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PHD TRAINING IN SIMULATION: NATCOR

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ABSTRACT

To provide a broader education for Operational Research PhD students in the UK, the Engineering and Physical Sciences Research Council funds the National Taught Course Centre for Operational Research (NATCOR). This is an initiative led by six UK universities and includes a one-week, residential simulation module taught for the first time in July 2009. We describe the background to NATCOR, summarize its content and reflect on its further development.

1 PHD TRAINING IN THE UK

Though there are exceptions, PhD training in the UK is mainly based on an apprenticeship model in which the PhD candidate is assigned one or more supervisors with whom (s)he works throughout the period of PhD registration. In many cases, the candidate is required to present an outline research proposal even before registration, though more often this develops during their first year. In most universities, PhD candidates are formally regarded as PhD students; that is, as postgraduates alongside others, taking taught courses, typically at Masters level. Most Masters students in the UK are registered on taught courses lasting the full-time equivalent of 12 months, on which they take assessed modules in which they must reach at least a pass standard. Though PhD candidates are encouraged to attend available taught modules, usually in their home university, these courses are not usually assessed requirements for the award of a PhD. However changes are now being introduced by some universities to ensure a more formal assessment of a range of aspects considered important in PhD training. These include delivery of oral presentations, attendance of seminars and conferences, assisting in teaching and also attendance of taught modules deemed important but not already familiar to the candidate.

Most PhD programmes in the UK assume that full-time candidates will submit their completed dissertation within 4 years. There is still an unspoken view that the norm ought to be doing so in 3 years; though doing so is increasingly rare. PhD students pay fees, though these may be paid by scholarships and bursaries of which there are more in some subjects than others. The UK Research Councils, which fund individual research projects and programmes, also provide PhD funding that covers fees and living costs

for some students. Though no official figures are available, our impression is that Research Councils fund only a small minority of PhD students studying in areas related to computer simulation. Until recently, most Research Council support lasted just 3 years, furthering the impression that completion in 3 years is the norm. In many cases, this support has now been extended to 3½ years, though this does not cover a taught Masters degree to prepare candidates for PhD work.

There is an increasing use of PhD students as Teaching Assistants, which enables them to earn their keep, but distracts them from their PhD research, lengthening the time they take to complete. Universities in which too few students submit their PhD dissertation within 4 years may be penalized by university funding bodies. There is thus great pressure on both PhD candidates and their departments to see that they complete in under 4 years.

In summary, most PhD training in the UK is different from that in some countries. The main differences are:

- Normally there is no formally assessed set of taught modules that must be completed as part of a PhD.
- Full-time PhD candidates are assumed to complete their work in 4 years or less.
- PhD candidates are regarded as students and not as junior faculty.
- Most PhD students work under the supervision of one or two faculty throughout their PhD period and these supervisors are often assigned when the student arrives at the university.

2 INTERNATIONAL REVIEW OF RESEARCH IN OR

In 2004, the Engineering and Physical Sciences Research Council (EPSRC), which is a major funder of research and PhD training in Operational Research (OR), conducted an international review of the status of UK research. Around the same time it conducted similar reviews of the various subjects within its domain. An international panel met representatives from a range of universities and user groups and used available metrics to assess the research status of OR. In general, UK OR was regarded as being in excellent health, with much high quality, innovative research. However, the panel expressed concern about the breadth and depth of UK PhD training in OR. As a response to this, six UK universities with significant numbers of OR PhD students (Brunel, Cardiff, Lancaster, Nottingham, Southampton and Warwick) collaborated in a bid for EPSRC funding with the support of the UK OR Society. This bid was successful and led to funding of about £250,000 for the creation of NATCOR (the National Taught Course Centre in Operational Research).

3 NATCOR

NATCOR provides a series of residential taught modules on topics of major importance in mathematical OR. During 2009-2011 these include:

- Heuristics and approximation algorithms
- Convex optimization
- Data envelopment analysis
- Stochastic modeling
- Simulation
- Combinatorial optimization

Students whose PhD work is funded by EPSRC attend free of charge and a small fee is levied on others who are not funded by EPSRC and this is usually paid by their departments. Though many students are from the six collaborating universities, attendees come from many other universities and include some from outside the UK.

This set of residential modules was devised to bring PhD students up to speed in a broader range of subjects than was normal in the past. This is obviously useful for those PhD candidates who will enter academic posts and will need to teach subjects other than that of their PhD. It also exposes them to other approaches than ones with which they are familiar and can greatly broaden their work in the PhD itself. The residential aspect also helps create a national community of OR PhD students as they spend time to-

gether, meet up from time to time on the modules and keep in touch in many different ways. Each module is assessed, though it is left to the university with which a PhD student is registered to decide how to use the marks obtained. In most cases, the module assessments do not formally count toward the PhD. More details of the NATCOR programme, including views from the students who attend, can be found at their website (NATCOR 2010).

4 THE NATCOR SIMULATION MODULE

Though a single university takes the lead in organizing a module it is taught by a team from several universities so as to reduce the risk of any one university dominating proceedings. This is important if the programme is to be a true collaboration between the universities. The simulation module is organized by Stewart Robinson of Warwick University. It has been taught once so far, in July 2009. It was attended by 84 students and its tutors came from Lancaster, Southampton and Warwick Universities, with a further contribution from an experienced simulation practitioner. The aim of the course was to provide an understanding of the mathematical and statistical principles of stochastic simulation modeling. The material available to students before the module told them:

> "Simulation is one of the most widely used operational research techniques. It involves the development of an imitation on a computer of the system under study, followed by experimentation to understand and investigate improvements to the system. This course provides an understanding of simulation, with a focus on the mathematical and statistical principles of stochastic simulation modeling. The main technique of interest is discrete-event simulation, although other simulation techniques will be introduced."

Specifically, the module aimed to enable PhD students to:

- Understand the basic principles of simulation and performing simulation studies.
- Understand the basic theory of simulation analysis including input data analysis, experimentation and output analysis.
- To be aware of the strengths and limitations of the approaches covered.
- In addition, by the end of the module, the students were expected to:
- Be able to develop and use a simulation model for a given problem situation.
- Be able to evaluate the quality of a simulation analysis.
- Be familiar with the use of a simulation software package (SIMUL8).
- Be familiar with the use of statistical analysis software (e.g. Excel, Minitab, SPSS).

Handouts were provided for each section of the module. In addition, the students were recommended to use Krzanowski (1998), Makridakis, Wheelwright and Hyndman (1998), Pidd (2005) and Robinson (2004) for further reading; plus, of course, the Winter Simulation Conference Proceedings. Since some of the attendees were undertaking PhD research in simulation whereas others had only a passing interest, it was important that the material covered was taught in a way that was interesting and engaging, but at a high enough level to enable students to read the research literature.

The simulation module began on a Monday lunch-time and ended on a Friday lunch-time to enable attendees to travel to and from Warwick University where the module was held. It included computer-based workshops and formal lectures. Some evening work was needed, but most evenings were devoted to networking/socializing. The material covered was divided into the 5 sections shown in Table 1.

An assessment exercise was given to the students halfway through the course. This involved using a pre-developed simulation model (in SIMUL8) for experimentation. The students were asked to investigate the warm-up, run-length and replications requirements with the model and to perform a comparison of a series of scenarios using the methods taught on the course. Working in small groups, the students wrote a short report on their work. This was handed in first thing on Friday morning and feedback was provided at the end of the course.

Table 1: Outline of the NATCOR simulation module

1: Principles of simulation	Introduction to simulation methods	Mike Pidd
	Generating random variates	
	Computing aspects of simulation	
	Distributed simulation	
	Simulation studies and the simulation modeling life cycle	Stewart Robinson
	Model validation	
2: Variance reduction	Random number generation	Ruth Davies and Katy Hoad
	Variance reduction methods	
3: Simulation in action	Simulation in action	Shane Kite, Saker Solutions Ltd
4: Introduction to output analysis	Analysis of a single scenario – obtaining accurate results	Stewart Robinson
	Basics of comparing multiple scenarios	
5: Experimental design & analysis	Time series analysis	Russell Cheng
	Experimental design	
	Metamodeling	
	Simulation optimization	
	Bootstrapping (for input data as well)	

5 REFLECTIONS IN OUR NATCOR EXPERIENCE

At the end of the week the students completed a questionnaire which asked for their reflections on the course. Questions sought feedback on a wide range of topics from the standard of accommodation to the delivery of the course content. The quantitative scores showed a good level of satisfaction with the course and many students said they would recommend the course to other PhD students in the future.

Space was provided for written comments which provided some interesting perspectives on the course. One of the key benefits of the week was seen to be the networking opportunities it provided with PhD students from other institutions. Most of the students could see the relevance of the course to their own PhD research and they appreciated the breadth of topics covered in the week. Some, however, felt that too much ground was covered in the time available. The students also found the inclusion of case studies and discussion on practical applications helpful; although some would have preferred more emphasis on these aspects.

A clear difficulty in running the course was the range of knowledge of simulation that the students had prior to attending the week. Some had previously studied simulation courses (largely as part of a Masters programme before registering for a PhD), a handful were using simulation extensively in their PhD research, and the remainder had little or no knowledge of simulation. This lead to some dissatisfaction with the level of the content in the course, with some asking for more depth and others suggesting less. Without splitting the course into two or more groups, such issues are almost impossible to address.

From the teachers' perspective the NATCOR simulation course provided an opportunity to teach simulation at some depth to those who may use it as part of their research. We were also able to meet those who will be the future researchers in OR and some in simulation. We look forward to running the course again in July 2011, with some changes in the light of comments received in 2009.

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