# TEACHING BAYESIAN METHODS IN BIO-MEDICAL RESEARCH

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*This paper considers experiences of teaching Bayesian statistical methods within a bio-medical research setting to both statisticians and non-statisticians at postgraduate level. In particular, it considers topics covered, level of mathematical exposition, software and texts.*

## INTRODUCTION

The use of Bayesian statistical methods in many areas of applied healthcare research has grown considerably over the last ten years (Spiegelhalter *et al*., 1999), and consequently the teaching of such methods at postgraduate level has reflected this. Much of this increase can be attributed to the development of computer software, in particular *WinBUGS* (Spiegelhalter *et al*., 2003) that enables researchers to apply Bayesian methods to realistically complex data analysis problems (Best *et al*., 1996).

This paper describes the development and delivery of teaching material on Bayesian methods at two levels – to students on a Masters of Science degree course in Medical Statistics at the University of Leicester, and to participants on a postgraduate short course on the use of Bayesian methods in evidence synthesis and decision modelling.

## MASTERS OF SCIENCE IN MEDICAL STATISTICS

The M.Sc. in Medical Statistics taught at the University of Leicester is a long established postgraduate course which aims to train medical statisticians for a role within either the pharmaceutical industry or public-sector healthcare research (www.hs.le.ac.uk/postgrad/msc/medstats/). Each year a cohort of approximately twelve students enrol with mainly an undergraduate degree in mathematics and statistics or occasionally an undergraduate degree in medicine or biological sciences. The course attracts funding from both the U.K. engineering and science research council and the U.K. medical research council, together with funding from the pharmaceutical industry.

The use of Bayesian methods of statistical inference has been formally taught since 1994, initially as part of a module on Statistical Inference, which has included both classical and Bayesian methods. The syllabus has typically included; Subjective probability, Bayes' Theorem, Conjugate models, Summarising posterior distributions, Prediction, Multi-parameter models and Computational methods. All taught modules on the M.Sc. at Leicester last for a week, and the Statistical Inference module uses a mixture of lectures, practical classes and student presentations. Formal assessment of the module is based on an examination covering both classical and Bayesian methods of inference.

Whilst the format of the module and the topics covered have remained broadly constant since 1994 the computational aspects of the module have changed considerably. When the module was developed there was a greater emphasis on the use of conjugate models, and the use of these to approximate more complex (multi-parameter/regression) models. In addition to requiring students to undertake analyses of datasets analytically, the *FIRSTBAYES* software package (O'Hagan, 2005) was used to help reinforce the methods and to allow students to obtain Highest Posterior Density Intervals and predictive distributions which are computationally more demanding even for relatively simple models. Practical estimation in multi-parameter models was implemented by the students using numerical integration (quadrature) methods in *MINITAB* (Albert, 1996). Typically the models considered were often only 2-parameter models, usually linear or logistic regression, so that students could compare results with previously obtained unadjusted estimates.

Since 2000, a number of changes have been made to the module, most notably in terms of computation. Whilst initial changes introduced the use of *WinBUGS* (Spiegelhalter *et al*., 2003) along side that of *FIRSTBAYES* and *MINITAB* together with an introduction to Markov Chain Monte Carlo (MCMC) methods, since 2003 the module has exclusively used *WinBUGS*, and students now spend a considerable amount of time in computer practical sessions gaining experience in using *WinBUGS*. Part of the rationale for focusing exclusively on *WinBUGS* was the formal introduction of Bayesian methods into other modules, so that at present students taking a module, say on survival analysis, will learn how to implement the models and methods covered in *SAS*, *Stata* and *WinBUGS*. In addition to the changes relating to computation, an optional module has been added on Advanced Bayesian Methods later in the course which covers in more detail methods of convergence and hierarchical models. Typically between three and six students currently choose this option each year.

The main text used for the Bayesian aspects of the inference module was initially Lee (1997), though this was supplemented by Albert (1996), Berger (1985), Bernardo and Smith (1994), Berry (1996), Thisted (1988). More recently, with the greater emphasis on the use of *WinBUGS*, Congdon (2001 and 2003), Gilks *et al*. (1996) and Gelman *et al*. (1995) are also now used. Since the publication of Spiegelhalter *et al*. (2004) this has become the main course text in terms of Bayesian methods.

A third of the total credits associated with the M.Sc. are for a Dissertation which students undertake after the taught-element of the course, and which lasts for three months. Dissertations usually cover either the practical analysis of a dataset or a detailed review of methodology. For the former a number of students will use Bayesian methods (and consequently *WinBUGS*) in their dissertation. Recent examples of such projects have included; analysis of longitudinal datasets, meta-analyses and clinical trials, especially in relation to missing data.

## POSTGRADUATE SHORT COURSES

In addition to the M.Sc. in Medical Statistics, academic statisticians within the Department of Health Sciences are involved in a number of short courses aimed at primarily at postgraduate healthcare researchers. In particular, a short course has been developed on *Bayesian Methods for Evidence Synthesis and Decision Modelling*. The rationale for developing such a course has been two-fold.

The use of Bayesian methods in meta-analysis, and more generally in evidence synthesis projects, together with the integration of such methods into a formal economic decision model (sometimes referred to as comprehensive decision modelling) (Parmigiani, 2002) is a primary research interest of members of the Medical Statistics Group within the department (Cooper *et al*., 2004). Thus, the development of a short course was a natural extension of the usual dissemination methods. However, simultaneously the use of formal economic evaluation methods (including meta-analysis, evidence synthesis and decision modelling) to inform healthcare policy in the U.K. has become standard practice with the creation of the National Institute for Health and Clinical Excellence (NICE) (www.nice.org.uk). NICE issues guidance to the National Health Service (NHS) as to which healthcare technologies (i.e., devices, pharmaceuticals and services) should be adopted routinely in clinical practice within the NHS. The use of Bayesian methods in both the synthesis of evidence and the appropriate propagation of uncertainty in decision models has been readily accepted by NICE, and indeed their own methodological guidelines indicate this (NICE, 2004). Consequently the development of a 5-day short course introducing and illustrating the use of such methods has been well attended in both the U.K. and in other countries which require similar assessments of healthcare technologies for policy decision making, e.g., Australia, New Zealand and the Netherlands.

The format of this 5-day short course typically uses half-day sessions which cover; Introduction to Bayesian methods and *WinBUGS*, Meta-analysis, Decision Tree Modelling, Multi-parameter evidence synthesis methods, chains of evidence, Markov decision modelling, Generalised Evidence Synthesis and Value of Information methods. The format of each session is usually a series of lectures/presentations interspersed with computer practical sessions in which participants learn to implement and interpret the methods using *WinBUGS*.

The 5-day short course (or variants of it) has been run so far six times since December 2003 in Australia, Italy, Netherlands, New Zealand and U.K. (three times) with over 250 people attending. Participants have mainly been clinical epidemiologists, decision modellers, health economists and statisticians. The diversity in background knowledge has often meant that considerable time has had to be devoted to both the introduction to Bayesian methods and the use of *WinBUGS*.

The development of this, and other short courses and the lack of introductory texts discussing the use of Bayesian methods in this context has led to the writing and publication of one text so far (Spiegelhalter *et al*., 2004), with another currently planned. The latter is intended to follow more closely the topics covered in the current 5-day short course.

## DISCUSSION

The development of relatively user-friendly software such as *WinBUGS* combined with the increasing appreciation of the benefits of using Bayesian methods in healthcare research, but in particular in relation to evaluation, means that the teaching of such methods to both statisticians and healthcare researchers will undoubtedly increase over the next few years.

The M.Sc. in Medical Statistics at Leicester and the development of specialist short courses illustrate the fact that this will need to take place at two levels. Medical statisticians will in the future be expected to have a more detailed knowledge of the fundamental principles of Bayesian inference, whilst applied healthcare researchers will frequently analyse their own data using *WinBUGS*, mirroring the current situation as regards classical statistics.

However, the appreciation of the fact that any statistical analysis should be subject to sensitivity analyses (i.e., sensitivity to both prior distributions and computational methods in a Bayesian context) is perhaps the most important element of introducing the use of Bayesian methods more widely. It is this aspect which decision makers, as opposed to analysts, have the most difficulty in appreciating or accepting, and in some ways is an unfortunate by-product of the lack of consideration of methodological (i.e., model) uncertainty in statistical analysis generally.

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