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LEARNING FROM EXPERIENCE

Training courses for researchers are discussed in some detail. The preparation of researchers and of statisticians for consulting sessions, and the opportunities such sessions provide for training, are considered.

1. INTRODUCTION

Training of researchers in the use of statistics is a large topic and involves consideration of the subject of statistics itself, of the interaction between statisticians and researchers, and even the training of statisticians. In this paper a *researcher* refers to someone researching in any area except statistics, whereas a *statistician* refers to someone with the qualifications and expertise required in a statistical post. See Smith (1993) pages 146-9 for a slightly different view.

Many researchers will have followed a course in statistics as part of their training in their main discipline, but will possibly need some further training in statistics when they are undertaking research. Others might get their initial statistical training while researchers, through formal courses, or, less satisfactorily, by referring to books or by using statistical packages. A further opportunity for training occurs when researchers consult with statisticians. As well as learning something about statistical design and analysis they would learn when to consult and what questions to ask the statisticians. In helping researchers, statisticians learn teaching and consultancy skills and, if presented with a challenging statistical problem when acting as consultants, might learn statistical techniques previously unknown to them or develop new techniques. Thus both researchers and statisticians *learn from experience*, learning from mistakes as well as from successes.

This paper focuses on two aspects of training – on courses in statistics for researchers, and on the consultancy process. It draws on the author's experience in teaching courses and giving statistical advice to students from other disciplines and to researchers. Ideas have also come from a selective review of relevant papers published during the last twenty years. Some of the comments made about the training of researchers in statistical methods and in the skills needed for a successful outcome from a consultancy session apply also to the training of statisticians.

2.1. TRAINING THE RESEARCHER – GENERAL MATTERS

The spread of statistics teaching both at school and at university level in recent years means that more people than previously have at least a basic knowledge and understanding of statistics and its potential. Thus it is likely that researchers in fields other than statistics will already have some expertise in statistical techniques. It is assumed in this section that this is the case, but many of the points made apply as much to the initial training as to further training – and indeed to the training of specialist statisticians. Training in statistics is, of course, a continuing process that comes partly through experience. Developing statistics from the perspective of the scientific user is "complex and challenging" (McPherson, 1989). He puts forward as important criteria underlying a consideration of statistics for scientists - the need to develop self-sufficiency, understanding of assumptions, and use of meaningful language. Sometimes researchers do not really know the scope of statistics or its relevance to their work, and might even have some wrong ideas. In fact, a study of researchers' errors in understanding and using statistics should help in the design of training courses, as awareness of errors is the first step in helping people avoid such errors. Greenfield (1993) makes some thought-provoking comments on reaching out to non-statisticians, and Hahn (1999), although writing in terms of industrial statisticians, makes many general points of relevance for training.

A course for researchers should give guidance as to a general approach to be taken in a statistical analysis and of how to balance out the effort spent on data collection and on data analysis, on probabilistic versus descriptive methods, and between numerical and graphical techniques (Cox, 1981). Successful courses will encourage a critical attitude towards data and the results of statistical analyses. Researchers need to be warned not to use too elaborate a technique on a poor quality data set, as well as to exploit extensive data sets fully, and to beware of what techniques they use on non-random data or on data collected by a complex sampling method. The importance of obtaining good quality data and of checking at all stages of an investigation – in the field, at coding stage, input to a computer, copying of results – should be stressed. Researchers also need to understand why the design stage in a study is important, the difference between a parameter and an estimate, and how variation can be described by the random part of models (Nelder, 1986, p.118).

The statistician has to some extent been replaced by the computer, so it is particularly important that researchers are made aware of the dangers of misusing statistical packages and of the errors inherent in some routines. References to known errors in Excel's statistical facilities are given on the ASSUME web page (http://www.mailbase.ac.uk/lists/assume/files/). To some extent the analysis which can be done is determined by what is available in the package, and the menu on offer reflects the producer's view rather than the customer's. It is all too easy to over-analyse the data, instead of being selective and to produce large quantities of output, almost as difficult to digest as the raw data (see Preece, 1987 for some comments on this). On the other hand the ease with which interactive analysis can be done, enabling each step and alternative steps to be studied before the next is taken, should not be under-rated.

Use of computer packages has enabled more efficient and sophisticated analyses to be undertaken, but the downside is that users will not necessarily have the theoretical background to understand what has been done, and it is more difficult to communicate the results than in those arising from more elementary techniques. Even if the technique itself is difficult to understand, it is important to help the researcher to understand and question underlying assumptions, and to appreciate the implication of the results of an analysis in practical terms. This should mean that in turn the researcher would report the results correctly and in an understandable way to others. Pictorial representation of results, when this can be done, is made easier by computer packages, and helps in communication (Bradstreet, 1999).

Statistics educators are in broad agreement that it is important to teach concepts rather than recipes. There have been many important contributions relating to this – research into different methods of teaching, suggestions of strategies to follow, and development of software and other learning material. There are, however, difficulties to be overcome, not least of which are the time constraint imposed on many courses at school and university, and the need to assess students on demonstrable skills. There is also something of a reluctance on the part of students to think about underlying concepts. Researchers are often busy people and possibly even more likely than students at a lower level to resent what they see as a waste of time. An attempt should be made, however, and here too the computer has made things easier for the teacher. For example, the modules produced by the STEPS consortium, designed to be used in conjunction with lectures to non-specialists are useful and interesting. They are based on real problems taken from biology, geography, psychology, and business. They enable the user to explore and analyse data, and can be worked through by students on their own.

Examples showing the importance and relevance of statistical methods to the researcher's area of interest, preferably based on problems the researcher faces (Hirotsu, 2001) are essential. These should, as far as possible, be real rather than contrived, and with the large amount of data available via the Internet, there can be no excuse for not getting students to work on real data. Here too the computer has changed what is feasible – computation and dealing with relatively large amounts of data are not the great problem now that they were at one time. However, some of the time which previously might have been spent on statistical concepts, now has to be spent on how to use software (and sometimes hardware in the case of those who are not computer literate). Reference to real examples should also help researchers understand the use of the more complex statistical methods. Some examples might be taken from articles in the researcher's area of interest. Helping researchers understand the results of statistical analyses in such articles is an important function of training.

Models are important in statistics and have a central role in the theoretical development of the subject, but matching of models to data is important in applications of statistics. Explaining to researchers that models are simplifications of systems and usually wrong, but that they are useful and necessary for successful quantitative thinking would help break down communication barriers between researchers and statisticians. See Nelder (1986) for more comments on this. A model might be considered to be a good approximation to reality if predictions from the model are consistent with observations. Finding the perfect model can be less important than finding a parsimonious model that "works". Sensitivity analyses, made easier by computers, help here.

An important part of any training is to draw attention to areas that have not been covered fully or at all, so that researchers will realise *when* they need to consult with statisticians. More difficult to do perhaps, but researchers do need to be cautioned that as a technique might be inappropriate for their data or problem, it is advisable for them to check with a statistician that a proposed analysis is meaningful. Similarly they should be advised to check on the suitability of a proposed design. Consultants would rather participate from the beginning than be asked to salvage an experiment. In some disciplines issues which are partly the concern of statisticians are considered to be part of general research methodology rather than statistical (Cox, 1981) so that researchers would not necessarily think to consult with statisticians on these. Training also needs to prepare researchers on *how* to consult, that is what questions to ask the statistician, and what information the statistician is likely to need about the research (and see Belli, 2001). Ideally training should also aim to give researchers *confidence* that a statistician can help contribute to the research, and stimulate them to want to learn more about statistics.

2.2. TOPICS COVERED IN TRAINING COURSES FOR RESEARCHERS

The specific topics taught in a statistics course for researchers will depend on their disciplines and needs, their background, and the length of the course. There is a large number of papers on various aspects of teaching statistics to those whose main area of interest is not statistics, for example some of the papers included in this book, and several have been given at the various International Conferences on Teaching Statistics (ICOTS). Some general observations on broad topics are made in this section.

Data is an integral part of research in an applied area, and there are a number of issues in connection with data that could be covered in some depth in a training course. It might seem trivial to those who are accustomed to using a spreadsheet or statistics package, but it is important that researchers know how to enter the data in a way that is conducive to statistical analysis. This sometimes depends on which package is being used and on what analysis is to be done. However, common mistakes include entering variables as rows rather than columns, entering text in a cell where a numerical entry is expected, and entering tabulated data in the form of a nicely presented table. Data collected by different researchers or coming from different sources can be difficult to combine because different units of measurement have been used or because data have been entered in different ways in the spreadsheet or a statistical package. Electronic forms of the data might be incompatible. Thus it is useful if researchers learn how to manipulate data both within and between packages. Increasingly automated methods of data collection are being used, often with direct input to a computer, and here too the form of the electronic version is important. For some groups of researchers it might be important to discuss the construction, management and maintenance of large data bases, and the associated documentation. Some researchers might be involved with data collected for administrative purposes, and there could be issues of confidentiality and linkage to other data bases to consider. See also points made in the paper by McDonald (2001).

The structure of data is important – their context, units of measurement, how and why they were collected, and properties of the units on which measurements were made (Nelder, 1986). Researchers need to appreciate that the accuracy of recording determines the degree of accuracy in results, and understand the effect of transformations (which can be useful for statistical analysis) on accuracy and on the interpretation of results. Examples can be found in Preece (1981, 1982). Computers are useful in checking on outliers, on missing observations, and consistency between observations.

Most training courses make use of software, usually the instructor's favourite packages or those readily available. Updated and new versions of software keep appearing, and the researchers might not have access to the software used in the course, so courses need to place more stress on the principles of using software than on specific commands (and see Blumberg, 2001). It is important to make researchers aware that there are differences in the menu offered by different general statistical packages and that there are specialist packages. Showing researchers how to analyse the same data set in different packages, and how to move output produced by one package into another package for further analysis, would be good preparation for when they are analysing data on their own. Spreadsheets are very popular in the teaching of introductory courses and it is the author's experience that researchers enter their data on spreadsheets and use spreadsheets for preliminary analysis. It is therefore particularly important to teach researchers how to use spreadsheets well. A useful reference, written for natural resources researchers, is *Excel for statistics – tips and warnings*, available from the ASSUME web page (http://www.mailbase.ac.uk/lists/assume/files/).

Hypothesis tests are both widely misunderstood and over-emphasised, and the ease with which P-values can be obtained from statistical packages has not helped. Rather than discuss the fundamental principles and limitations of inference some instructors might be tempted just to tell students that if the P-value is less than 0.05 the result is *significant*. This is a poor teaching practice, which leaves students with little understanding of procedures, or even the difference between a null and an alternative hypothesis. There have been notable attempts to wean researchers away from tests and to present results in terms of confidence intervals, for example Gardner and Altman (2000), but while confidence intervals are obtained from packages as part of a test procedure we might be fighting a losing battle. On the other hand some statisticians recommend that all of test results, confidence intervals, and power analysis or estimation of effects should be presented. Others favour using a Bayesian approach in inference, for example see Lecoutre (1999) who gives arguments in support of this with many references, and Stangl (2001) who discusses why medical researchers should be trained in Bayesian methods.

Exploratory data analysis (EDA) and the initial analysis of data (IDA) (Chatfield, 1985) are very important. Too many courses rush over these important stages and rush on to advanced techniques and methods of analysis. Yet sometimes in a research problem scrutiny of the data and simple summaries and presentations of the data are sufficient. See Chatfield's paper for some examples. Simulation is important in non-standard problems, which do not lend themselves to use of existing techniques (see Mullins and Stuart 1992 for some examples), and researchers could perhaps be taught something about its potential.

2.3. EXAMPLE OF A TRAINING COURSE

In the Autumn of 1998 the author taught the statistics component of a course on research methods given to students taking either an MSc in Sustainable Agriculture or an MSc in Natural Resources at the Natural Resources Institute (NRI), which is part of the University of Greenwich. The statistics content which the author was requested to teach in six 3-hour blocks on 23rd, 27th, and 29th October was "Basic statistics (summary statistics, graphs, etc.), Design of experiments, surveys and sampling schemes, Methods of statistical analysis, including analysis of variance and regression". The statistical backgrounds of the students were unknown at the time the course was prepared, but it was suspected, and was indeed the case, that they had had little previous instruction in statistics.

Clearly, the statistics content of this course in Research Methods covers a very wide syllabus and it was neither possible nor appropriate to cover it in depth. The author decided to base the statistics teaching on the use of SPSS (computer skills were covered in another part of the course) and to use a data set (Johnson, & Wichern, 1998) in practical sessions.

Hand calculations and the reading of statistical tables were not covered, but references were provided. The author's objectives, as circulated to the students, were:

- To make students aware of the scope of statistics;
- To familiarise students with statistical terms and methods, including the assumptions behind the methods and the situations when the methods would be used;
- To show students how to obtain and interpret output from SPSS;
- To encourage students to consult with statisticians when they have reached the limits of their knowledge of statistics or wish to check they are applying their knowledge correctly, and to give them the confidence to approach statisticians;
- To emphasise the importance of planning in studies involving statistical analysis and that statisticians can give useful advice at this stage;
- To indicate how easy it is to obtain meaningless output from statistical packages.

Four of the five students on the course were from overseas, had little computing experience and were hesitant in English. On the first and third day classes took place in a computing teaching room, but on the second day we were in a classroom without computers in the morning and in a computer laboratory in the afternoon. It would have been preferable to have had all sessions in a computing teaching room, and to have had more time between each of the six 3-hour blocks to give the students a chance to assimilate the material between sessions. Students were given copies of overheads and a few longer handouts to read on their own. The content of the sessions is indicated in Appendix 1. For the most part little more than definitions and ideas were given, but there were linking sections between topics giving, for example, some explanation of concepts. No attempt was made to give derivations, and only a very little notation was used.

It has to be said that the course was not a great success in the sense that students appeared to be overwhelmed by it (hardly surprising given its intensive nature and the amount to be covered) and they did not perform very well on the examination question. This focussed on the understanding of when particular methods of design and analysis were appropriate, and on interpretation of SPSS output, and accounted for 50% of the marks in a 1-hour examination. A colleague had approved the question, but with hindsight there were too many different things for students with almost no experience of statistics to think about and to do in the time. I think that my general approach to the course was satisfactory, but the syllabus is rather long and either should be pruned or more time should be allowed for teaching it, and over a longer period. SPSS was chosen because it was the only statistics package available on the site. The overseas students would probably not have access to any package on return to their own countries, but hopefully it will only be a matter of time before they do, and teaching a calculator-based course would have been restrictive.

On the basis of my experience, if I were to repeat the course, or to teach a similar course elsewhere, I would: a) reduce the amount of algebraic notation used in the notes even more, b) include examples of SPSS output in the notes (the request to give the course came at a late stage so that it was prepared in something of a rush), c) give students more specific tasks to do as computing exercises instead of open-ended tasks.

2.4. CONVERSION COURSES IN STATISTICS

Researchers who realise the importance of statistics in their area of work or speciality might decide to follow a conversion course in statistics. The University of Greenwich has developed a MSc course of this nature. The University won a contract to provide the college-based component of the UK Government Statistical Service Trainee Statistician Scheme for the three-year period starting in October 1993. Persons in the government statistical service designed the training scheme, to give graduates who had little or no formal statistical training the practical skills and knowledge to become a government statistician. The trainee statisticians would be involved in research during their careers as government statisticians, and so were potential researchers. While preparing the proposal for providing the college-based component the University had the course validated as an MSc degree in Applied Statistics to be taken in part-time (over 2 years), full-time (over 1 year), or block release mode.

When the scheme was first run trainees followed two intensive eight week blocks at university separated by a period of similar length in the government departments to which they were attached, where they worked on projects under the direction of their line managers. The scheme has since been dropped, partly because the internal funding arrangements within the statistical service made it expensive for departments to have trainee statisticians, with the result that very few bids to have trainees were being made.

During the third year of the training scheme, that is in 1995-96, the university offered the MSc degree in part-time mode to be taught on two evenings a week for two years. In the following two years it was also offered in full-time mode to be taught in the evenings as a combination of the year 1 and year 2 of the part-time degree. No entry was taken in 1998-9, but in the 1999-2000 session the degree is being run during the day and there are both full-time and part-time students, the latter attending on one day per week only. The degree does not attract many applicants. There are several possible reasons for this – statistics is not a popular subject, employers tend not to support employees who wish to study either financially or in release from work commitments, those not in employment might not be able to afford the fees. In the case of a conversion degree people also have to be convinced that it is going to be of direct benefit to them in their work or enhance their career prospects. Entrants to the degree have to have basic mathematical skills (see Jolliffe, 1997, p.446) and this might deter some potential applicants.

The syllabus and the way of dividing the degree into teaching units have evolved since it was first proposed. A brief description of the contents of each unit as taught in 1999 to 2000 is given in Appendix 2 and a fuller description is given in Jolliffe (1997). For the award of the MSc students have to spend three months on project work written up as a dissertation after successfully completing the taught part of the course. A postgraduate diploma can be obtained for successful completion of the taught course and this was awarded to those on the trainee statistician scheme. As students are not required to know any statistics when they start, but are studying for a master’s degree, a lot of material has to be covered in a short time. This means that whenever a new topic is introduced there will be a quick progression from an introduction at a low level to a fairly advanced level. As the degree is in *applied* statistics the emphasis is on the practical skills of applying statistical methods to data rather than on mathematical proofs of statistical results.

As a conversion degree it appears to be successful in that several of those who passed the assessment on the taught part of the course (some are still working on their projects) have obtained a first statistical post or have changed to another statistical post since completion. A few of those who started have found the work difficult, although they have had an appropriate background, and a few have dropped out because of heavy employment commitments. Some of those who followed the course are currently in research posts, but working as statisticians. A researcher from other discipline who becomes a statistician in that discipline is in an ideal position to give statistical advice, but it might be argued that training researchers in statistics is counter-productive if the researchers do not remain researchers!

2.5. OTHER METHODS OF TRAINING RESEARCHERS

Another kind of statistical training course is a short course on a specific topic designed with a particular target group of researchers in mind. Such courses typically take place over a one to five day period. Sometimes these are in-house courses, but possibly more frequently are a commercial venture. Topics related to the design and analysis of surveys, and topics in medical statistics are fairly popular, but "brush-up" courses, for example for psychologists, and courses on the use of a specific statistical package, are also offered. The problem with such courses is that they are very tiring both for those attending and for the facilitators, so concentration and attendance are likely to flag before the end of the course.

The main disadvantages of courses on general offer are that people have to spend time travelling to them, and those attending are likely to differ from one another as regards their needs and backgrounds. Researchers do not usually have to travel to in-house courses, and both their needs and backgrounds should be familiar to the course facilitators, which are advantages. The disadvantage is that those attending such courses might be tempted or required to miss some sessions in order to do their ordinary work – which suggests holding residential courses away from the work-place. Even on in-house courses those attending could be a very heterogeneous group as regards their needs and backgrounds. Successful on-site training programmes, which have been developed over several years, are described by Horgan et al (1999) and by Saville (2001) together with the thinking behind the programmes and an assessment of their effectiveness. Although the programmes described are for biological researchers (Horgan, 1999) and agricultural researchers (Saville, 2001), much of what is said is of relevance for courses for researchers in other disciplines.

When the author and some colleagues gave a two-day course to social science researchers at the NRI in 1998 an attempt was made to find out what statistical topics they were familiar with. The lists which came back varied from researcher to researcher, and many of them added such comments as "very rusty", so that this information was almost useless. Similarly the researchers were not unanimous in suggestions as to what they would like us to teach, perhaps because they were not fully aware of how statistics might help them in their work. It would be interesting and useful to perform fairly detailed surveys of researchers to ask them about their past statistical training, what they perceive their current needs to be, and what kinds of training they think are most successful. There is much anecdotal evidence, but few hard facts. The methodology and results of the MeaNs project (e.g. Holmes, 1996), which looked at employment needs in statistics in general, would be useful background to such studies.

Distance learning courses either by correspondence or over the Internet are another possibility, but these tend to work better if there is also some face to face contact, and they are not necessarily going to match the researcher's needs. Researchers can also be trained "on the job" as and when the need arises, perhaps by another researcher in the case of a routine research exercise, perhaps by consulting with a statistician.

3. CONSULTANCY

3.1. TRAINING STATISTICIANS

It might be thought that a discussion of the training of statisticians as consultants is inappropriate in a meeting to discuss the training of researchers in statistics, but if statisticians are good consultants those who ask their advice will learn some statistics. Much has been written on consultancy skills and on training statisticians to act as consultants. Barnett (1994) gives an overview, and papers on consultancy have been given at all the ICOTS. In some ICOTS there have been whole sessions on consulting, the latest being one at ICOTS5 (Pereira-Mendoza et al., 1998). The paper by Hunter (1981), which is based on actual examples of statistical consulting, contains many useful comments on what to do (or not do) when acting as a statistical consultant. Preece (1987) discusses the role of a statistician in a research project through from planning to writing up, with an emphasis on good practice.

Like any practical skill, statistical consultancy is learnt by practice and experience. Teaching of consultancy, if to be effective, must attempt to give students practice in doing consultancy, for example, by having them sit in on or participate in consulting sessions (see Rangecroft, & Wallace, 1998), or by setting up consultancy situations based on real problems. See also Belli (2001), Godino et al (2001) and Ospina and Ortiz (2001) for discussion of training in consultancy. Ideally facilitators of training courses in consultancy should themselves have experience of acting as consultants, or at least have worked as practical statisticians, and, as Nelder (1986) comments, every statistician's training should involve collection and analysis of their own data – and that involves learning about the area of application. This makes statisticians better able to identify with those who are at the receiving end in a statistical consultancy session. Students who do a period of industrial training might gain experience of research problems, and hence of consultancy.

Training in communication is of prime importance. Statisticians who are strong in theory but weak in application are at a disadvantage working alongside experts in particular subject fields and tend to be pushed into a support role, especially if they are poor communicators (Moser, 1980). Lack of training in written and oral communication skills might partly explain why there has not been the increase in the demand for statistics and the services of statisticians we might have expected to follow developments in information technology (Nicholls, 1999). Requiring undergraduate and postgraduate statistics students to write a dissertation, and to give an oral presentation on it, could help statisticians to acquire communication skills. Statisticians also need training in listening and questioning skills to help them become effective in finding out the researcher's needs.

Statisticians need to sell themselves and the contribution that statistics can make to other disciplines. One way to do this is to demonstrate the utility of statistics and to build on success stories, that is, to communicate the usefulness of statistics. Greenfield (1993) argues that statisticians must change their culture in order to bring about a greater acceptance of statistics among non-statisticians. Statisticians need to be trained to communicate statistical information in everyday language free of statistical jargon and concepts (Nicholls, 1999). They might need to communicate results to clients, at meetings of research groups, to committees, at courses, at conferences. They could well be involved in making an input to a research proposal.

There is a strong argument that even courses for specialist statisticians should include some teaching in an application area. The trend towards joint degrees in statistics and another subject, for example economics or psychology, goes some way towards meeting this (though cynics would say that such joint degrees are introduced with the aim of attracting more students into statistics departments, not in itself a bad thing). Reading relevant journals and attending conferences in an applied area will help statisticians become known and accepted, and enable them to discuss recent developments with specialists in the area on equal terms. In turn their greater involvement with the application will make them better teachers and consultants.

3.2. INTERACTION BETWEEN THE STATISTICIAN AND THE RESEARCHER IN CONSULTANCY

Perhaps the most important condition for a consulting session to be successful is that the statistician and the researcher can communicate with one another (Belli, 2001; Saville, 2001). Notation, abbreviations, vocabulary and jargon can be a barrier in communication, something which both the statistician and the researcher will need to bear in mind, and to remind one another that they do not always speak the same language. The Royal Statistical Society and the Institute of Electrical Engineers have in 1999 to 2000 held a series of joint meetings because some statisticians and engineers recognised that improving communication would benefit both groups. Differences in vocabulary have been a barrier to communication between these two disciplines.

First the researcher has to communicate the problem to the statistician – and here the researcher must be careful not to assume that (s)he knows a suitable method and ask only that the statistician works out the details. The statistician has to have at the very least a general understanding of the research problem. It helps if the statistician has some expertise in the researcher's field, but is not essential provided the statistician is interested in the subject matter of the research and is willing to learn more. In fact by explaining the problem in layman's terms the researcher might see the problem in a new light. It could also be the case that a "general" statistician is more likely than a statistician who has specialised in the research topic to realise that a statistical method not usually used in that area of research is appropriate. Related studies and relevant theory from the subject area need to be taken into account and the statistician needs to find out about these. If simplifying assumptions are needed for the statistical analysis the statistician has to ensure that these are sensible from the point of view of the subject matter.

In any investigation the planning, what data are collected, and the analysis depend on the objectives of the study, and the statistician needs to be aware of what these are, and to be involved as a member of the research team from the start. If necessary, objectives may have to be modified in the light of financial, time and staffing constraints, and even by the statistical techniques and methodology of the day. As Chatfield (1985) comments, the true objectives of the study might turn out to be different from those suggested in the initial consultation. Here the statistician can help clarify the questions that the researcher wishes to consider (Hand, 1994) and both researcher and statistician will learn from this as they move towards a common understanding. What are sometimes called "errors of the third kind" – giving the right answer to the wrong question – must be avoided.

The statistician needs to be able to communicate in statistical terms at a level appropriate to the statistical knowledge of the researcher. It can, however, be difficult to explain some of the more complex statistical techniques in simple terms so that not only the researcher, but also those to whom the researcher plans to disseminate results, can understand what is involved. Nevertheless this is an important part of the statistician's work as a consultant. Bradstreet (1999) makes a strong case for communicating effectively through graphics, and for placing more emphasis on this in statistical education.

Collaboration between researcher and statistician at all stages is important and the consulting aspect should perhaps be played down. Consulting has "overtones of pretentious servitude" (Cox, 1981. P.294). Significant progress in any field of application needs the participation of both specialists in the field and of statisticians. This has happened in the pharmaceutical industry, but in few other areas. Most statisticians would prefer to be collaborators and joint authors rather than thanked in a foot-note if their contribution is at all substantial, but the survey results reported by Godino et al (2001) suggest that it will be some time before statisticians are readily accepted as joint authors. In all cases statisticians must be given the opportunity to veto any incorrect statistical work or misunderstandings on the part of the researchers, and mistakes can occur as Stangl (2001) comments. Saying that a statistician was involved does not give work statistical credibility.

It is not uncommon to hear of difficulties in getting papers involving statistical methods and results, and papers correcting erroneous statistics, published in application areas. One argument is that those who will use the results are not interested in how they were obtained. Yet description of the statistical analysis, including the assumptions made and limitations of models, and perhaps comparison of using different statistical techniques, are as important as a description of the method of data collection (and sometimes even that is omitted). Collaboration at the report writing stage is crucial for the public image of statistics and statisticians, and statisticians should review papers with a substantial statistical content. Depending on the intended readership, the statistical section could be written in a form suitable for the lay person, or as a technical report for fellow statisticians.

On occasion the statistician might have to overcome negative attitudes towards statistics and the role of the statistician such as the attitude that only those with the appropriate professional qualifications can be a medical doctor or social worker or whatever, but anyone who can add up or click on a mouse can analyse data (see Cox, 1981, and Bangdiwala, 2001). Both researchers and statistical consultants might find the paper by Brook (1994) useful preparation for consultancy sessions.

3.3. HOW THE STATISTICAN AND RESEARCHER LEARN FROM ONE ANOTHER

By consulting with statisticians, researchers learn when to consult and what questions to ask, as well as learning about statistical concepts, design and analysis (Belli, 2001; Saville, 2001; Svensson, 2001). It is sometimes easier for the consultant to suggest a design for a study and to analyse the data than to tell the researcher how to do this, but by helping the researcher to do these things him or herself the consultant is giving the researcher statistical training. There might be an opportunity to encourage the researcher to repeat the study and under standardised conditions – to look for significant sameness as opposed to a significant difference in a single experiment (Nelder, 1986). In general the statistician might be able to help the researcher think quantitatively.

Researchers often come for help with statistical analysis after they have collected their data, and sometimes they have already entered the data in a spreadsheet or have attempted some preliminary analysis. If not done well this can create many problems for the statistician, and sometimes the design is not ideal for the researcher's purpose. This does, however, provide an opportunity to extend researchers' statistical knowledge, and to save them from making the same mistakes on another occasion. Statisticians learn teaching and consultancy skills when they help researchers, and consultancy sessions are a guide as to the development of suitable training (see Caulcott, 1987).

As well as learning about the research itself, statisticians might get into another area of statistics, and they might even learn some statistical techniques previously unknown to them from the researcher. Smith (1993) takes the view that the great majority of work which could be classified as statistics is carried out by specialists who have no wish to be called statisticians, for example agronomists, biologists, and chemists, and says that subject matter specialists, such as psychometricians and econometricians are statisticians working as scientists. It may also be the case that some researchers become more expert in a specialised area of statistics than a "general" statistician.

If presented with a challenging statistical problem when acting as a consultant a statistician might develop new techniques (for example, Svensson, 2001). Practical problems stimulate statistical research (Barnett, 1994) and the growth of statistics as a discipline depends a great deal on application areas. In particular, agricultural research has had a huge influence on the development of statistical methods (see Gower, 1988). Yet many statistical papers tend to deal with theories looking for data rather than with real problems needing theoretical treatment (Moser, 1980). Some examples of interesting problems arising from consultancy are given in Barnett (1994) and Chatfield (1985) amongst others.

4. CONCLUSION

This paper has considered various aspects of training and consulting, from the viewpoint of both the researcher and the statistician. It is suggested that both would learn from the experience of interacting with one another and that this experience should improve the training of researchers in statistics.

APPENDIX 1. CONTENT OF SESSIONS IN A SHORT TRAINING COURSE

1. Types of data. Frequency tables, bar charts. Frequency distributions, histogram, stem and leaf, median, quartiles, box plot, mean, standard deviation. SPSS session on this material.
2. Basic idea of probability as a relative frequency. Discrete random variables. Discrete uniform, binomial and Poisson distributions. Continuous random variables. Uniform, normal and exponential distributions. Idea of a sampling distribution, sampling distribution of the sample mean, use of the normal distribution for finding a confidence interval for a population mean. SPSS session on confidence intervals for a mean, and on areas under normal curves.
3. Tests of hypotheses – concepts, terminology. Tests of normality. Inference re means (1 sample t, independent samples t, paired samples t) and non-parametric alternatives to t. Bonferroni inequality. Definition of bias. Scatter diagrams. Pearson's coefficient of correlation. Simple linear regression, comments re multiple linear regression, treatment of categorical variables. Spearman's coefficient of rank correlation. χ^2 tests of association, homogeneity.
4. SPSS session exploring a data set and trying different techniques.
5. Design of experiments – terms, principles. Matched pairs designs, one-way ANOVA, two-way ANOVA, Latin square design. SPSS session on one-way ANOVA.
6. Sampling from finite populations – overview of methods. Notation and basic results for simple random sampling and stratified sampling. Estimation of sample size for estimating a mean and proportion under s.r.s. Proportional and optimal allocation in stratified sampling. Non-sampling errors, imputation, deff.

APPENDIX 2. DETAILS OF AN MSC CONVERSION DEGREE IN STATISTICS

Outline syllabuses

Statistical Methodology and Techniques: Inference (point and interval estimation, tests of hypotheses including non-parametric methods); Methods of estimation and properties of estimators; Multivariate analysis; Computer intensive methods; Quality control

Statistical Modelling: Probability and probability distributions; Simple and multiple regression; Design of experiments, analysis of variance; General linear model; Logistic, loglinear, and other models

Applied Statistics: Survey methodology (qualitative aspects, sampling methods); Time series analysis

Statistical Investigations: Data analysis; Communication skills; Case studies

Medical Statistics: Epidemiology; Clinical trials

Assessment

Statistical Investigations is assessed 100% by coursework, which includes open-bookwork tests in a computer laboratory. Assessment in the other courses is 80% by examination and 20% by coursework.

Statistical Methodology and Techniques, Statistical Modelling, and *Applied Statistics* are worth 20 credits each and *Statistical Investigations* and *Medical Statistics* are each worth 10 credits. The project is worth 40 credits. 120 credit points are needed for award of an MSc.

A 10 credit course is time-tabled as 3 hours a week for 13 weeks.

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Web addresses

ASSUME (Association of Statistics Specialists using Microsoft Excel): *http://www.mailbase.ac.uk/lists/assume/files/*

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