EXPERIENCING THE COMPLEXITY OF REALITY BEFORE GRADUATION

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The curriculum for undergraduate students offers not only basic statistics courses but also optional courses regarding statistical methods for times series, modelling, epidemiology, econometrics and other topics potentially useful in a statistician's career. This means that the students believe that they will get a comprehensive statistical toolbox for solving a variety of real life problems after graduation. But can they use the tools in a complex reality? The aim is to present the use of inter-disciplinary statistical problem solving courses for introducing the complexity of reality to statistics students before graduation. Experiences of the discordance between students' theoretical and practical skills regarding statistical description, analysis and understanding will be given.

INTRODUCTION

At Örebro University, Statistics department, the curriculum contains, besides the basic courses, a range of optional courses regarding statistical methods for times series, modelling, epidemiology, econometrics and other topics potentially useful in a statistician's career. The textbooks and the lectures mainly concern mathematical and statistical theories, derivations, and fitting exercises. Such exercises often specify the statistical method to be used on the data sets, like "calculate the mean and standard deviation", "the correlation coefficient", "perform the t-test", etc. The students can get a substantial toolbox of statistical methods by such courses, but can they communicate statistics with non-statisticians and use the tools in a complex reality? Furthermore, the main part of statistical courses and methods taught are suitable for quantitative data, and parametric methods are dominating. Empirical data are seldom nicely distributed, laboratory data are quantitative but often positively skewed, and ordered categorical data from assessments on questionnaires and scales are frequently used in various applications.

My research deals with development of statistical methods suitable for ordinal data (Svensson, 2005), and besides that, in my role as supervisor, consultant, teacher, advisor, I have gained a genuine experience of statistical problem solving of complex research questions in medicine, psychiatry, pedagogy, and in social and behavioural sciences (Svensson, 2001a; Svensson 2001b). Since 1980:s I have offered PhD students, supervisors, researchers from various disciplines statistical problem solving courses with different main themes. Biostatistics, rating scale statistics and laboratory sciences have been the most frequent application fields followed by informatics and social sciences. The educational model of such courses has been presented in previous conferences on teaching statistics, (Svensson, 1998a; Svensson, 1998 b).

In order to prepare the second-year students in statistics for future work, I integrate the optional course of biostatistics with a statistical problem solving course. The aim was twofold, to introduce statistics students to real life problems and to introduce statisticians to researchers from various disciplines. Overall experiences and evaluations of previous joint research courses are reported (Svensson, 2002).The aim of this paper is to present some pedagogical approaches to training the students to statistically evaluate, solve, and communicate real life problems mainly from medical and behavioural sciences before graduation. Examples of discordance between

students' theoretical and practical skills, not only regarding statistical methods for description and analysis but also regarding communication and understanding, will be given.

STATISTICAL PROBLEM SOLVING COURSES

At Örebro University I meet the students during their second year of studying statistics. One most obvious and comprehensive way of preparing the students for future work is to involve the students in the statistical problem solving courses. By doing so, they have to collaborate with the participants, since all exercises are related to the applied problems that are represented in the course by the researchers and by me, and not from a specific section in a textbook (Svensson, 2002). The main approach is that the courses are multi-disciplinary focussing at statistical strategies for problem solving. They are interactive, which means that the participants will apply the statistical methods to their own problems, when applicable. A large proportion of time is spent on study design, especially to identify dependent and independent individual data, and its consequences on to choice of statistical methods. The measurement process and the measurement properties of data are thoroughly discussed, especially regarding questionnaires and rating scales. Consequently, the link between the properties of data and the choice of statistical methods for description and analysis is the crucial issue of the course (Stevens, 1946; Stevens, 1955; Hand, 1996; Svensson, 2001a). The statistical literacy, the verbal interpretation of results, is trained by reviewing scientific papers and by formulating good descriptions and conclusions of the results of their own data.

INTERACTIVE EXERCISES

The following types of exercises are central in most of my courses. The performance of exercises is an ongoing process during a course, with repeated follow-up discussions, in order to improve the learning process and to gain experience of the complexity in real life problems. My indirect message is that there is seldom one single response to a problem, and that multi-disciplinary aspects including statistical perspectives offer a deeper understanding of problem solving in research.

A. *The research project*. The aim is to give a very short presentation of the main theme of a research project. One specified research question must be presented, focussing at the purpose and the study design. The type of study and if there are independent or dependent groups of data (cross-sectional, follow-up, etc) should be identified.

B. *The measurement process*, especially concerning the operational definitions of the main variables, the use of measurement instruments and scales and the measurement properties of the data, is one of the most central exercises.

C. *Statistical descriptions*. The aim is to give relevant descriptions, graphically and with relevant summary measures of different types of data sets. The participants should preferably use own data sets when present, but they can also chose from a pool of empirical data sets from me. Then they have to select suitable sets of raw data from individual observations for each of the types of data. Six fundamental sets of statistical descriptions by graphs and by statistical summary measures must be performed. The individual types of data sets to being described are: two independent groups of dichotomous, ordinal and quantitative data, respectively and data sets of change based on individual pairs of dichotomous, ordinal and quantitative data, respectively. The table and figure legends must be given, and common rules for publication must be followed.

D. *Review of scientific papers* from the research field of interest. Part 1 has the focus at the main study purpose, the design, the sampling procedure and the measurement process. The variables, the measurement levels of data and the statistical methods used must be reported and reflections regarding the relevance of statistical methods to the data and the research questions must be given.

E. *Review of scientific papers.* Part 2 has the focus at the presentation of results, the use of text, tables and figures, if any. The information given in at least one table or figure must be interpreted.

The statisticians must give a deeper reflection regarding the statistical methods used, and present which statistical assumptions on data must be met for each statistical method used. An overall reflection regarding the scientific quality of the paper and of the validity of results is desired (Altman, 1998).

F. *Applied problem solving of a data set.* The participants get the opportunity to analyse a specific problem of their own. The empirical data set is preferably provided by the participating researchers, but the participations, both statisticians and researchers, can also get empirical data sets from me. The problem solving must include all steps in research methodology, and the data analysis must include operational definitions of the variables, the measurement properties, statistical description and other methods required for the problem solving. Common types of problems to be solved are: evaluation of intervention(s), comparisons of treatment effects, reliability in scale assessments, inter-scale comparisons.

EXPERIENCING THE FUTURE WORK

Each statistical problem solving course normally has about five statisticians and 12-25 researchers from a range of disciplines, such as nursing, social science, psychology, culinary arts, physiotherapy, chemistry, which provide insight of the complexity of real life problems. Normally this is the first time the statisticians meet statistical problems outside textbooks, and the first lectures are very confusing for them. Therefore, performing the interactive exercises is an ongoing process with repeated follow-up discussions during the course. Meanwhile, the students' skill and confidence will improve. The table gives some generalising examples of contrasts between statistical courses and the statistical problem type of course regarding content and approaches to statistical methods.

Table: examples illustrating contrasts in approaches and issues of interest between traditional courses of statistics and statistical problem solving courses.

Traditional courses	Statistical problem solving
The aim of an exercise is to perform a specific statistical method related to the section of the text book	The aim is to suggest, and perform a statistical method to solve a problem
Intra-disciplinary communication	Inter-disciplinary communication
Statistics in formulae	Talking statistics
The data set is given	The link between the study design, the measurement properties of data and the choice of statistical methods is taken into account.
Most data sets are quantitative and at least approximately normally distributed	The operational definition of the variable of interest, and the measurement level of data must be identified
Little attention is paid to statistical description of data	Much attention is paid to alternative ways of describing different types of data for different types of studies
Focus at parametric statistical methods of analysis	Non-parametric statistical methods appropriate for evaluation of dependent and independent ordinal data, and non-parametric and parametric statistical methods for quantitative data are included.
Populations have known parameters,	Small samples are common, and the

the sample size is assumed to be large enough for the statistical method presented.	population consists of a description of properties of eligible individuals only
o One single question, and one single statistical test	o Complex multi-variate and multiple tests in studies
o Isolated statistical results	o Interpretation of statistical documentation in an applied context
o One solution to each exercise	o More than one solution might be suitable to a problem
o	o Statistical and scientific reflections regarding relevance, quality and alternatives are always present.

MY EXPERIENCES

Exercise A, the research project. In this exercise the statisticians experience statistical consultation or at least communication. The first inter-disciplinary discussion takes place at the start of the course, and the students of statistics usually have large problems to even understand what the researchers talk about. On the other hand, the researchers have difficulties to specify one single research question and to focus at the important issues for problem solving. After repeated follow-up discussions all participants' skills improve.

Exercise B, the measurement process. This topic is practically unknown for all participants. Some of them have read about the measurement levels of nominal, ordinal, interval and ratio data, or scale levels, as Stevens (1946) named them, but as these measurement properties often are ignored in practice. The link between the measurement properties of data and appropriate statistical methods are always discussed before problem solving. The statisticians often get surprised and upset that they never have had such discussions during the first-year courses of statistics. I have discussed this with the teachers and hopefully it will be a change.

Exercise C. Statistical description seems to be a very simple exercise, but my experience is that this is one of the most demanding parts of the course. It is too easy to press the button of the computer and uncritically accept what SPSS or other software produce.

Exercises D and E regarding paper review are expectedly difficult, but the participants have at that stage of the course got used to the interdisciplinary discussions, and their skills and confidence gained are a good help.

Exercise F is a kind of final proof of statistical problem solving, and most participants are feeling much better that after the first meeting ten weeks earlier.

During the course, I have to tell the statisticians repeatedly that the aim of the exercises is not to satisfy me as a teacher but to perform a satisfactory problem solving, and also to prepare them for a future work as a statistician. Therefore I also suggest them to document their experiences. A typical comment from the students is then that this is the first time a teacher says that the aim of the course is to learning for life and not only for passing the exam, and they like the message!

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