A New Way to Teach Statistics to Engineers

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In May 1999 Richard Parry-Jones, Group Vice-President Product Development & Quality, Ford Motor Company, delivered the Royal Academy of Engineering Manufacturing Lecture. He covered three themes, namely customer insight, engineering manufacturing quality and wealth creation & shareholder value. Within the second theme he described the importance of taking into account, while keeping a keen eye on quality, variability in engineering design. The lecture, comprising nearly 30 pages of typed script and 57 PowerPoint slides, can be found at www.raeng.co.uk/Statements/pubs/CorpSuccess/index.htm

The importance of using statistics and statistical thinking for managing variability in product design was emphasised time and again through well thought-through and illustrated examples. Furthermore he suggested that the approach to teaching statistics to engineers should be somewhat more radical than has been the case within UK higher education in recent years.

He cogently argued that promoting the *use* of statistics in engineering, rather than statistics per se, should be the approach taken to making engineers stand up and take note of the very powerful tools that they can utilize to improve any engineering process. Briefly he suggested that:

- The responsibility for adopting this approach rests squarely with management;
- There is a need for *coaching* in statistical engineering methods;
- These methods should be embedded in undergraduate curricula and professional experience requirements of our institutions;
- (Statistical Engineering) should be taught by engineers in the context of design and engineering, supported by first class applied statisticians as necessary;
- These methods should not be taught on a separate course in statistics.

The last two bullet points may well be controversial, but in this article I do not argue for or against the suggested approach. At a similar time to the Parry-Jones lecture, statisticians within the RSS, together with engineering colleagues, had been informally expressing concern over the general practice of what some perceived to be a rather old-fashioned approach to inculcating statistics to engineers in general and, in particular, prospective graduate ones. In fact the Quality Improvement Committee (QIC) of the RSS, jointly with the Institute of Electrical Engineering (IEE), organised four open meetings on statistics for engineers between October 1999 and February 2000.

In the remainder of this article I shall describe how, from a combination of both the RSS/IEE initiative and the Parry-Jones lecture, an innovative, and some might say radical, approach to helping to better tackle the problem of statistical education for engineers has been developed.

Joint Venture

Leading up to and following the Parry-Jones' lecture, a good deal of discussion took place within Ford Motor Company about how they could attempt to take forward his suggestions in a formal way. The momentum generated from the jointly organised RSS (QIC) and IEE meetings gave rise to a further three exploratory ones that took place between interested parties at Ford, the RSS and Dan Grove, an independent statistical consultant who has had a long history of involvement with training Ford engineers in statistical methods. These meetings were rather more focussed on how at least some of the suggestions of

Parry-Jones could be implemented at Ford.

Over summer 2000, Dan Grove, along with Ed Henshall of the Ford Design Institute and Tim Nicholls of Ford of Europe Education, Training and Development using an engineering process/statistics model for delivery, wrote specific training materials using the Parry-Jones philosophy in the context of a generic engineering process. The material was created around realistic engineering scenarios, with each of 12 sections introduced by an engineering task based around the design and manufacture of a fuel filler flap. The sections and tasks build on each other in the context of the scenario storyline. Statistical concepts and tools that support the engineering task are taught in an engineering context and there is participant activity based on the engineering task for each section.

The following 12 engineering tasks were designed, initially at least, as 1.5-hour sessions over an intensive three-day period:

The course is delivered with a minimum of theoretical input and uses graphically based techniques of analysis in preference to more mathematically based ones.

Supporting materials comprise:
- PowerPoint slide based presentation materials for each statistical technique covered, with each presentation using (different) automotive engineering examples
- Class notes based on the PowerPoint slide presentation materials
- Participant exercises, each with a model answer
- Teaching notes

By February 2001 the training course had been delivered as two three-day pilots to engineers at Ford. The academic background knowledge required of these engineers was only GCSE Physics and Mathematics, and familiarity with Excel. However, the materials have been designed to be used in a flexible manner and so can form the basis of a more typical undergraduate course taught as a series of learning interactions over a longer period.

Statistical Engineering Education

Section	*Engineering Task*	*Statistical Tools*
1	Capture the voice of the customer	Dot Plots, Introduction to frequency distributions
2	Evaluate functionality of design concept	Simple linear regression, least squares method
3	Assess robustness of design concept	Two level designed experiments
4	Quantify piece to piece variation	Run charts, probability distributions, mean and standard deviation
5	Optimise design	Quadratic response surfaces, multiple regression
6	Verify design	Weibull distributions, Weibull plot, estimation of percentiles
7	Establish the engineering process	Two level designed experiments revisited, Daniel plots
8	Estimate functionality of manufacturing process (1)	Linear models/planar response surfaces , Designing a response surface experiment, Standard 3 level designs, optimal designs
9	Evaluate functionality of manufacturing process (2)	Residual analysis, Statistical significance: t ratios, p-values
10	Optimise process	Excel solver
11	Validate the process	Shewart charts, control limits, capability
12	Using knowledge gained	Review of tools covered in the course

As can be seen by scrutinising the statistics 'syllabus' in the above table, what is learned by adopting the case study/engineering process approach is very different, both in order of topics taught and content, from conventional introductory statistics courses. The approach enables 'harder' topics to be taught successfully assuming a much lower level of background knowledge. The approach relies much less heavily on traditional syllabuses that are often driven by demands of hand-computation, combined with an over emphasis on significance testing. The case study approach in each section uses hands-on participant activities that employ Microsoft Excel/Minitab for data analysis and display.

Dissemination

During early April the RSS hosted a day meeting in London designed to introduce the engineering statistics training materials to interested parties, and to consider how these might be used within the education of undergraduate and graduate engineers. The two LTSN Centres, Engineering (http://www.ltsneng.ac.uk) and Maths, Stats & OR (http://ltsn.mathstore.ac.uk), together with Ford, co-organised the day, with representatives

from 13 universities attending. In addition there were four representatives from the RSS QIC including Dan Grove and five from Ford

Following an overview of the material and detailed scrutiny of one of the sections, the general view from everyone present was that the proposed approach to teaching engineering statistics was innovative and that it deserved careful consideration by engineering departments in the UK.

LTSN Engineering at Loughborough University volunteered to host the material, via a secure password protected web site, and interested engineering departments are being invited to look at the material with a view to running the course during the next two years. The following actions were agreed:

- Volunteer universities would be invited to take the developed material back to their departments;
- The material would be examined closely and consideration would be given to how it could be used as part of undergraduate and/or postgraduate teaching programmes;
- Suggested changes would be recorded;
- Consideration would be given to the delivery mechanism that best suits them, for example as an intensive course, spread over 1 term, electronic, web based, or combination of these;
- Assessment issues should be thought through, including formative and summative ones;
- Different self-study/learning options should be entertained, such as how long the end of session exercises should take, and whether mini or full project work was appropriate;
- Extensions of the filler-cap scenario into other engineering applications should be thought about to take into account local needs within a department's portfolio.

Finally, in order to attempt to implement the material for the 2001 - 2003 academic years, a further meeting will take place at the RSS in London by the end of June 2001 if possible. The results of the national deliberations about this innovative and radical way to teach statistics to engineers will be reported in future issues of *MSOR Connections*.