Some Issues in Teaching Statistics at University Level

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In moving from being two CTI Centres in Mathematics and Statistics to a three site Centre as part of the Learning and Teaching Support Network (LTSN) the breadth of work to be covered by the new Centre for Learning and Teaching in Mathematics, Statistics and OR has increased substantially. This article aims to raise some of the issues that affect the teaching of statistics and to encourage participation in an active dialogue to improve this teaching in UK universities. A lot of good work is being done in many institutions and one of the best ways of improving is to share our experiences. Please email either myself (Peter.Holmes@ntu.ac.uk) or Neville Davies (Neville.Davies@ntu.ac.uk). You could also join an appropriate discussion list (such as the MeaNs list - means@mailbase.ac.uk).

Over the two years to April 1998 the **MeaNs** project (Matching Education and Assessment with employment Needs in Statistics) had many working groups, discussions and a final conference on the theme of the suitability of university statistics courses in preparing students for work after graduating. The full versions of newsletters, reports and conference papers can be found on the **MeaNs** web site and much of the content of this article is based on information gathered during this project. The project brought together lecturers, recent graduates in employment and employers from many different areas where statisticians are employed. Of course some jobs require greater and more specialised statistical skills than others, yet there was a remarkable degree of unanimity between employers and employees as to what was wanting. The following is a quotation from the first **MeaNs** newsletter.

Employers - assessing their needs

The employers were generally more interested in attitudes and personal skills than in specific technical competence. A good grounding in basic statistics was rated higher than deep theory. Companies differed greatly, from those who provide training to those who do not; from those who have specific expectations about the statistical activities of their employees to those where senior and middle management still need to be convinced of the usefulness of statistics.

A common requirement of employees is that they should demonstrate good communication skills - both oral and written. Statisticians often need to work in a team with non-statisticians and may also have to communicate in non-technical language to clients. Interactions of this sort require a maturity of outlook and the ability to ask intelligent questions and to express complex ideas simply.

Employers welcome courses with more practical orientations and placement years (in universities that have them) were felt to be extremely beneficial. They are generally disappointed at the lack of practicality in new recruits, something that shows up particularly at interview. In general employers are critical of sanitised and over-theoretical courses.

Employees - reflecting on their experience

The employees were encouraged to compare the needs of their current jobs with their experience as university undergraduates.

Those who had had a placement year said that it had been very useful. They also appreciated courses which were genuinely practical. There was some disappointment with pseudo-practical courses.

Some felt that the university first course had not convinced them of the usefulness of statistics or given them a sufficiently global overview. For some, this had come on MSc courses.

Many recalled being spoon fed on their own courses and being assessed for their ability to recall theory rather than exercise their statistical skills and understanding. However several appreciated the depth of their courses for helping them gain important perspectives on their present work.

Very few had learned how to write reports as part of their statistics course In fact, some had had to produce reports but had not been taught how. Some had acquired the necessary skills in other subjects such as Economics or Management Science. All would have welcomed something more positive by way of help to develop their communication and consultancy skills.

Most recent graduates found that they were having to apply their statistics in new areas, and there is a clear need to learn on the job. Some had needed to learn how to learn, a skill that they had not acquired at university.

Teaching statistics is a complex interaction between aims and objectives, subject matter, thinking processes, learner, teaching methods, teacher and assessment. These are considered separately below. Nothing remains stationary in education; we all have a responsibility to keep up to date with new ideas in the subject and in teaching and learning. Most of us try hard to do that. There are specific problems relating to the teaching of statistics. These include those concerned with the role of technology and the way it is affecting the subject of statistics as well as its teaching, and the large number of different students who have to do a statistics course as part of another qualification.

Course content and aims

The aims and course content will differ between those doing specialist courses and those doing service courses. They will also differ from university to university though, for specialist courses there may be some commonality.

Specialist courses

For the specialist the **MeaNs** project highlighted the importance (i) of getting the right mixture of specific skills, concepts, techniques and insights together with the more general transferable or key skills of communication and working in a team and (ii) giving students a global overview of the nature of statistics and statistical thinking into which they can fit particular courses and applications.

Nearly all university subjects are having to consider how to incorporate key skills into their teaching and there are possibilities of cross discipline co-operation in doing this - if the administrative difficulties of working across departments can be overcome. Practical and project work in statistics is an obvious area in which these skills may be developed along with the specific ability to solve a practical problem using statistical methods. In principle there is nothing new in this as can be seen from the work of Anderson and Loynes (1983) in the early 1980's. It would be relatively new to involve cross-disciplinary teams to match up with what happens in employment

With so many modular courses, together with student choice, it is not as easy to ensure that the student gets a good overview of statistics. At the very basic level all specialist students should be well conversant with the big ideas in statistics. It would be interesting to have a discussion in this newsletter of what these big ideas are for specialist students. For secondary school students the latest version of the National Curriculum in Mathematics has the following as part of the foundation Key Stage 4 requirements.

> 'Pupils should be taught about the major ideas of statistics, including the identification of appropriate populations; obtaining a representative sample in order to draw inferences about populations; different measurement scales; probability as a measure of uncertainty; randomness and variability; an awareness of bias in sampling and measuring; inference and its use in making decisions.'

Surely we can build on these.

Non-specialist courses

There is a wide range of service courses and a wide variety in the ability of students taking them. They will differ from subject to subject; the approach to engineers will be different from that to management and business students. The content and aims are

obviously bound up with the main courses they are servicing. One comment made to me by a middle manager reflecting on his service course at university was 'They tried to teach me how to do statistics - what I find I really needed was a course teaching me what statistics could do'. I find it a real challenge to decide what is an appropriate service course - particularly as some on the same course may well go on to do research in the subject and have to use advanced statistical methods. The challenge is to assess the appropriate level of understanding for future need and teach towards it.

There is an innate conservatism in many service courses. One aim of a service course could be to enable a student to be able to interpret the statistics that are found in that subject's publications. Medical students have to be able to read medical literature. But this may mean that there is a tendency for more emphasis on older techniques (e.g. significance tests) rather than more appropriate ways of looking at things (e.g. *p* values or confidence intervals). Although this is a trivial example it also raises the problem of how much time we spend trying to teach the concepts of hypothesis testing which research has shown students find notoriously difficult to understand. It also highlights the difficulty of trying to introduce something that is completely new (computer intensive methods, Bayesian decision making)

There is a move to include interactive packages and encourage students to use them and learn from them. Although this seems, at first sight, an obvious development to enhance the student experience, the optimal balance between the use of such packages and other methods of learning has not been investigated scientifically. It would be interesting to hear from those who have attempted to measure the success, or otherwise, of interactive packages, to find out how they were used, what were used and what the results were. For example, there is anecdotal evidence that some have found it difficult even to motivate students to do *anything* outside the lecture room.

Assessment and motivation

In many ways it is assessment that drives student learning. The student is very aware of the nature of the summative assessment of the course and works to succeed in that assessment. What is part of the summative assessment is seen as important; what is not part of that assessment is not as important and, if there is pressure of time etc, can be neglected. Some universities have seen this effect and have taken the view that we must assess what we consider to be important. This includes the key transferable skills. This has led to a large increase in the number of ways that students are assessed. Along with standard examinations (which increasingly allow open books) these include: coursework; project reports (by individuals and groups); posters; presentations; case-studies; laboratory examinations; portfolios of practical work; commenting on published papers and peer assessment of group work.

We must remember, though, that the aim of education is that students should be educated, not that they should be able to meet the assessment criteria. It may be that we need a more careful split between formative assessment (where grades are not appropriate - the aim is for the students to assess their own level of competence and to learn from their mistakes and difficulties) and summative assessment where a grade is given. In his book *Punished by Rewards*, Kohn (1993)points out that the real danger of giving grades is that the grade is seen as more important than understanding the material and that the student is satisfied with the grade even when the material is not understood. This gets distorted by the student into finding ways of getting a good mark in the assessment by whatever is the easiest means (question spotting etc.). The same effect was pointed out many years ago by Holt (1982) in *How Children Fail*. The aim of the game for the student is survival, and learning is not necessarily the most efficient way of doing this.

The **MeaNs** project was given anecdotal evidence of these effects being true. We were told of instances where a lecturer who included an interesting side note in a lecture was asked afterwards if that would be on the examination. We were told of other instances where modules that required practical work in statistics and could be seen to develop important practical statistical skills were not being chosen by students because they felt they could get higher marks on other modules. A recent piece of research, not in statistics, also highlights the power of marking. A lecturer split a class into three; one third of the class had their work returned with thought provoking and positive comments (such as ' that is a good point, have you also thought of … '); the second third was just given a mark; the third were given the comments and the mark. Only the first group were found later to have learned from the experience. In the third group it appears that being given the mark meant that the comments were ignored. Truly they were punished by rewards.

One of our major problems is how to motivate students (particularly on service courses) to want to learn.

Students

Students come from a wide range of backgrounds and courses have to be geared to start at the lowest common base of knowledge. Changes in the National Curriculum for Mathematics may well be beneficial to us when these students come through to university, particularly for service courses. It does not look as though current changes to GCE Advanced courses will make much difference. The proposals for courses staring in September 2000 are very similar in content to existing syllabuses and the choice of modules means that we shall still have specialist statistics students coming from a wide range of statistical backgrounds.

There are ongoing problems with motivating students and with devising appropriate courses for those with non-mathematical backgrounds. There is a trend to introducing more data-oriented courses and including more work on exploratory data analysis. One challenge here is how to move towards an understanding of statistical inference. How do we encourage enjoyment and satisfaction in learning, and can this be linked to more self-learning?

Just as different statistical topics may best be taught in different ways (theoretical probability may well best be taught by formal lectures and example classes; solving practical problems may best be taught by using practical classes and working in groups) so different students may learn best in different ways. Some learn best by listening, some by working on their own, some by practical trial and error and so on. Maybe we need to consider providing the same material in different modules to be taught in different forms for different students - though the practicalities of this may be difficult to overcome.

Lecturers

Lecturers are under a great deal of pressure. We are all being exhorted to spend more time on research; our student numbers have risen; our teaching quality is being assessed by the Quality Assurance Agency (QAA) exercise and the new LTSN centres are encouraging us to see teaching as important as research. Our role in teaching is changing. We have to be more aware of the nature of our subject and of the students and of different effective ways of teaching. At a recent conference I heard a speaker talk about lecturers moving from being information gurus to a 'guide on the side' and all stations between.

The job title *lecturer* implies an activity that few of us now, in practice, carry out. What we *actually* do has changed over the last 30 years and is much more interactive than the job name suggests. Even the term *teacher* now has a broader meaning that better captures our involvement with students so that they can learn more effectively. What we *try* do is to guide their studies using an increasing array of tools, modern and traditional, in combination and harmony with each other. Getting the right mixture of these tools is an unsolved problem.

The constructivist approach to learning seems very appropriate for statistics - we learn by doing. This has implications for getting more student involvement in their learning; more practical classes and team projects. This has to be linked in with the growing amount of subject material and the need to help students to learn how to learn. We are responsible for helping students develop specific and transferable skills. We try to maintain a global overview in a modular culture We have to see the appropriate ways of including technology in our teaching and use them. Finding time for all these things is a real problem.

If, as statistics specialists, we teach service courses then we have to be *au fait* with the user discipline and the uses made of statistics in it. If we teach statistics courses within our own subject discipline (not statistics) then we have to make ourselves aware of the difficulties and the appropriate ways of teaching the statistical concepts as well as keeping up to date with new developments in statistics.

Technology

Much has been written about the use of technology in teaching statistics. It was a major theme of the previous CTI centre in statistics so I'll only mention some of the issues here.

There are issues of keeping up to date with what is available and finding what is appropriate to incorporate into our own courses. A balance needs to be made between using learning aids developed elsewhere and using our own material. Many people have been put off using technology because of the initial time commitment. Ed Redfern (who will be greatly missed) at Leeds University spoke many times about his experience of setting up a one-year service course incorporating the Statistical Education through Problem Solving (STEPS) material. He recorded how much time he spent in the first year developing the course and then how much time it took in the second and third years. His figures showed that over the three-year period he spent less time than on a

conventional course for three years. He was able to use the technology to take over some of the routine work he would have done in a conventionally administered, delivered and marked course.

As well as being a tool for doing statistics and for illustrating statistical concepts the computer is also changing the nature of parts of the subject. Computer intensive methods are becoming part of our way of thinking. More productive and useful work can be done using simulation and Monte Carlo methods, including numerical Bayesian methods, with students whose lack of mathematical ability would not allow them to understand much of the background theory.

More and more useful material is becoming available on the Internet (as is more and more rubbish!). How can we best use this as a resource in our teaching and also enable our students to make good use of it?

Investigations and Research

The new LTSN Centre for Learning and Teaching in Mathematics, Statistics and OR has a brief for initiating investigations and research into the teaching and learning of statistics. We would welcome ideas as to what are the most important areas to cover. Several themes are implicit in the main body of this article. The following are some of the questions that we are considering, and they include some suggestions from eminent statisticians outside the UK:

- What are the effects of technology on teaching and learning?
- How does the computer affect what needs to be known?
- How best can we incorporate technology into our teaching?
- How do we motivate our students to want to learn
- What are the best methods of teaching different aspects of statistics?
- How can we enable specialist statisticians to be good communicators and good team members?
- What kind of understanding of probability is required for conceptual understanding of statistics at various levels?
- How do we develop the practical ability to use statistics in real situations?
- Do interactive packages such as *DataDesk*, *ActiveStats*, *Statplay* improve student comprehension of difficult topics and concepts

Please contact us with your views.

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References

The **MeaNs** web site is at
http://science.ntu.ac.uk/rsscse/means/means.html

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