition, or mint site have any consistent relationship with the observed proportions? What about coins other than U.S. pennies? These kinds of questions provide ample opportunities for additional student investigations of what is often regarded as a very simple random process.

Dice & The Central Limit Theorem

Ten six-sided dice in an open box are passed around the room during the class *before* we discuss the Central Limit Theorem. Each student rolls the ten dice, records the frequency for each of the six possible digits, computes a total score, and hands in his or her results on a slip of paper. The results are tabulated and combined for all students before the next class. A handout contains the theoretical (uniform) distribution for individual rolls and a histogram with the combined sample frequencies for individual digits from the student rolls. These clearly demonstrate that the underlying population is not bell-shaped. On the back of the handout we consider the means for each of the student samples

of size 10. Generally, the class size is too small (around 25 students) to get a very clear picture of this distribution, so we add in values from past semesters to get a display of 400 or more sample means. Students readily observe that the empirical distribution of these means is more bell-shaped than the underlying population and has considerably smaller variance. We can calculate the mean and variance of the sample of means and compare to what we would expect to see theoretically. While this doesn't *prove* the Central Limit Theorem, it does demonstrate that it's plausible for the distribution of a sample mean to look much more normal than the individual underlying population values.

Red Die vs. White Die

We have two distinctly colored six-sided dice. One is red, the other is white. Let's have a competition to see which is the "better" die. The dice are rolled together, whichever die shows a higher number is declared the winner for that round (ties are ignored). As the dice are passed around the room, each student rolls ten or so "rounds" and keeps a running tally of the number of "wins" for each die on a sheet of paper. As we get towards the end of class (where the topic for the day happens to be tests for proportions) we have accumulated 312 decisions, 181 wins for white and just 131 wins for red. The proportion of white wins is 0.58 -- seems a little high, we would expect about 0.50 for fair dice. Let's try a test with null hypothesis that $p=0.50$ against a two sided alternative. A little calculation gives a test statistic of 2.86 and a p-value of 0.0042. Hey, that's pretty small. Could these dice really be fixed?

Yes. Although the students have all rolled and handled both dice, they invariably fail to notice that the white die comes equipped with two

"5" sides and no "2"! It's a relatively easy task to drill three extra holes down the diagonal of the original "2" side, which is opposite the "5", and fill in the spots with a black marker to create the second "5". Thus the white die has an advantage that is clearly revealed by the statistical analysis, but not detected by the student dice rollers. A couple of interesting follow-up questions might be appropriate for some classes. What is the theoretical proportion for white wins after it has been "loaded" with the extra "5"? How large a sample should the instructor collect from the class in order to have a reasonably good chance of avoiding a potentially embarrassing Type II error?

Pepperidge Farm Goldfish

Edible data sources are a popular way to generate student interest. M&M's, those brightly colored chocolate candies that come conveniently packaged in small (sample sized) packages, are a well-established favorite device for classroom investigations. Students can count chocolate chips in cookies or take a "field trip" to investigate the number of fries per bag at local fast food outlets.

One of our favorite food-based exercises is a demonstration, developed by Jeff Witmer, of the capture-recapture technique. The Pepperidge Farm company produces a popular snack cracker shaped to resemble a fish. We dump a bag of these "goldfish" into a bowl that serves as the local lake or ocean. How many fish are in this population? To estimate the population size, students capture a random sample from the bowl. A good-sized handful might contain about 50 fish. To follow actual practice the fish should then be tagged and returned to the "water", but most reasonable tagging methods would either be too time consuming

or tend to render the fish inedible. Instead we substitute an equal number of different flavored (and colored) goldfish and eat the original sample. The population is well mixed and a new sample is drawn. The number of marked fish that are recaptured in the second sample is noted and an estimate of the population size is easily generated.

The goldfish exercise can stimulate an interesting discussion of the assumptions needed for the capture/recapture technique to work in real situations. Applications to estimating population sizes of endangered species or trying to adjust for undercounting when collecting a national census are easily motivated.

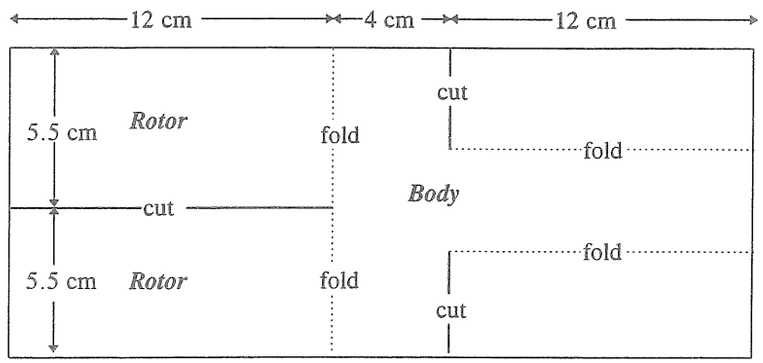
A Blank Sheet of Paper

Some basic principles of experimental design can be nicely illustrated with some simple aeronautical devices crafted from a sheet of paper. For example, paper airplanes are easily constructed and offer lots of opportunities for investigating how design characteristics might affect flight performance. What would we like to optimize? distance? accuracy? stability? What folding methods work best? How does the size or angle of the wings influence flight? Students can easily generate lots of interesting questions and gain valuable statistical experience from designing simple experiments to investigate the effects.

A less familiar, but equally intriguing, flight device is the paper helicopter. A typical design for a standard helicopter is given below. The two top "rotors" are folded in opposite directions to be at right angles to the main "body" of the copter. A helicopter flight consists of dropping the contraption so that it revolves and the spinning rotors slow its descent. The main objective is to *maximize* the drop time by adjusting parameters

such as the size of the wings, length of the body, or type of paper. One might also investigate whether flight time can be increased by adding a paper clip to the main body or taping pieces together. Although dropping can be done from ceiling height for early experimental runs, a longer drop zone (such as an open stairwell) facilitates timing the flights. Capping the exercise off with a flight competition between student teams further stimulates enthusiasm for the project.

Basic Paper Helicopter Design



Funnel Swirling

Another experiment to maximize drop time can be constructed with a long plastic funnel which is normally used for adding fluids to an automobile. The purpose of the experiment is to roll a small metal ball down a tube and into the funnel so that it swirls around as it slowly descends to the bottom of the funnel. The investigator may control the height at which the funnel is tipped, the distance the ball descends in the tube, the angle between the tube and the funnel, and the size of the ball bearing. Typical drop times might range from two to fifteen seconds.

The optimal arrangement is not immediately obvious and includes an interesting interaction between the funnel height and tube height. A good description of the funnel apparatus, including construction tips, is given by Bert Gunter (1993).

Conclusion

In this paper we have described some ways we use ordinary objects to encourage students to apply statistical techniques to investigate common phenomenon. These represent only a very small portion of the wide range of possibilities for such activities. Other examples can be found elsewhere in the ICOTS Proceedings. For example, a different way to use coins (together with some water and a medicine dropper), is described by Witmer (1994). Some other examples involving modeling clay, sponges, and a mysterious viscous liquid can be found in a paper by Dale Kopas and Paul McAllister (1992). Although we have deliberately avoided computer applications, many of the examples cited here can be enhanced with a follow-up simulation. For example, once students have all thrown their ten dice and looked at the distribution of the sample means, they are better able to appreciate a computer simulation of the same events.

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STATISTICAL CONSULTANCY IN AGRICULTURAL INVESTIGATION

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The paper presents some experiences in statistical consultancy with undergraduates, candidates for master's degrees and doctorates and other research workers at the Faculty of Agriculture in Novi Sad. Years-long experience in teaching at undergraduate and postgraduate studies spontaneously expanded onto statistical consultancy in the application of statistical methods in solving the questions and problems of agricultural investigations. The experience in statistical consultancy indicates that consultations are necessary and justified, even though they have been carried out as and when required by research workers themselves, on a case by case basis. The experiences of statistical consultancy at the Faculty of Agriculture in Novi Sad are a part of the general education in teaching statistics, as quoted in literature (Schuenemeyer, 1991).

The problems in agricultural investigations which have been dealt with in consultations of statisticians and non-statisticians are varied and specific. A great variety of statistical procedures have been applied in numerous fields of investigation in agriculture. The application of statistical methods in general indicates that advice by statisticians in the choice of an adequate method, interpretation of the obtained results and explanation of the studied phenomena is very important and justified.

The experience in statistical consultancy shows that most research workers in current conditions tend to use ready made statistical programs in statistical data processing, but that advice by statisticians remain important. Indeed, in consulting statisticians, researchers are looking for ideas on how to carry out an adequate plan of investigation, particularly in setting up experiments, chosing of adequate methods to elucidate the problem under investigation and interpreting the obtained results and explaining the studied phenomena. It turned out many times that a problem was better explained after an adequate statistical method had been applied.

In consultations between statisticians and non-statisticians, it is important to understand the problem and find a common tongue with non-statisticians. It is certainly important for the statistician to grasp the essence of the phenomenon under investigation, and therefore the core of the problem, in order to give a realistic and adequate advice for the application of a statistical method, interpretation of results and drawing conclusions. The need to become familiar with the problem and the way and method statisticians take in approaching the problem in investigation has been pointed out by a number of authors (Schuenemeyer, 1991; Smyth, 1991).

The statistician's experience in consultations with various specialists shows that in each particular case the selected statistical method was worthwhile, that the statistician's advice was beneficial and that there is a permanent need for consultations between statisticians and non-statisticians.

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Recent Developments in Statistics Distance Education at the Open University

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Abstract

The British Open University has been teaching statistics at a distance for twenty years, and it remains as the main provider of distance teaching at university level in Britain. In recent years, the university has changed its teaching of statistics, both in terms of the curriculum taught and in terms of the way that different teaching media are used.

The curriculum has moved away from mathematical statistics and towards applied statistics and data analysis. These changes fit our teaching more closely to the needs of our students, who are generally in employment and studying part-time. They also fit in with the wider and wider spread of computer software as a means of doing statistics.

In terms of media use, we have increased our collaboration with commercial publishers in the production of texts. This move is intended to make our texts more easily available for use by other teachers and institutions. In line with most other academic institutions, we have increased our use of the computer as a teaching tool, though this change has faced difficulties because not all our students have easy access to appropriate hardware. We have also made changes in the use of television and other audio-visual media. This paper outlines all these changes and discuss the reasons for them, concentrating on curriculum, computing and text issues. (The use of television is discussed in another paper, by Lunn and Jaworski, to be presented in the session on 'Use of video and multimedia technology for teaching'.)

"Teaching Statistics for Students of Biology: Necessity, contents, concepts"

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Introduction

A useful starting point may be the recommendation Laplace addressed almost two centuries ago to physicians (and, in a broader sense, to biologists as well): to associate "the knowledge of their art, and its related sciences, with the strict sense of rigour and criticism which can be acquired by the study of mathematics and especially the science of probability".

One century later, in the first issue of Biometrika - devoted to research perspectives in biology, in the light of the theory of evolution -, it was taken for granted that a "progressively closer discussion" would involve "the biologist and the mathematician".

What had happened in the years separating Laplace's recommendations from the first Biometrika issue? Undoubtedly, after Galileo the scientific method had been translated into an experimental philosophy that had increasingly challenged natural sciences in the face of the strict determinism of physical sciences. Thus, in the 19th century, there had been an attempt by physiology to cope with criteria and requirements of experimental physical research that had failed, actually resulting in a number of difficulties and contradictions which could not be easily reconciled; on the other hand, a "naturalistic" method of research had been developed, which introduced the concept of biological variability - or rather, rested upon such a concept.

The conflict between the attempt made by some biologists to comply with the "classical" methodology of research - doomed to failure because of the supposedly intrinsic diversity between the phenomena under study - and the development of a different approach - based exactly on the flaws attributed to biological investigations, i.e. casuality and diversity - was bound to result in a "contamination" of the predominant methodology as well: no longer imitated, this latter was actually "converted".

The classical model of experimental research - which had been adopted for over two centuries - first showed its flaws when the attempt was made to apply it to biological phenomena; its limitations were made apparent in this way even to those disciplines that had made it their own unshakable foundation.

The current approach to scientific research is therefore rooted in life sciences, which is often forgotten by many: variability and diversity of biological phenomena led research and experimentation from a deterministic to a probabilistic approach, in the attempt to identify trends of regularity, global properties, empirical constants rather than absolute laws.

"In the infinite diversity of single phenomena", J.Monod wrote, "science can only search for invariants". Statistics is exactly the method of searching for invariants: the invariants emerging from variability.

Thus, it should be stressed how much the current philosophy of research owes to disciplines that are characterized by an interplay of casuality and variability: it was from biology, through Darwin and Mendel, that the above methodological shift originated; biology was the discipline where the statistical approach first grew its roots and bore fruits.

Leonardo da Vinci said that "each instrument should be used with the experience which created it"; we should always remember to remind other people of the "naturalistic" origin of statistics, of the application of statistical concepts to life phenomena, of the logical and historical reasons making statistics a methodology of biological sciences.

Statistical Methods and Experimental Research

We saw that statistics developed as a methodological tool capable to solve the eternal duality conflict between reality and hypothesis, between fact and artifact, between empirical result and theoretical assumption - in the search for immediate and remote phenomenal significance.

May we consider ourselves satisfied of the way biology and statistics have been cooperating so far? To what an extent are statistical methods and investigated phenomena (not necessarily biological ones) currently interacting? In the past, "statistical" philosophy - both as a conceptual framework and as an approach to scientific investigation - gave origin to scientific disciplines of its own: from thermodynamics and radioactivity to the biology of evolution, from genetics to quantum mechanics. Mawwell and Boltzmann, Darwin and Mendel, Bohr and Born were no statisticians; still, they shared a new way of reading and investigating nature, i.e. the statistical one.

Today, statistical definitions and methods are typical of the whole area of experimental research, being the main tools to assess the relationship between hypothesis and demostration; on the other hand, the implementation of such methods is fraught with ambiguities:

a) tests that appear intriguing by virtue of their complexity and obscurity are often used without considering (or, even, by positively distorting) the underlying theoretical assumptions;

b) sometimes statistical analysis looks like an attempt to mask the absence of any sound working hypothesis, almost as if statistical conventions could substitute for real matter, appearance prevail over reality;

c) a few methods (often being the most recent and sophisticated ones) are applied to a jumble of collected information as if to perform its interpretation (or rather, its exorcism), in the "a posteriori" search for explanations that

may hopefully result in new ideas. It appears that this is done to lend scientificity and the required palatability to a paper that otherwise might not be accepted for publication, rather than as a basic approach to investigation which should be implemented "a priori" to formulate the hypothesis and subsequently validate the results.

Statistics and Statistical Packages

The problem is compounded by the availability of statistical packages which make analysis increasingly easy and rapid as well as more treacherous: indeed, their seemingly simple implementation contributes to further preventing a correct organization of research and a sensible choice of methodology.

Using formal techniques - statistical and/or computerized - with no consideration either for their theoretical background or for the relationship with the area of implementation, cannot but result in a purely manual routine where the increasing amount of data and calculations is counterbalanced by the progressively decreasing quality of the analysis.

Far from making computer science (even less so, statistics!) the sole responsible, we would like to stress that methods are not detrimental or bad in themselves, but rather in that they are often used acritically - in good or bad faith.

Only the interaction between statistics and biology (either in the same subject or in different members of a research group) can prevent formal components from prevailing over the contents, the processing of data from replacing the thinking on data.

The main advantages of the computer are storage of data and speed of processing: they should be used to aid our thinking, not to substitute for it! The computer should remain a tool and not be the main concern of biostatistical analysis. It should be used as a research aid, taking advantage of its huge memory storage capabilities and high processing speed to better serve (rather than to make subservient!) the purpose of research.

Statistics in the Training of Biologists

Statistical methods may offer the opportunity for unification to biological research, as a sort of common language to counteract the increasing trend toward hyper-specialization. In this regard statistics might lead the way to gather the scattered herd of biological disciplines under the common roof of research methodologies. This unifying role may be played both in the training phase of would-be biology researchers and during the subsequent research practice.

Based on the above concepts and considerations, we may now proceed to establishing whether and how statistics contributes to the current training of biologists, and whether and how it characterizes current research activities in the field of biology.

As to the former issue, reference can be made to the results of a survey performed in Italy before and after the introduction of a new

curriculum studiorum; it appears that the possible contribution of statistics as a research method to the student's training is basically inadequate.

Unfortunately, the concept underlying the curriculum studiorum of Italian biologists appears to give preference to specialistic issues with an excessive attention to leading-edge (fashionable?) topics - while statistics might, or rather should, have offered an opportunity for unification.

A change in the conceptual framework is therefore necessary, which cannot be achieved by adding new university courses to those already existing, but rather by means of a statistical philosophy that should pervade the whole biological research and thereby start a process stimulating experimentation, scientific curiosity and methodological rigour.

This happened in the past with such scientists as Bessel, Galton, Pearson, Spearmann, Gosset and Hotelling: though not trained as statisticians, they gave a fundamental contribution to statistical methods.

Proposals

The previous considerations strongly recommend the inclusion of two courses on statistics (see table 1 at the end of the paper), at different levels, during the graduation in Biology:

- the basic one, at the beginning of curriculum, with the essentials of statistical tools;
- the advanced one, focused on biological research activity, strictly object-oriented.

We considered that a sound proposal could derive from some empirical points:

1) the consideration of which statistical tools are needed by a Biologist in his/her professional activity;
2) a critical reading of the scientific biological literature to identify the minimal needs of statistics to organize and understand a modern research activity.

As regards the former point, most positions open to a Biologist require a non trivial understanding of statistics. A few examples may be as follows:

- Lab.Analysts (microbiology, biochemistry, and so on) usually need sequential testing and Quality Control methods;
- Ecological and Environmental specialists use time series, multivariate methods, capture-mark-recapture experiments;
- Biologists responsible for research activity in clinical and pharmaceutical programmes widely use advanced experimental designs;
- at least in Italy, a Biologist can teach (Mathematics and Science) in pre-graduate schools and Statistics begins acquiring more and more importance at that level.

As regards point two of our empirical observations, any graduate in Biological Sciences needs a minimal background in Statistics to be able to read and understand the current scientific international literature. Getting in touch with the problem generally begins during the thesis activity. A survey

of the biological literature may provide useful information on the level of this minimal required knowledge.

The Current Contents data-base covers approximatively 1270 Journals of the Life Science Sector: the Section "Agriculture, Biology and Environmental Sciences" about 930 (Journal coverage of January 1993). It is positively impossible to examine this amount of information to find the level of statistical uses. We decided to use a small sample of significant Journals belonging to different biological fields and to count the number of articles in each of them, belonging to the following categories:

a) without any statistical processing;
b) with simple descriptive statistics and simple statistical tests (Student's t , Chi-square,...);
c) with more complex techniques, such as ANOVA, linear models (regression, smoothing, ...), non-parametric methods;
d) with high level methods, such as multivariate analysis, time series, new tests and so on.

In table 2 a first part of the survey results, referring to the last issue of 1993 (or the first of 1994) for each selected Journal, is reported.
The results obtained show that 2/3 of the published papers include some statistical analysis and almost 25% required a good level of statistical know-how. It is clear that biometric tools must be included in the minimal background of a Biologist, at least if his/her activity is likely to be connected with research!.

Nowadays many statistical packages are available to the naive biologist with the consequent interaction between use and understanding of a statistical reasoning: it is well known that the large availability of low cost computers has stimulated the use of "user friendly" packages in the field of applied statistics as well. [For example the brochure of the program "InStat" (GraphPad, Intuitive software for Science, San Diego CA, USA) states that "unlike heavy-duty programs designed for statisticians, InStat is designed for scientists, even those whose knowledge of statistics may be a bit rusty..... You simply install InStat, and use it right away"].

User friendly interfaces are a great improvement in computing, but as regards statistics, our students should not be deviated from a right planning and a motivated choice of different methodological approaches. Teaching should convince students to avoid an acritical use of formal rules or of pre-built solutions. These can be useful, but only if they are strongly connected with the theoretical background and the applicative field of interest.

Statistics in biology can be offered to the student with the help of a computing facility, which should be seen as an useful tool to explore and put in practice the theoretical basis. It is necessary to think more and to compute less: the computer should remain a tool rather than the main concern of biostatistical analysis!

P.S.: As to the relationship between Statistics and Biology, we largely made reference to papers, reports and lectures held by Prof. I.Scardovi during the Biometric Society-Italian Region courses.

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Table 1 - Elements of statistics and biometry

Basic Course - in connection with Mathematics, 1st year.

Elements of Probability, Conditional probability and Indipendence
Distribution, Probability and Density Functions
Elements of Sampling and Descriptive Statistics
    Population and sample
    Presentation of data and descriptive statistics
Sampling Distribution
    Distribution of the sample mean for Normal and Non-Normal populations: Central Limit Theorem
    Distribution of sample variance
    Chi-square distribution
    Other Sampling distributions of interest (applicative examples)
Statistical inference: Estimation
    The Point Estimators and Confidence Intervals
    Examples of estimation procedures: mean of a population, difference between the means of two populations, variance known and unknown
Statistical inference: hypothesis testing
    Null hypothesis, Type I and II Errors, Test Procedure
    Examples: test about the mean
    Comparison of two means; Comparison of two variances
    Test about proportions
Regression and Correlation
    The method of least squares
    Simple linear regression, its model and hypothesis testing
    Determining the regression equation and testing of fit
    Correlation index
    Correlation and simple linear regression
Personal Computer Workshops
    Analysis of illustrative problems by teams of students
    Report and critical discussion from teams of students

Advanced Course - beyond the basics, third year or later in connection with Biological specific Courses

Designing Experiments or Trials
Analysis of Experiments with more than two Treatments
- Analysis of Variance
- Fixed, Random and Mixed Models
- Factorial and Nested Experiments
- Multiple Comparison

More on Regression and Linear Models
- ANOVA and Regression
- Multiple Linear Regression
- Generalized Linear Models
- Calibration Curves
- Polynomial regression
- Analysis of Covariance

Biological Assay
Topics in Statistical Quality and Control
Distribution Free Methods
Basic Topics in Multivariate Analysis

Table 2 - Survey results relating to recently published issues (last 1993 - first 1994): papers classified according to the level of statistical analysis

Journal	issue	a	b	c	d	total
J.of Applied Ecology	30(4)-1993	1	10	7	2	20
Ecology	74(8)-1993	1	14	6	4	25
J.of Ecology	81(4)-1993	3	12	3	2	20
Genetics	136(1)-1994	9	6	4	10	29
Heredity	7/6-1993	4	3	4	-	11
Theor.and applied Genetics	87(6)-1994	6	2	3	7	18
J.of Genetics and Breeding	43(4)-1993	7	3	2	-	12
Genome	37(1)-1994	10	9	2	1	22
Cell	76(1)-1994	12	2	-	-	14
Tree Physiology	13(4)-1993	3	5	-	-	8
Plant,Cell,Tissue &Organ Cult.	35(3)-1993	7	6	3	-	16
Plant Physiology	104(1)-1994	18	10	1	-	29
Plant Science	98(1)-1994	6	5	1	-	12
Plant Molecular Biology	24(1)-1994	18	2	-	-	20
Ethology	96(1)-1994	-	2	1	2	5
The American Naturalist	143(3)-1994	1	3	2	2	8
J.of Zoology	233(1)-1994	3	4	3	1	11
American Zoologist	33(6)-1993	6	4	1	-	11
Animal Behaviour	47(2)-1994	1	11	10	1	23
J.of Comparative PhysiologyA	174(5)-1994	9	4	1	-	14
Am.J.of Physiology part 2*	266(4)-1994	3	23	12	1	39
Biochemistry*	33(19)-1994	5	9	-	-	14
Total		**133**	**149**	**66**	**33**	**381**
%		**35%**	**39%**	**17%**	**9%**	

*(1/3 papers included)

a) without statistical analysis

b) descriptive statistics, mean ± S.E., t test, χ^2

c) Anova, regression, non-parametric methods

d) multivariate analysis, generalized linear models, time series

Stat Tutor: A Computerized Tutoring and Marking System for Teaching Statistics

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An abstract for The Fourth International Conference on Teaching Statistics (ICOTS 4)

This paper and demonstration will include presenting a computer-based course in statistics which is under-development at Athabasca University (Canada's open university). The project is funded by Alberta Heritage Fund. The system is developed in a Macintosh environment using Auotherware Professional.

The purpose of this project is to investigate the utility of using computer-based instruction technology in order to enhance the effectiveness of the teaching/learning process of statistics course. The study includes achieving the following specific objectives:

1. Design a conceptual framework for developing a computerized tutorial and marking system (CTMS) for statistics course.
2. Develop an unique prototype of the CTMS based on the conceptual framework.
3. Implement and evaluate the prototype in classroom and distance education environments.

The proposed system will include several computer-assisted learning components such as tutorial module, practice module, simulation module, assignment marking module, and an artificial intelligence component for feedback analysis. The prototype will be tested with a 2 x 2 experimental design using two teaching modes (classroom, home study) with and without CTMS. The quality of learning outcomes and the cost effectiveness of the teaching/learning process will be evaluated using the following criteria: (1) completion rate, (2) average class mark, (3) student satisfaction, (4) cost of delivery, and (5) students' studying effort and time.

JUDGING CORRELATION IN SCATTER PLOTS

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In this paper we describe an experimental study of students' strategies in assessing correlation in scatter plots. The sample has been constituted by 213 students in the last year of secondary school (18 year old students). The questionnaire has included 3 items concerning direct correlation, inverse correlation and independence in scatter plots and was given to the students before the instruction was started. So this study can be considered as a research on students preconceptions (Confrey, 1990) concerning correlation.

This report is part of a wider study concerning the effect of a teaching experiment, based on problem solving and on the use of computers, on the learning of statistical association (Estepa, 1993). The classification of the students' strategies, from a mathematical point of view, has allowed us to identify intuitive correct and partially correct strategies as, for example, studying the shape or the spread of the graph.

In the same way, incorrect strategies and judgment have served to identify three following incorrect conceptions: a) Determinist conception of correlation, when the student expects a correspondence which assigns only a value in the dependent variable for each value of the independent variable; b) Unidirectional conception of correlation, when the student considers the inverse correlation as independence; c) Localist conception of correlation when the student bases his judgment in only part of the data provided in the scatter plot. Finally, a correspondence analysis has been performed, in order to relate strategies and task variables of the items.

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The Use of Audio-Video Tchnology for Statistical Training in China

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1. Background

The task of statistical training in China is very ardous, as China has a large number of Statisticians. The full-time training provided through Universities and Colleges can not meet the needs of the rapid development of statistical work. The use of audio-video technology for statistical training is an important and effective way to train competent statistical personnel.

2. The organization and implementation of statistical training by using audio-video technology.

The Statistical Training Center of the State Statistical Bureau has set up two networks all over the country for statistical training by using audio-video technology. One is the network of audio- video technology and the other is the organization network for teaching. Since 1983 we have conducted the following training:

(a) Education and popularization of elementary knowledge of statistics.

(b) In-service training for statisticians leading to diplomas in statistics. The State Statistical Bureau and the China Central Television co-sponsored the Statistical TV-correspondence College of China, under which the statistical discipline was established.

(c) Training for purpose of applying professional knowledge combined with the judgement of professional title.

(d) Training of enumerators and interviewers for census and special survey.

(e) Training on new knowledge, e.g. SNA and computer software.

3. The advantages of statistical training by using audio- video technology.

a. the training methods are advanced and really effective.

b. the networks have been formed and well-organized.

c. the state examinations are strict and the quality of training is guaranteed.

d. learning is job-oriented and the training meets the needs.

e. work and study are done together and competent personnel are trained on the post.

f. the training is cost-effective.

THE 4TH INTERNACIONAL CONFERENCE

ON TEACHING STATISTICS

MARRAKECH, 25 -30 JULY 1994

FREE COMMUNICATIONS

AUTHORS: Doctor of Statistic Ms.Virginia M.Koatz

Doctor of Statistic Ms.Noemí Prado

THEME: The Teaching of Statistics in Tertiary Carees and Universities connected with Social Sciences in Argentina Republic.

PLANNING THE THEME: What sort of capacity from the professorship must be given to the future professionals of Social Sciences.

OBJETIVE: To fit the Teaching of Statistics in the different subjects of study (or disciplines) which conform the Social Sciences in order to be recognized by their professionals as a necessary tool to work with the problems of their own discipline and to interpret the results which are obtained from one investigation.

Adress:

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Telephone number: 041 - 309209 / Fax. 041 - 309209

The Problems of Teaching of the Theory of Probability and Statistics for non-Mathematical Specialities of the Kazakh National Al-Farabi University

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In the report it is suggested to discuss the number of problems connected with learning by the students of non-mathematical specialities of basic definitions while teaching of the common course of the theory of probability and statistics.

The ground of the discussion is an experience of teaching during several years the course at the biological and geographic departments of the Kazakh National Al-Farabi University.

As a rule the first part of this course is the Theory of Probability when the students are required to learn the number of abstract definitions, first of all the definition of probability of random event and other ones as well.

In order to improve the presentation of the common course it is suggested to change the structure of the course and pay much more attention to the conceptual treatment of the basic definitions.

Secondly, in the report it is suggested to share some experience of teaching the special course on "Methods of Optimization of Computer Systems" delevered to the students of "computer science" speciality and to discuss interconnections this course with the basic mathematical courses.

On Teaching the Big Ideas of Statistics : a project-based approach

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Students of Statistics, whether they plan to be statisticians, or only to use statistics as a tool in their professions, often fail to grasp the big ideas of statistics from their courses. "Service" courses concentrate on methods, while "mainstream" courses emphasize mathematical structure, and in both types of course, the powerful concepts most useful in practice are not given much emphasis. The textbooks that guide our teaching style do not seem to include a broad appreciation of statistical ideas among their objectives. Statistics courses that do provide some pedagogic emphasis to the big ideas, may still fail to convey these ideas if the examination does not require their comprehension. In this paper, I give some examples of "big ideas" and exam questions that would assess students' comprehension of them, and argue that even though they are the most important aspects of a course, that they will not be absorbed from courses following currently available textbooks. I suggest the use of a project-based teaching technique with which I have had some experience and success, and how to use traditional textbooks as support for such a project-based course.

COURS D'ANALYSE DES DONNEES ENSEIGNE A L'ECOLE MOHAMMADIA D'INGENIEURS

Abdelhalim SKALLI

Le programme d'Analyse des Données prévue à l'EMI favorise énormément l'application : Cela, en raison de la vocation même de l'Analyse des Données qui n'est pas d'être un objet de méditation et de construction Théorique pour le mathématicien uniquement mais d'être un instrument pour le praticien. Cettte formation s'adresse par ailleurs à des futurs ingénieurs qui seront plus souvent confrontés à l'application de ces méthodes.

C'est la raison pour laquelle le programme d'Analyse des Données se compose de 4 parties :

- La première partie fait connaître l'Analyse des Données sur le plan théorique mais avec une présentation intuitive. Cette partie se compose de sept chapitres nécessitant quinze séances de deux heures chacune.

- La deuxième partie consiste en cinq séances de travaux dirigés. Cette partie vise la compréhension de certaines propriétés nécessaires aux applications.

- La troisième partie consiste en la présentation de quelques cas décrivant sur des données réelles et précises l'objectif des méthodes. On présente des exemples de gestion financière ou de sciences expérimentales dont le domaine est facile pour des raisons pédagogiques.

- Dans la quatrième partie et pour que l'étudiant puisse utiliser et interpréter une méthode d'Analyse des données, quelques séances sont nécessaires. Des données relevant d'un domaine particulier de l'économie marocaine lui sont soumises.

L'étudiant doit alors rédiger un compte rendu du travail qu'il a réalisé après traitement d'Analyse des Données.

Ces quatres parties nécessitent 27 séances de 2 heures chacune. Pour la compréhension de ce cours une grande maturité est nécessaire de la part des étudiants. Par conséquent, il est souhaitable d'intégrer ce programme en dernière ou avant dernière année.

Using Microworlds to Elaborate more Faithful Models for Reasoning in Probability.

J. Bordier[1]

The normative rules used to evaluate human reasoning in probabilistic situations are based on knowledge that nobody should be expected to learn from routine experimenting, intellectual development, or being introduced to the mathematical theory of probability. Proving these rules depends, in an essential way, on hypotheses that could only be justified on the basis of empirical data or generalizations from these (Bordier, J. 1994). A related view is that misconceptions in probability judgments are only misconceptions in relation to the reality of large-scale random phenomena, which humans have no real opportunity to acknowledge.

Anyone who accepts these views could be sceptic about the possibility of destabilizing erroneous judgments in this domain and in helping students to elaborate more faithful models for reasoning in this area. In this paper, we use microworld simulations to analyze these possibilities. We also present an example of how computer environments can be used to ascertain spontaneous conceptions in probability. The empirical results will be presented at the Marrakech conference.

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Using Microworlds to Elaborate more Faithful Models for Reasoning in Probability[1].

J. Bordier[2], G. Bergeron[3] & P.Weidmann[4]

In the last forty years or so, beginning with the work of Piaget and Inhelder (1951), there has been a tremendous number of investigations about human reasoning in situations involving random phenomena. While the set up of these investigations has varied a lot, their general aim has always been to see if human beings, in their reasoning, use rules that are compatible with accepted normative rules.

But, depending on how one understands normative rules, the results of inquiries receive different interpretations. If a researcher thinks that the truth of normative rules should be obvious for a rational mind, he will be tempted to interpret any misconception relating to them as a case of irrational thinking (Cohen, J. 1981). A conflicting view is to think that normative rules are founded on the mathematical theory of probability. In this case, misconceptions relative to such rules are likely to be interpreted as illustrating either ignorance of some mathematical principles or incompetence in that domain. There is still another view about misconceptions in this domain (Bordier, J. 1994): misconceptions are only misconceptions in relation to large-scale random phenomena which humans have no real opportunity to acknowledge. This last view implies that misconceptions in probability judgments are not the result of faulty reasoning but only of not knowing what would result, for example, from flipping coins millions of times (except boredom).

Based on these ideas, we proposed, in a recent paper (Bordier, J. 1994), a theoretical framework for the correction of spontaneous judgments in probability. Four major considerations have served to define this framework:

1) the fact that the normal evolution of the human mind does not lead to a correction of misconceptions in probability judgments;
2) the recognition that the mathematical theory of probability can not serve as a basis for the correction of such misconceptions;
3) the fact that routine small scale experimentation is, in itself, not much better.
4) the fact that misconceptions in probability are only misconceptions in relation to large-scale random phenomena

In regard to such considerations, one can be sceptic about the possibility of destabilizing erroneous judgments in this domain and in helping students to elaborate more faithful models for reasoning in this area. If reasoning and/or small scale experimentation is of no avail for the correction of mental models, how could we possibly alter these models?

In this paper we explore the possibility of using computer simulations in relation to the correction of misconceptions in probability judgments. But before considering this issue, we will look at some of possible difficulties that could come along with using computer simulations.

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On the Justification and Possible Limits of Computer Simulations

Nisbett and Ross (1980) and Fishoff (1982) recognized that any processes which intend to modify intuitive models, by making one doubt his/her views, must include a factual demonstration of their inadequacy. This is also the point of view of many researchers who see structured experimentation as a mean of getting people to develop a more realistic vision of random phenomena (Fishbein and Gazit, 1984; Shaughnessy, 1977). But, because of time consideration, such an approach is in most cases impractical.

Even for very simple situations, it is not easy to destabilize initial conceptions by using physical experimentation. An example will help clarify this point. If we throw a coin four times, all the 16 possible patterns have the same chance of being produced. This is the normative rule that is used for evaluating people's judgment about the relative chances of distinct combinations like

<head, head, head, head>
and
<head, head, head, tail >.

This normative rule cannot be justified by a mathematical argument because the proof would depend on accepting the hypothesis of independence between the throws. As reported by Wagenaar (1988), in verbal reports of players playing blackjack, most of them believe that the probability of winning a hand increases after three losses. For one who does not believe in independence, no argument can be put forward to convince him or her that it is a mistake to think that the event <head, head,head, tail, > is more likely to come up than the event <head, head, head, head>. But, could that rule be justified by throwing coins? Even for such a simple rule, it is not easy to show its validity on experimental grounds. By repeating the experiment of throwing a coin four times, a very large number of times, one would realize that the relative frequency of the 16 different patterns turns out to be about the same. But doing this would take a lot of time. For someone who sees the possibility of faithfully reproducing the same experiment on a computer, the experimental proof of the normative rule would be much more probant. It is a simple task to write a program that will simulate the experiment of throwing a coin four times and to repeat this basic experiment until a specific pattern like <head, head, head, head> turns up[5]. The variable of interest here would be the number of elementary experiments needed for this event to happen. By repeating this experiment a large number of times, while keeping track of the evolution of the mean number of elementary experiments needed for it to end, one would see that the mean waiting time converges toward 16 and that we get the same point of convergence for any of the 15 other patterns.

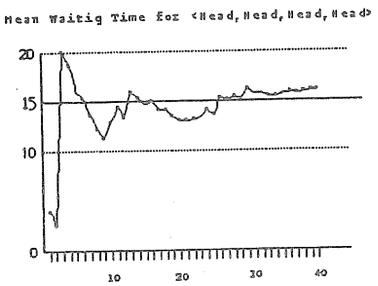


FIGURE 1: After 40 experiments, the mean waiting time for the event {Head,Head,Head,Head} is 16,03.

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[5]In (Bergeron, A., Bordier, J. 1991) we present a general environment for simulating a large variety of random phenomena.

But, using a computer program for getting students to learn about modeling in this domain rest on the capacity of the computer to faithfully reproduce the reality of random processes. It also rests on the belief that students will trust the computer. Finally, there is a much more profound difficulty: even if a simulation program can serve to illustrate the fact that common views about chance events are often false, it does not follow that such experimenting is really going to change beliefs, especially if it pleases one to retain these beliefs. We briefly examine below these three possible limits on the use of computer simulations.

The Possibility of Reproducing Random Events on a Computer

The relation between computer simulations and mathematical modeling of randomness as well as those between mathematical modeling of randomness and the reality of random processes are complex. Let us first say that random number generators are specifically constructed so that the sequences they produce pass successfully statistical tests for various properties of the mathematical model, like independence. What has been shown is that it is very difficult to build random number generators that are not somewhat deficient (L'Ecuyer, P., 1990; Park, S.K. & Miller, K.W., 1988). As to the relation between mathematical modeling of randomness and the reality of random processes it can only be studied by statistical tests of experimental data. All that is known, from systematic experimentation's in specific cases, is that objects like coins, notwithstanding their imperfect symmetry, exhibit minimum bias relatively to the mathematical models of randomness (Feller, W., 1968).

Will Students Trust the Computer?

One may doubt that students will trust the computer if it produces results which contradict entrenched beliefs. Students could then think that such results do not represent the reality of random processes. For example, sequences of heads and tails produced by a computer are a lot different from sequences built by humans. A typical human sequence is 0101000100110110011011001100100001100100101101001110100101101011101101010011100110010011011010101010 which contains far too many alternations. Now, if a student were to examine sequences produced by a computer program he or she would note major differences from his/her view of a random sequence. The computer sequences are likely to contain many long runs of identical results which we do not find in human sequences. Their reactions could then go two ways:
- to think that their idea of a random sequence is mistaken;
- to think that the generator does not faithfully represent the reality of random processes.

In fact, what we have observed (Bordier, J., Wiedmann, P. & Bergeron, G., 1994; Bordier, J. 1991) is that young students and most adults have a blind faith in computers. For this reason, it would be most important to get students to understand that good random number generators are hard to find (Park, S.K. & Miller, K.W., 1988).

Can Beliefs be Altered

For a belief to be altered, or eliminated, one must normally replace it with another. What if the new belief is drab? In the domain of probability, misconceptions seem related to the desire of getting some control over random events and the complete eradication of misconceptions would mean thinking that no such control is possible. Because of this, even if the use of simulations were to have some positive impact on cognition, the complete eradication from the human mind of deterministic thinking, in probability judgments, appears illusory.

In the next section, we illustrate the use of simulations to get to know the workings of spontaneous conceptions in probability. Afterwards, we will present and discuss

In the next section, we illustrate the use of simulations to get to know the workings of spontaneous conceptions in probability. Afterwards, we will present and discuss investigations that we are now pursuing on the use of simulations to correct erroneous conceptions in probability. The experimental findings are to be presented at the Marrakech conference.

Using the Computer to Get to Know Human Conceptions in Probability

While they can be very useful, verbal reports coming from subjects realizing a task are not sufficient for studying human reasoning. First, subjects might not be willing or able to reveal their inner thoughts and even if they do, we have no insurance that their rationalization represents their thoughts or that they reveal everything that passes through their mind. For Nisbett and Wilson (1977), the rationalization produce in such moments might be very different from the cognitive processes in the subject's mind. Let us give a simple example to illustrate that verbal reports can give a false idea of human conceptions. Suppose one were to ask the following question:

> *If I throw a coin three times and get three heads, do you think that, for the next throw, the chances for a ail are somewhat greater then the chances for heads?*

For someone who feels that the chances for a tail increase after three heads, it is not clear at all that he will answer that way. The rationale for his answer might be that he knows that a "yes" answer is likely to bring about the question "*why* " and he would not be able to provide a rational answer to this second question. However, if we do observe subjects completing a task, where no question has to be answered, we might find that, after three consecutive heads, the subjective probability for a tail gets higher than 0.5[6]. We will illustrate below how the computer can be used to elicit such spontaneous conceptions in probability judgments.

Consider a situation where one were to ask experimental subjects to throw two regular dices and try to predict the next sum that will appear. As sum 7 is the more likely sum to appear, subjects would have interest, for increasing their potential winnings, to always predict sum 7. Our research hypothesis is that subjects, even when they know this property of sum 7, and understand the rationale behind it, will take account of past results and so, would not predict sum 7 on every try.

At first sight, this hypothesis appears very risky, for how can one doubt that a rational human being would always choose sum 7, especially if there is a price attached to an exact prediction. However, if it is true that the subjective probability of an event is a variable which is strongly dependent on past events, we will observe that many subjects, who know that sum 7 has more chances than others sums, do not choose, at all times, this sum as the more likely sum to appear next. Normally, in the first tries, subjects should choose sum 7 but, if a sum like 5 has not been thrown in the last 15 throws, the subjective probability of that sum should increase. Also, after having obtained, for example, sum 7 twice in a row, the subjective probability of that sum, for the next throw, should decrease. It is fairly easy to elaborate a computer environment with which such a risky prediction can be tested. We present one below.

A Simulation Microworld to Test a Prediction

Below we define an experiment made up of two complementary parts. In the first part, subjects are given the opportunity to discover that sum 7 is the more likely sum to appear if one throws two dices and to discover the rationale behind this result. In the

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[6]In "The most Fundamental Misconception in Probability Judgment" (Bordier, J. ; Weidmann, P & Bergeron, G. 1994), we show that the concept of probability, as a fixed number independent of past results, is not part of an adult's mental model for chance events. In an adult's mind, the probability of an event is often seen as a variable strongly dependent on the events that happened just before.

second part, subjects have to predict, with monetary gains if their prediction happens to be right, the next sum that will appear in a series of twenty five throws.

For the first part, we elaborated a microworld for simulating the throw of dices. We asked each subject to keep on simulating until he gets absolutely convinced about the most likely sum to appear (if there is one). Subjects are told that they will receive $5 if they find the right answer. The following figure show the kind of information that is accessible to the subject after 500 simulations.

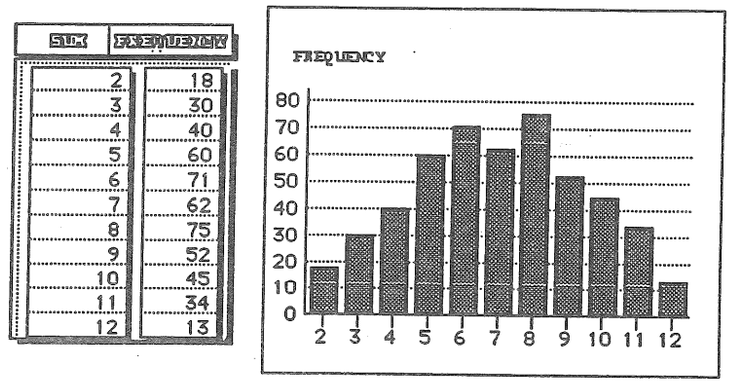


FIGURE 2: Five hundred throws of two dices

As one can see, in figure 2, even after 500 throws the most likely sum is not necessarily presumable. For that reason, subjects will normally have to make a fairly high number of simulations before getting totally convinced about the most likely sum. With the software, simulations can be produced one at the time, with an upgrading of the graphic of frequencies after each simulation, or at the rate of 10 000 simulations in 1 second.

When the subject is sure of his answer, we present him/her with an environment which can help to rationalise the fact that sum 7 is more likely than other sums. For this, a simulation of the occurrence of the different possible sums is presented to subjects (see figure below). Subjects are expected to play in this environment until they can give an explanation for the symmetric shape they have observed for frequencies of different sums.

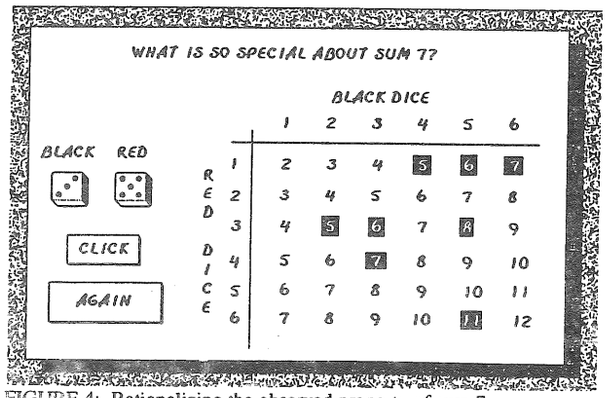
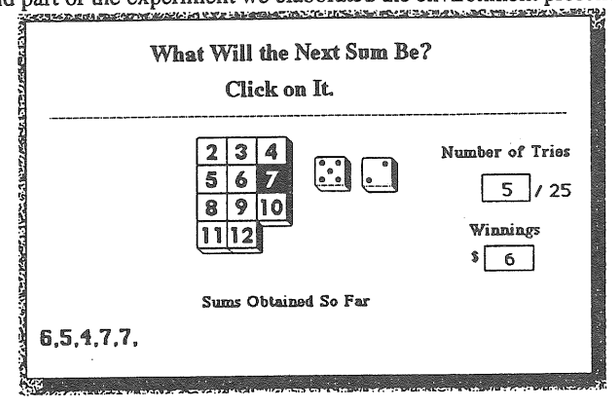


FIGURE 4: Rationalizing the observed property of sum 7.

For the second part of the experiment we elaborated the environment presented below.



In this set-up, the subject has to click on the sum that he predicts for the next throw. The sequence of actual sums that have already been produced appears on the screen. The subject is also given information about the number of tries and the actual amount of his winnings. The game is over after 25 tries at predicting.

In order to test the main hypothesis of this investigation, we had to trick the software so that, for every subject in the study, the same sums would be produced by the computer (the dices roll but the results are fixed in advance.). We used the following sequence of results: <<6,5,4,7,7,10,7,9,3,11,6,8,8,5,7,7,7,11,9,6,6,6,12,9,5>>.

Our main hypothesis is that even if a subject knows that sum 7 is the most likely sum, he will not put to use that knowledge at every stage of the game. His choices should be somewhat dependent on the sums that have already appeared. For example, after seeing two or three consecutive 7 the probability of that sum should decrease for the next throw.

The investigation is to be conducted in June 1994. At the Marrakech Conference, we will present our factual findings on this. If our hypothesis happens to be validated, it would mean, in particular, that knowledge about the probability of an event is not, for the human mind, the decisive information for decision making in situations where uncertainty prevails. In making a decision, in such an area, the human mind tends to use information which decreases the expected return.

The Correction of Misconceptions

In this section, we will only present one of the computer environments which was built for testing the hypothesis that simulations can be of some use for the correction of mental models in probability. The object of this environment is to get students to experience the fact that there is no useful way of using past information for predicting future results of chance events. At the Conference we will present a second environment whose object is to get students to experience the fact that any two combinations at LOTO games have the same chances of being produced.

On the Use of Information About the Past

In the first part of this investigation, a *random* sequence of length 100 is generated, step by step, by a computer program and the subject tries to predict its elements. Subjects are to receive $3 for every percentage-point over 50%. The subject may, while performing this task, use information about the sequence that is being generated by the computer: the number of heads and tails in the part of the sequence

already generated and the list of elements already generated by the computer. If a subject chooses to use this information, he/she will have to pay for them: $1 for one type of information and $2 if he uses both types. This is paid in advance by the subject from the $10, in coins, that he receives at the beginning of the session.

If a subject has actually paid to get information, we present him/her with a situation where he could possibly learn that information about the past is worthless, in the sense that it can not be of any help for predicting future random events. In this second part, the subject first asks the computer to generate a random sequence of length 100. He then uses different predictors for this sequence, that were incorporated in the environment (see figure below). Some of these predictors use past information. For example, one of them makes his predictions using a global equilibrium principle: if there is an imbalance between the number of heads and the number of tails, it predicts that the next element generated by the computer will tend to reequilibrate those numbers, otherwise it predicts that the next element will be different from the last. Other predictors do not use past information. For example, *The systematic* always predicts a Head for the next element that will be generated by the computer. Subjects are first asked to predict which of these predictors is going to be the best in the long run. Afterwards, they are to experiment about the relative power of these predictors, by comparing their mean percentage of successes: the idea being that they will come to realize that every predictor is just as good as any other.

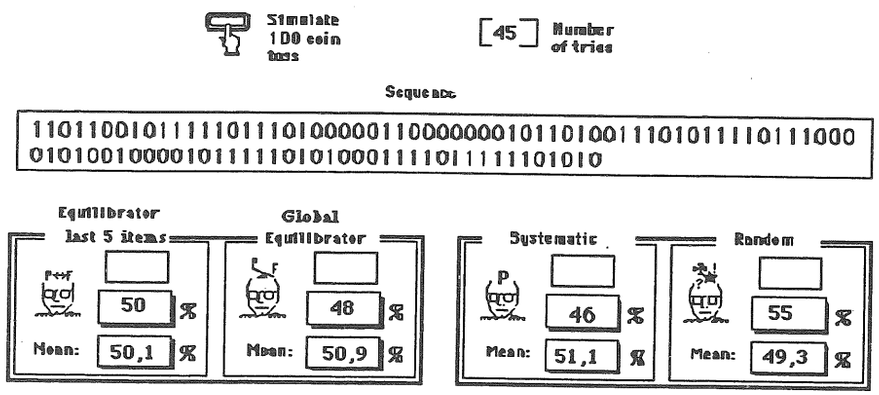


FIGURE 2: Comparing the mean percentage of successes of different predictors

Subjects should come to realize that, on the average, no predictor can be any better than 50%. They could also infer that it had been a mistake, on their part, to pay for past information (this is the main hypothesis). In order to verify this hypothesis, we ask subjects to go back to the first task and to try again at predicting the computer sequence (they do not build the whole sequence this time). The real question is: will they pay or not, this time, for past information? The experimental findings of this investigation will be presented at the Conference.

Conclusions

The idea of using simulations, for dealing with the problem of misconceptions, is based on the fact that normative rules for probability judgments cannot be justified by reasoning alone and that routine experimenting can not be of any help because of time considerations. Not being able to justify normative rules, in this domain, is equivalent to not being able to show that a misconception is a misconception. If one were to accept these views, as well as the proposition that misconceptions in probability judgments are

only misconceptions in relation to the reality of large-scale random phenomena, the idea of using simulations for destabilizing spontaneous conceptions should be obvious . But, as we already noted, this does not mean that such a didactic approach is going to work. We do believe however, albeit pending confirmation, that computer simulations can be of some use as didactic tools for helping to build more accurate models for reasoning in this area. We will present our experimental findings on this at the Marrakech Conference .

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L'ordinateur pour le retour à des procédures naturelles? L'exemple des procédures inférentielles.

Denis CORROYER. (LaPsyDEE - CNRS - Université Paris V. 46 Rue Saint Jacques 75005 PARIS).

Quoi d'apparemment moins naturel que l'outil informatique? Pourtant en ce qui concerne le traitement statistique des données on peut penser que l'outil informatique permet de revenir à des procédures plus proches de l'intuition et d'en faciliter ainsi l'enseignement. Nous illustrerons ce point à propos des procédures inférentielles.

Après avoir précisé ce que l'on entend par statistique descriptive et statistique inférentielle, nous évoquerons les difficultés de l'enseignement de la démarche inférentielle traditionnelle. Ces difficultés se traduisent ensuite par des pratiques erronées, qui consistent par exemple à prendre les valeurs observées des statistiques inférentielles, ou le seuil, comme indicateurs de l'importance des effets.

Il est important de rappeler, dans une perspective d'apprentissage, le statut des statistiques inférentielles traditionnelles (T de Student, χ^2, F de Snedecor...): elles ont été conçues principalement pour éviter la construction d'un grand nombre de tables; ce sont des intermédiaires de calcul (pour parvenir au seuil) et apportent en elles mêmes peu d'information sur les données.

L'outil informatique, en libérant des contraintes du calcul, permet de concevoir une autre démarche inférentielle, plus naturelle, qui consiste à calculer le seuil en prenant comme statistique de test, plutôt que les statistiques inférentielles traditionnelles, les statistiques utilisées lors de l'étape descriptive (écart-réduit, ϕ^2, rapport de corrélation...).

Le résultat obtenu (seuil observé et conclusion) est strictement identique à la démarche traditionnelle. Mais cette nouvelle démarche présente plusieurs avantages pour l'enseignement. D'une part, elle contraint à une démarche en deux temps: la description d'abord, l'inférence ensuite, et l'étape inférentielle apparaît mieux ainsi comme un *prolongement* de l'étape descriptive. D'autre part l'étudiant (futur utilisateur) n'est amené à calculer que des statistiques apportant une réelle information sur les données (contrairement aux statistiques inférentielles, ces statistiques descriptives permettent d'évaluer l'importance des effets).

Il s'agit d'une démarche plus naturelle au sens où c'est celle qui est apparue d'abord chez les pères fondateurs (cf. en particulier, Student, 1908, qui, dans un premier temps, a présenté l'écart-réduit comme statistique de test).

On présentera brièvement un logiciel (DS3) qui permet de mettre en pratique la démarche proposée.

On conclura en soutenant l'idée que proposer cette démarche inférentielle, ce n'est pas éviter à l'étudiant les rigueurs du raisonnement formel qui constitue le point central de la démarche inférentielle, mais c'est lui donner des chances de ne pas perdre de vue les questions qu'il se pose, de mieux comprendre le sens des procédures qu'il met en oeuvre, à chaque étape de l'analyse, et d'éviter des erreurs dans l'interprétation des résultats.

PRESERVICE PRIMARY TEACHERS' NOTION OF RANDOMNESS

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Because of the Educational System Reform, the introduction to the study of the random situations becomes a reality in our country. We are considering, from our perspective as primary teachers educators, the training of preservice teachers related to this new school mathematics topic.

We have approached to this problem with a first descriptive study through the analysis of a questionnaire that have been responsed by 57 preservice teachers. The goal was to make explict their conceptions and level of identification of the phenomena randonmness throug the answers and explanations given to that questionnaire. We have identified several approachs to the way of thinking of the people tested. These are:

a) Those who reflected an inportant incidence in their way of reasoning of the determinist approach, they almost do not recognize the randomness of the some phenomena,

b) Those who explain the phenomena randomness because of causal reasoning and

c) Those who have an important recognition of randomness for some events, but that have not yet very elaborated characterizations.

Another two groups are detected with a poor explicative body, those who seems to be insensitive to the information given, and those who show a way of reasoning without clear characteristics.

We believe that these types of randomness conceptions, that are the focus of the probabilistic thinking, which are confused and sometime controversial should be reconstructed by those who are going to be the ones that introduce children in the probabilistic thinking.

TEACHING STATISTICS WITH REAL QUESTIONS

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At ICOTS 2 invited speaker Terry Speed pleaded strongly for an approach to teaching statistics which was a considerable departure from the norm. His message was to always teach statistics in context : begin with a real question, develop the necessary analysis and return to an answer to the initial question.

Following the ICOTS address, a pilot course was taught in this fashion at the University of Canterbury in New Zealand. This talk will tell you all about it. What questions we asked, the answers we found and how students reacted. Suffice it to say that the department decided to teach all streams this way the following year.

Reform of the Statistical Teaching and Statistical Textbooks in China

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With the rapid development of China from a planned economic system toward the market-oriented economic system, the statistical education of China is faced with important change. The original model of statistical teaching and the statistical textbooks that served for the planned economy over the past decades can not meet the needs of statistical work under market economy. Reforming the statistical curricula of universities and colleges and updating the contents of statistical textbooks are the central tasks of statistical education of China. The Statistical Training Center of State Statistical Bureau, as the leading organisation for statistical education in China, pays great attention to this matter and is making investigation and research. In this paper we discuss the relevant issues of this matter.

1. The original model of statistical teaching and statistical textbooks: the background and existing problems.

2. The progress that have been made in the reform of statistical teaching in recent years.

3. The direction of the reform of statistical teaching in the future

Abstract

STUDENT CENTRED LEARNING

A report on the Teaching of Statistics to a Wide Variety of Students at Auckland Institute of Technology, Auckland, New Zealand.

Paul Grose
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I attended ICOTS3 in Dunedin in 1990, where almost all the lectures and papers presented were on WHAT was taught in statistics courses, and only one paper was on HOW statistics was taught. This report discusses some of the methods, we at A.I.T., use to make statistics relevant to the wide variety of students that we teach.

We use simple objects like pieces of string to introduce data types. We encourage students to collect their own data, like body measurements for dress designers, and hamstring lengths for physiotherapy students. Students are encouraged to discover as much as possible about the information available in their approach to statistics.

ABSTRACT

Using Statistics and Data Analysis to Motivate Other Mathematical Topics

M.B. Ulmer - University of South Carolina at Spartanburg
and
M. Scott - Western Illinois University

In the years preceding the Cockcroft Report and the Teaching Statistics and Quantitative Literacy movements, statistics was considered little more than an optional condiment on the school math syllabus. Subsequent to ICOTS 1 some schools began putting in courses at the junior/senior level. About the time of ICOTS 2 some US school districts began requiring some statistics for high school graduation. This was most often accomplished by teaching modules that were often more probability than statistics. Then efforts such as the ASA/NCTM Quantitative Literacy Project began to have an effect, emphasizing strands of statistics running through the math syllabus and Project 2061 promoted a totally integrated science curriculum with data analysis as an integral component. These programs and their underlying philosophies made the introduction of statistics a bit more palatable to teachers reared in a math world.

One variation that includes these philosophies is the idea of a curriculum that is data driven, a curriculum in which data analysis and statistics form a foundation on which other concepts are integrated. One such project, the Campobello Project, used a separate course in statistics and data analysis to introduce and motivate topics in algebra while providing teacher inservice training in elementary statistics.

In the first part of the project students were concurrently enrolled in statistics and Algebra I. Each topic in the statistics course began with an experiential exercise that resulted in some form of measurement or data collection. Analysis of the resulting data employed elementary statistical techniques that increased in difficulty as the course progressed. That analysis led to the use of algebra, either to communicate that which was gleaned from the analysis or to refine the statistical techniques. The statistical techniques thus developed could then be applied to the same data or to data generated in another experiential exercise. A textbook written for the project guided the students' investigations.

This Experience > Statistics > Algebra > Statistics > Experience instructional model had a notable effect on the algebra performance of slower learners. In statistics the benefit went to the more advanced learners who performed well enough to win in national statistics project competition.

This instructional model met with more resistance when used with older slow learners who had taken, but not mastered, three years of algebra and geometry. These seventeen-year-olds already had the fear of quantitative notions that several studies have identified in US adults. It was opined that even with the resistance, exposure to statistics and data analysis in a realistic setting left the students with a more applicable quantitative orientation than they might have had on exiting the traditional math sequence. Experiences with these groups of students seem to verify the reports indicating the need for early exposure to topics considered by many US educators to be "post-algebra" topics.

Exploring Probability and Statistics Through Hands-On Experiments and Cooperative Learning

Dr. Martha Bilotti-Aliaga

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USA

The new standards in education stress communication, cooperation, and group performance. The major thrust of this talk is to share with you my belief that knowledge is best gained through a collaborative learning context, with the group constructing it themselves. Students must learn how to gather evidence to make conjectures, to formulate models, to invent counterexamples, and to build sound arguments. The power of manipulatives as teaching tools lies largely in the fact that they appeal to the students' senses. I will use the Graphing Calculator TI-81, data gathered from the audience, and *different* hands-on materials to explore modeling in Statistics and Probability.

USING A CLASSROOM MICRO TO TEACH SECONDARY STATISTICS

by

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OUNDLE SCHOOL, Peterborough, England

KEYWORDS:
Classroom computer - TV Monitor - Interactive Software - Data Handling

Summary:
The Author and colleagues at Oundle School have been using a classroom micro to teach mathematics for the past 10 years, and have developed a range of interactive software. The computer is linked to a TV set, which can then act as an electronic extension to the white board,

The programs covering the teaching of probability, statistics and data handling allow a large range of concepts to be developed on screen. The programs run on the Acorn 32-bit RISC computers, which are in wide use in schools in the UK and Australia.

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A survey on the role of computers in teaching Statistics

Traditional teaching appears as a simple transfer of information from teachers to students. In statistics the result is often a formal knowledge of methods and procedures divided from intuition and from student's knowledge of other subjects. Recent opinion among education researches holds that it is necessary to introduce new instructional system that can guide construction of statistical understanding and encourage the active partecipation in learning of students. A mixture of instructional media improves the average comprehension of students, in particular computer gives a new style of teaching and learning. Its use has important cognitive effects. By computer it is possible to illustrate concepts through animated graphics, to make real applications, to introduce simulation of repeated samples and so on.

The most part of teachers have experience about the substantial differences among students in their ability to comprehend concepts presented by interaction between teacher and computer.

Our goal in this paper is to survey the role at the present time computer plays in Italian University statistical teaching. For this end it has been done a classification among the Faculty where there are some statistical subjects.

Through this study it is possible not only to consider the present situation as to methods of teaching, but even to forecast the future trend.

Key words: Computer, teaching, learning

Statistical Software and the Selection of Outliers

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The teaching of statistical principles and methods has for many years been an important part of training programmes for statisticians, and there is now broad agreement on what should be taught and on how it should be presented.

Most programmes contain subjects on: probability and mathematical theory of statistics and specifics statistical methods. In general we find specific topics such as: sampling theory, design of experiments, time series, non parametric methods, etc. Most of these topics are studied in excelent textbooks. The teaching of the pratical application of statistical methods on the other hand is in a less satisfactory state.

Good data analysis starts from carefully phrased questions. A very common mistake is to start instead from a predecided method of analysis.

It is very easy to fall into the trap of doing an statistical inference because the data have a form amenable. In pratice, there are no standard problems, only standard solutions.

From the statistical point of view it is very important to study discordant values, for instance, in model identification and model fitting.

Most statistical software deal with those observations, "identifying" them. Using subjective criteria the influence on statistical inference may be decisive. We need to pay careful atention to the data - and its quality - and to the underlying theory or structure of the problem.

Clearly computers have an important role to play in teaching statistics. We present some examples from well known statistical packages to conclude how important is to generate genuine data in which we have confidence to provide satisfatory statistical inference.

Keywords: teaching statistics; statistical software; outliers; model identification and model fitting.

Learning multivariate statistical methods with a PC programme

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A research group at the Faculty of Statistics, the University of Padua, has implemented a software programme for data analysis named STATREE. The approach is decision tree-like: the system gets the description of the problem by asking the user a set of chained questions and when problem specifications are sufficient, it suggests one or more appropriate techniques. The system is capable to perform the statistical analysis, provided the SAS statistical package is present on the user's computer.

The software programme is composed of four components: the database containing the available statistical expertise, the structured query module to the database, the on-line help to statistical topics and technical terms, and the interface to the SAS data processing system.

The knowledge of the system is based on a hierarchical network database, so that the system can easily "learn" new techniques and new solutions to problems. The database creation and updating are enabled through an interactive full-screen oriented managing module.

The interfacing module to SAS package supports univariate, bivariate and trivariate analyses. The coming version of STATREE will expand the knowledge database for multivariate analysis and implement the multivariate techniques available in the SAS package.

While being an operative tool, the programme has been designed with a primarily didactic purpose, as promoter of learning, effective in making the user aware of the criteria for identifying the methods that fit the objectives of the analysis. It has been used several times in University courses and other teaching occasions.

The programme can help a researcher with a limited statistical background to choose statistical methods for research purposes, avoiding the misuse of inappropriate analysis techniques, and to perform the data analysis without experience of algebraic packages.

From our experience, the decision tree approach, far from a black box or cookbook approach, is effective in terms of learning. The user develops the ability to state the research problem in statistical terms and to screen the properties of the methods available. The iterative dialogue between the user and the system to identify the suitable analysis makes him aware of the basic role of the research goals, and informed of the conditions which must be satisfied before the technique can be applied. Thanks to the on-line statistical help, the system may be used as a teaching machine, with occasional consultations of the manual.

TOWARDS THE UNDERSTANDING OF THE SUBJECTS AND THE BORDERLINES OF TODAY'S ECONOMIC STATISTICS

By M. Cuffaro and M. Davi'
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Summary

The aim of this paper is to propose a simple novel framework for Economic Statistics.

The lack of a standard framework has appeared with particular evidence by a sample survey referred to the Italian Faculties of Economics and Statistical Sciences (Davi', 1993), by means of the examination of Italian textbooks.

This proposed program is founded on the "core" of the discipline as defined by Zellner (1992) "learning from data and solving practical problems".

The program is divided into the following arguments:

a) definitions of macro-aggregates and of interrelations among them;

b) classifications of economic data, statistical sources, quality of data and methodological aspects of collecting data;

c) use of economic data.

For this section it needs referring to the real object of Economic Statistics that "deals with specific ways of ordering data and testing hypotheses" (Kane, 1968).

Data may be gathered with reference to the time (time series data), to the individuals (cross-section data) and both to time and individuals (pooled cross-section and time series data) by these following tecniques:

1) univariate and multivariate analyses of time series (classic and Arima models, business cycle analysis, forecasting, consumption and production analyses);

2) multivariate analysis, factorial analysis, shift-share analysis, cluster analysis;

3) models considering different hypotheses relating to the constancy of intercepts and slope coefficients.

In our opinion this "corpus" of arguments could constitute a reference for teachers, also leaving to these teachers an ample freedom for deepening subjects and methods.

Key words: Economic statistics, academic courses, program.

THE FOURTH INTERNATIONAL CONFERENCE ON TEACHING STATISTICS ICOTS IV

Abstract: Contributed Paper

WRITING A STATISTICS TEXT FOR BUSINESS: THE COOKBOOK APPROACH

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It is not uncommon to hear a statistics text, particularly in business statistics, dismissed as a "mere cookbook". This disparaging remark almost always goes unchallenged. But what is meant by a "mere cookbook"?

The author is currently writing a statistics text for first year university courses in business and economics in Australia. Due for publication in 1995, the project will have taken more than three years to complete. The author, however, is also a keen chef and food writer. Besides occasional contributions to the Melbourne "Age" on the subject of food, with his wife as photographer, he is also the regular food writer for a widely distributed Australian colour magazine. His range of cookbooks more than matches his collection of statistics texts.

Clearly some textbooks are better than others. And some cookbooks are better than others. But what are the essential ingredients of a successful statistics text and is there anything wrong with the cookbook approach?

In his paper the author examines the problems confronting the writer of a statistics text for first year university courses in statistics. In an approach that is both light-hearted and serious, he uses his experience in the culinary field to examine the proposition that a text in first year business statistics cannot be anything other than a "mere cookbook".

ECONOMIC STATISTICS TEACHING IN ITALY

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Economic statistics studies the collective economic phenomena by the use of convenient methods and statistics patterns built up to meet the specific needs of each problem and defined on the basis of a set of logicals principles, criteria and processes which form the theory of economic statistics (Cusimano,La Rosa,Buccafusco,1984)

Among the economic statistics tasks, it has recently been emphasized the task of locating, defining, pointing out, measuring and analyzing the manifestations of the collective economic phenomena so that they may contribute, together with other subjects, to answer to the fundamental question that troubles the scientific thought how the economic phenomena, in their temporal continuity and territorial articulation, take place (Alvaro,1992)

The comparative analysis of the contents of economic statistics, as they come out from the reading of "text-books" recommended in Italian Universities, has let us gather the discussed subjects in the following three classes 1)definition and measuring criteria of macroeconomic aggregates and of the relationship among aggregates, 2)technics of analysis, 3)specific subjects.

With this study we want to ascertain which changes have taken place in economic statistics in Italy in the last decade, especially in economic statistics teaching and, first of all, to point out the increasing attention dedicated to data formation, to the check of its connection with the manifestations of the economic phenomenon which is being examined, to the evaluation of its reliability and, more generally, of its trustworthiness.

The increasing consistence of quantitative economic information, of statistics or simply administrative origin, indeed sets the economic statistics on additional task, that is the one of a critical evaluation of such information, and the economic statistician the task of helping the possible users know the results of such evaluation in order to stop twisted opinions which often have a deep political impact.

The obtained results seem to be worthy of attention even from the point of view of the economic statistics teaching and of the relationship with statistics.

Key words: economic courses, economic statistics

Statistics in Computing Courses within the Engineering Faculty

Susan Starkings, South Bank University, London

Statisitcs in what is known as traditional engineering courses tend to cover areas like calculus and statistics for physics plays an obvious paramount role. Computing courses have been in Universities and Higher Education Establishments for several years now but has the statistical content changed to support this type of engineering course? Students join these computing courses from a wide variety of backgrounds, especially in their statistical experience, and there is a growing need to ensure that lecturers have a common core of mathematics/statistics, that the students have acquired, to build on. The needs of employers are a consideration that must not be ignored especially if students intend to join the relevant engineering bodies to enable them to seek employment in this area of work. The lecturing staff have the daunting task of designing and implementing curriculum changes that reflects changes in students backgrounds, engineering bodies requirements, employers needs and funding for such courses which is now a major consideration in all fields of education.

This paper intends to address some of the problems of teaching statistics to computing students; to investigate what is required and useful for the students on these courses to acquire; to suggest new ways of how to implement curriculum changes and various examples will be explained to elucidate the content of statistical computing and how computing and mathematical degree students can be taught together.

TEACHING STATISTICS IN PSYCHOLOGY

R. GIAIMO - A.M. MILITO

In recent years Statistics has been inserted into many faculties, such as Psychology, Medicine and also in some Humanistic courses. In these academic majors only one course of Statistics has been introduced so that the programme includes both Descriptive and Inferential Statistics and in some cases also Multivariate Analysis. This occurrence has determined a very synthetic exposition of the diverse subjects of the discipline and consequently this rapid exposition of the different subjects does not aid in the full comprehension of the arguments dealt with. However, in these academic majors, the discipline is very important to the formation of the students in their varying fields of study and so it is necessary that Statistics in the different majors have different contents. For this reason, we have tried to study the academic context into which Statistics may be inserted.

Last year, we carried out a survey with the purpose of acquiring information on the teaching of Statistics in diverse faculties. From our analysis it emerges that in the faculties where Statistics has been most recently inserted there are professors of other faculties and the contents of the courses vary little from one faculty to another. The need for a common statistical base, with variations in the contents of the courses in relation to the major field of study, has appeared evident.

The aim of the research is to explore didactical needs of the academic major in Psychology. We distributed a questionaire containing a few questions on the argument of the actual teacher situation, on the real needs of the various disciplines of study and on the means proposed to improve the comprehension of the subject to the students of Psychology. The results of the survey are going to be presented during the conference.

The first results of the analysis appear to show that students are interested in the methodologies that are specific to their areas of research and that they prefer to study with real data. The students also mention the need to approach Statistics in a very new manner, using new didactical and technical means.

Key words: Teaching Statistics, Didactical Problems, Psychology.

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