EXPERIMENTAL DESIGN TRAINING ON THE WORLD WIDE WEB

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Statistical expertise is available at the University of Adelaide to help novice researchers select designs for their projects, but resources are limited and so it is helpful if young scientists have other avenues to obtain the information they require.

Using the framework of SMART, developed collaboratively by several institutions to provide timely and cost effective training to users of statistics, I am currently developing a suite of training modules in experimental design for delivery via the World Wide Web. In this paper I shall describe two training modules, one introductory and one advanced, that use the full multimedia capabilities of the Web, allowing user-interaction, video and photographic illustrations, dynamic demonstrations and links to public domain software.

INTRODUCTION

The literature on teaching statistics concentrates on introductory and service courses. In the past few years there has been strong emphasis on moving introductory courses away from recipes for data analysis and more towards understanding the whole picture. An example of this is the Problem, Plan, Data, Analysis, Conclusion (PPDAC) cycle used at the University of Waterloo in Canada (Mackay and Oldford, 1995). Nonetheless there are still a lot of service courses, particularly those taught by non-specialist statisticians, that have not adopted this modern philosophy. Furthermore, many students take an introductory course at the beginning of their undergraduate studies and then think little more about statistics until they reach Honours level and must conduct an experiment or a survey. Consequently students at Honours or postgraduate level are often unfamiliar with, or have forgotten, the terminology and the important aspects of experimental design.

At the University of Adelaide, we provide a consulting service for Honours and postgraduate students from the sciences and social sciences. Their statistical backgrounds are varied, some requiring much more elementary help than others. Sometimes all that is required is a reminder while at other times, students need pointers to useful texts.

The project reported in this paper is the development of two multimedia training modules about experimental design, accessible via the World Wide Web. The modules have been developed using the SMART infrastructure, described in Bishop and Talbot (1996) and elsewhere in this conference (Talbot et al, 1998). Since they are for use on the Web, they are written in html with Java applets for dynamic demonstrations.

OVERVIEW OF MODULES

The first module provides a brief introduction to the general concepts of design including randomisation, replication and blocking. A student completing this module will be able to:

1. describe the difference between an experiment and an observational study;
2. assess the likely main and interaction effects by looking at an interaction plot;
3. assess when blocking is useful in an experiment;
4. perform a randomisation for a completely randomised design and for a randomised complete block design;
5. access a package via the Web to generate randomised designs;
6. look up suitable references for their level of knowledge.

The second module is about fractional factorial designs, describing in some detail a $2^{(n-1)}$ design with brief extension to more complex designs. Students working through this module will:

1. learn about the need for conducting partially replicated experiments;
2. learn the meaning of confounding and its impact on what can be estimated;
3. learn some new terminology such as resolvable and alpha designs;
4. be introduced to software for setting up fractional factorial designs, such as Gendex.

Pfannkuch (1996) recommends that because students may lack the contextual knowledge to interpret statistical reports, examples used should either come from high profile issues or should be accompanied by background material. I have adopted a similar strategy in teaching experimental design. Students must understand some of the practical difficulties of an experimental procedure before they can comprehend the need for blocking, factorial treatments and incomplete blocks. To facilitate their understanding I have used a real experiment to illustrate each module.

The example in the first module is a wheat field experiment in which the treatments comprise three wheat varieties grown at each of two sowing rates with two different rates of fertiliser applied. The experiment is a 3x2x2 factorial arranged in four complete blocks. Blocking has been used because of a slope in the land and for project management purposes. Response variables include plot yield and measures of early vigour, such as leaf area index and light interception at the tillering stage of growth.

The second module example is an experiment conducted by a drug company. In order to investigate various properties of manufactured tablets, chemists experimented with six types of filler, three types of disintegrant, two binders, two lubricants and two hardness levels. Had the full factorial experiment been conducted this would have involved 144 treatment combinations. A resolvable design was constructed using 43 of these treatment combinations. An experimental unit was a kilogram batch of tablet mixture from which approximately 1000 tablets were made. Response variables included the disintegration rate, dissolution rate, friability, the amount of compression force to breaking strength and several components of taste.

In order to illustrate a simpler fractional factorial design, the experiment is introduced with only two levels of each factor. The full experiment is described as part of an extension that describes resolvable designs.

USING WEB CAPABILITIES

The multimedia facilities of the World Wide Web have enabled me to show the practical aspects of conducting each experiment using photographs and video clips. In the first module, the student is able to see the plots and blocks of the wheat experiment and the practical reasons for blocking. The second module shows the student not only the tablet manufacturing process but also the methods by which response variables are measured. The student gains insight into how time-consuming the measurements are and why it is necessary to use partial replication.

A common theme in both modules is that of interaction effects. The dynamic capabilities of the Web have been used to allow students to investigate the relationship between means and interaction effects. The introductory module contains a graph of means for three wheat varieties at two sowing rates. This is accompanied by a table of means and a table of interaction effects. The student can move the means on the graph, observe their numerical values in the first table and see what happens to interaction effects in the second table.

In the second more advanced model, a 2^3 factorial model arranged in two half-replicate blocks is represented geometrically in two cubes with means at the vertices. When the student selects a main effect or a second-order interaction effect, the means that are used to estimate this effect are highlighted. Thus the student can see which effects are confounded with the blocking.

Nowadays, numerous computer packages will generate randomised layouts for experiments but it is important to understand the basic concepts of randomisation. Dynamic illustrations of randomisation for completely randomised and randomised complete block designs are included in the first module, guiding the student through the process.

One of the major feature of the Web is its ability to make links to other sites. The first module includes a link to EDGAR, software developed by Brown (1997) to generate experimental designs. In the introductory module, students are shown how to use EDGAR for the wheat experiment example and they can then try other possibilities.

Similar links to appropriate software are planned for the more advanced module. Finally, feedback can be solicited about the modules using the Forms facility and also by providing the email address of the author.

EVALUATION

At the time of writing, these modules were still under development but it is expected that they should be available for use by the middle of 1998 via the Web address given below. Prior to that there must be an evaluation stage. Selected students from a range of backgrounds will be asked to act as reviewers. Once the modules are made available and publicised on the Web, there will be continuous evaluation of student-user comments facilitated by the avenues for feedback within each of the modules. At this stage it is not possible to comment on student reactions to the modules.

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Web address: http://www.maths.adelaide.edu.au/people/gbishop/gbishop.html

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