

UNIVERSITY STATISTICS – WHAT ARE WE TRYING TO TEACH AND HOW?

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1. Introduction

It is widely agreed that there is more to Statistics than the Theory & Methods which form the traditional backbone of academic courses. If a Statistician is to make a useful contribution to real problems he needs a battery of further skills that inform and direct his application of statistical ideas. In the next section we discuss in some detail what these further abilities are. We call them the skills of statistical practice. Though the emphasis of current teaching remains heavily on Theory & Methods some attempts have been and are being made to teach these skills. There remains a widespread feeling however, especially amongst first employers of new graduates, that these efforts are not succeeding (see e.g. Bartholomew (1985), Healy and Nelder (1977)). In section 3 we consider why this should be so and in section 4 we describe a new approach to the teaching of statistical practice which we claim is more effective than earlier methods.

2. The Abilities Required of a Statistician

A standard approach in educational circles when designing a course is to list in some detail the skills that it is intended to convey, and it is somewhat surprising that, as far as we know, this has been done to only a very limited extent in Statistics. Restricting discussion to rather broad abilities only, we suggest that a working statistician needs the following, at least, and one might therefore try to teach them by means of a course or, more realistically, a whole programme:

- A1. To work successfully with others, and to work to a deadline.
 - 2. To communicate efficiently, in writing and orally.
 - 3. To appreciate the fact that in real life an answer must (usually) be found, however imperfect.
- B1. To appreciate the ethical position of a statistician.
 - 2. To determine the aims of an investigation.
 - 3. To translate general aims into specific and realistic problems.
 - 4. To recognise situations which call for checks or controls on the quality of data, and to construct suitable procedures for checks.

5. To organise work – e.g. data collection - effectively.
 6. To recognise the limitations of one's knowledge.
 7. To find and read, critically, other relevant material, both in Statistics and in the subject area of the investigation.
 8. To interpret and/or utilise the results of the analysis.
 9. To understand what Statistics can and cannot do.
- C1. To recognise which techniques are valid and/or appropriate.
2. To apply any techniques necessary (and to interpret the results and draw valid conclusions): comprehension and computing.
 3. To find and use the main sources of published data.
 4. To understand and use previously unfamiliar techniques.
- D1. To appreciate that real data will have imperfections, and to react sensibly to difficulties.
2. To recognise the various levels of sophistication of techniques of analysis appropriate for data of different reliability.
 3. To choose an appropriate plan or design for an investigation.
 4. To build models and to develop new methods.

This is a rather formidable list, but surely a fair statement of a statistician's needs. Of course by no means all of it is specific to Statistics, and indeed we would suggest that A1-A3 are to be expected of any competent and mature worker, B1-B9 of the statistically literate, C1-C4 of those technically competent in Statistics and D1-D4 of fully fledged professional statisticians. One question to be asked is – should there be an attempt to teach these? Our answer is yes. A second question is then whether they can be taught, and our answer is that, to a large extent, they can be taught or at least encouraged.

3. Teaching Approaches

It is not difficult to identify a dozen or more types of course (in the broad sense) that are claimed to be useful in teaching the skills of statistical practice. They all have their virtues, but many also have real disadvantages. We cannot discuss them all here, so concentrate on just two: large projects and drill exercises.

Large projects are very common in postgraduate programmes, but less so at more elementary levels. The benefits conferred vary greatly according to topic and detailed arrangements: the design and execution, perhaps in a partnership, of a sample survey may well call upon virtually all the abili-

ties list above, whereas a literature survey, while it may be very valuable in other respects, will need few except the ability to communicate in writing. But even if the topic is carefully chosen, one disadvantage and one danger remain. The disadvantage is that a project is not really a very good teaching tool: the student has no opportunity to consolidate what he has learnt by using it on a new problem. The danger is one of putting all one's eggs into one basket: some projects just do not turn out to be satisfactory, and if this is discovered relatively late there is insufficient time for a fresh start on a different subject.

"Drill exercise" is an expression which is not widely used in the present context, though it seems an apt description. In so-called practical classes one often finds problems such as "The weight gains of pigs under diets A, B, C, D are as follows. Carry out an analysis of variance to test for a difference between diets". Such problems no doubt can be extremely valuable, say in giving the student practice in arithmetic, but it is quite clear that few if any of the abilities listed above are engaged, and very little is contributed to the development of practical skills.

4. The Mini-Projects Framework

We now describe a way of teaching statistical practice developed especially with the abilities of 2 in mind, and which avoids most of the drawbacks in 3. The approach aims to develop in the student the abilities he will need when working as a statistician: accordingly its underlying technique is to give practice in a variety of real problems, tackled under conditions not too dissimilar from those which face a working statistician, but with some supervision at the time and constructive feedback afterwards. The detailed arrangements, together with some comments on them, are:

- students work on a sequence of assignments - or "miniprojects". A sequence of assignments is used rather than a single larger-scale project in order to give variety of interest; give variety of abilities developed; allow feedback,
- work on assignments is completed to regular deadlines. This is for organizational necessity (see below); for motivation (as we all know, deadlines concentrate the mind wonderfully); and to give experience at working to deadlines (to do an effective job in the time available, rather than a perfect one in a longer period),
- a written report is submitted on each assignment. This is to give practice in communication and organization; give a focus for activity
- the report is assessed and returned rapidly with detailed comments - the comments providing encouragement and suggestions for improvement; the assessment strengthening motivation.

The selection of assignments is crucial. They are chosen to be real, open-ended and non technique-oriented. They often do not give all the information needed, and sometimes some of the information that they do give is not relevant. Students are encouraged to interpret them imaginatively, seeking

further information for themselves if necessary and recasting the questions into an alternative form if they judge that to be helpful. Work on many of the assignments will require application of standard techniques and use of the computer, but the purpose of the course is emphatically not to give drill in these: much more weight is attached to justification of the choice of a particular technique as appropriate for a given question, and interpretation of formal output from it in the terms of the original question.

Examples of assignments will be distributed at ICOTS II and are not reproduced here because of pressure on space. Our forthcoming book on the Teaching of Statistical Practice will contain a wide selection of further examples and detailed discussion of their use. We confine ourselves here to describing some types of project that might be used. In some ways the most important single type is the experiment or survey. This allows both group collaboration and close acquaintance with an investigation from the first stages of planning, through data collection, to the final analysis and reporting. Rather different abilities are called for in a critical review, which asks the student to review one or more applied statistical papers, summarising their purpose and methods, explaining obscurities and evaluating their achievements. A large number of projects might be classified as one form or another of statistical analysis. This might range from an invitation to discuss - partly by finding relevant data, say from official sources - statements that might appear as newspaper headlines ("criminals are increasingly evading punishment", "the English are giving up drinking beer, but the Scottish are looking after the surplus" etc.) to problems requiring detailed technical analysis, say that of shifts of allegiance of voters in successive rounds of an election. The overriding requirement in all cases is that the question should demand serious statistical thought, and not just a stock response.

Just as a variety of different types of project are used in the mini-projects framework, so a variety of different teaching methods may be employed within different projects: group-discussion, case-studies, oral presentations, simulated consulting sessions and role-playing are all possible. It is for this reason that we use the word "framework": many distinct methods can be used within it.

The student is able to learn in this framework both through the experience he gains in working on each assignment, and also through the feedback provided by the teacher's comments. Discussion of the problem with fellow students or with the teacher is encouraged, since it promotes thought - though the teacher needs to be careful not to provide ready-made answers. Strict deadlines and the knowledge that his report will be subject to detailed criticism are powerful enhancers of the student's concentration on a project, and concentration produces fertile conditions for learning. The sequential nature of the activity also provides for consolidation and reinforcement of what has been learnt. The framework therefore produces an arrangement that is educationally highly attractive, at whatever level it is used. Indeed it can be used at all levels, with appropriate modification of the technical demands of projects, and we recommend that it should be, from the first year onwards.

What of the consumer's view? We find that on the whole it is favourable: comments from students suggest that the approach is seen to be useful and that it is at least modestly successful in realising its aims. Students also say, to our surprise, that they have found the work enjoyable, though they usually add "in retrospect". Part of the reason for enjoyment, especially of the retrospective variety, may be the confidence-enhancing discovery that what initially seem daunting tasks can, with effort, be tackled successfully. An attractive feature is that this built-in reward appears not to depend much on the absolute quality of the student's work: weak students find their confidence bolstered as much as strong ones – maybe even more so in relation to their own lower expectations.

To sum up: it seems to us vital, both for the effectiveness of the training we offer our students and, ultimately, for the health of Statistics as a discipline, that we should attempt directly to teach high-level skills of statistical practice, and we see the mini-projects approach as the most effective way of doing so.

References

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