

## STATISTICS FOR THE BIOLOGICAL AND ENVIRONMENTAL SCIENCES: IMPROVING SERVICE TEACHING FOR POSTGRADUATES

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*A challenge for statistics educators is to maximise the effectiveness of service teaching to non-statisticians in order to create successful end-users of statistics, build research capability and to raise the profile of statistics within the wider community. In 2008 we undertook an evaluation of statistics service teaching within the Lancaster Environment Centre at Lancaster University. Collaborating with staff and students enabled a thorough study of the strengths and weaknesses of the course. Recommendations for how to make the course more suitable for occasional users in the biological sciences were made. An evaluation of the revised course was completed in 2009 and the results, presented here, are compared with feedback from 2008. We demonstrate that with close collaboration between all departments, making swift and tangible changes based on 'real' suggestions by the students who take the course is the only way to reach specific users.*

### BACKGROUND

Teaching of statistics is notoriously difficult in the face of misconceptions on the worth of statistical data, intrinsic or learned fear of the subject, complicated sounding concepts and the self-perceived lack of numeracy in those learning the subject (Garfield, 1995). These feelings are not exclusive to students on introductory courses, or those who are meeting statistics for the first time. As a result of these problems students are frequently unconfident in their statistical abilities and can be seen to suffer from what has more recently been referred to as 'Statistics Anxiety' exacerbated by waning emphasis on statistical thinking and reasoning (Verhoeven, 2006). Within the wider population mistrust and misunderstanding of statistics and how to use them or best understand them is commonplace.

As a direct result of an increasing drive to improve the success of statistics teaching, leading statistics educators in the early 1990s called for educational reforms in the way introductory courses are taught, to place greater focus on statistical thinking and data analysis, and less on derivations and computational 'recipes'. Since this time the statistics education community has been working hard to develop new pedagogical approaches and activities to accommodate these changes (Garfield, 1995; Scheaffer et al., 1996; Moore, 1997). These reforms have led to a constructivist-centred, active-learning approach that moves away from passive-absorption of information and rote learning, and places increased emphasis on active and cooperative learning techniques (Garfield, 1993, Verhoeven, 2006). Recommendations made in a seminal paper by Cobb (1992) on educational reforms for statistics can be summarised as "*Teach statistical thinking. More data and concepts, less theory and fewer recipes. Foster active learning.*"

Despite an increasing volume of literature being published on statistics education, much is focused on undergraduate statistics to statisticians. Published data on service courses in statistics is less studied and hence harder to access. This is confirmed by Garfield (2002) who noted that teachers of statistics in the biological sciences are harder to reach and support than in other disciplines. The challenges facing statistics education at the Tertiary level and particularly within service teaching is explored in depth by Nicholls (2001) and more recently Gordon (2004). It is not our intention to rewrite this succinct review of the common challenges involved, only to say that the challenges faced within service teaching at tertiary level in Australia are comparable to the challenges faced in UK universities. The pressures of decreasing time slots for statistics, insufficient training of instructors, communication between departments and competition for student time are hurdles that effective educators must overcome in order to deliver successful service teaching.

Recently, the benefits of familiarity with theories of learning, informing theories of instruction have become better understood. Pedagogical theories of learning are better known and better used to inform practice (Garfield, 1995). A survey by Garfield in 2001 found that many

instructors have acted on the proposed reforms of the nineties, increasing active and cooperative learning, and have adapted these ideas into their courses, believing that the resultant changes have been beneficial. However, aside from a few notable examples (e.g. Fields *et al.* 2006) the benefits and effectiveness of such reforms within the postgraduate sphere are little reported. Garfield *et al.* (2002) encourage collaborative research amongst colleagues and students on the success of statistics courses in the classroom.

With the challenges facing statistics service teaching in mind, and the lack of published data on postgraduate courses in particular, we have undertaken an evaluation of the service teaching within a landmark Environment Centre, in order to gain valuable insight on the strengths and weaknesses of the current provision. By bringing to light the successes and failures of the current statistics provision for non-statisticians, we are able to identify areas of teaching for future improvement. We offer a set of recommendations where changes can be made. Whilst, these will be tailored to our institution, it is hoped that they will be useful for other educators who may identify with the problems that our students face when trying to learn statistics that is relevant to their discipline. The ideal situation is that by highlighting tensions and conflict within a service teaching system, positive action can be taken by all involved, to resolve such issues without becoming a casualty of it (Engestrom, 1999; Gordon, 2004) and therefore ensuring best practice amongst all involved. We ask the question, how as learning facilitators can we begin to turn service teaching from being inherently problematic, to a valuable source of statistics provision that encompasses effective, efficient teaching?

At present, statistics is service taught to postgraduates from the Environment Centre by the Postgraduate Statistics Centre. The course is delivered as a ten week module in Michaelmas Term and comprises of weekly assignments (70% of total mark) that culminate in a final test worth 30% of the total mark. The course is optional for most students except for those registered on MRes Science of the Environment, where the course is compulsory.

In order to evaluate the statistics service teaching provided for postgraduate students within the biological sciences by the Postgraduate Statistics Centre, we conducted interviews and sent out questionnaires to both staff and students in order to gain a thorough, unbiased, representative and collaborative evaluation. Here we report only on the key findings on student perspective gauged through online questionnaires. We then discuss how these findings were used to inform service teaching practice from 2008 onwards.

Online questionnaires were posted to all students who were registered on Taught Masters programmes, Masters by Research and PhD modes of study. 63 students completed the online questionnaires, equating to 78% of all those sent the questionnaire for completion. Only four student respondents had to take this course as a compulsory module. We recognise from the outset that 22% of students did not respond to this questionnaire for which there could be a variety of explanations. We bear this in mind when reporting and interpreting the data, acknowledging that their voices may be the ones that need to be heard the most, and may offer further insight into the strengths and weaknesses of the course they have attended, without which only a partial picture of the current provision can be drawn.

#### KEY FINDINGS FROM ONLINE QUESTIONNAIRES

The student responses can be divided into four main themes which will be discussed below; *Perception of statistical ability, current provision and resources, problems and problem solving* and *future directions and improvements*. Before questioning the students on their own sense of statistical ability, we asked them about their level of pre-experience with statistics (and Maths) and found that 53% of respondents had up to GCSE Maths only (most schemes including only nominal statistics teaching), A significant minority of 40% had up to A-Level Maths and only 7% (4 students) had degree-level maths (i.e. where they felt that Maths made up a significant part of their undergraduate degree), three of whom were enrolled on PhD programmes. We then questioned the students on their use of basic and inferential statistics. Whilst most students had used basic statistics 'often' previously, we found that only 16% of respondents used inferential statistics (in this case, giving the samples of Chi-square tests, t-tests and ANOVA) 'often' in their previous degrees. Inferential statistics are used widely within the statistics service course offered at postgraduate level.

### *Perception of statistical ability*

Students were asked to respond to a series of statements using the scale; Strongly agree, Agree, Neither agree or disagree, Disagree, Strongly disagree. Presented with the statement '*I think that my statistics skills are worse than other students*' 26% of respondents were not sure either way, whilst 40% did not think that their ability was worse than anyone else's. A significant minority of 34% of respondents felt that their statistics skills were worse than those of their fellow students. When probed about work style 50% of the students agreed or strongly agreed that they find it hard to work independently on a statistics project. Students were then asked to respond to the following statement, '*I think that statistical analyses are useful but I do not feel able to use them*' to which 43% agreed with the statement, 23% did not agree or disagree and 34% disagreed or strongly disagreed claiming to see the importance of statistical analyses and feeling able to do them. However, when probed on their knowledge of statistics, 85% of respondents agreed or strongly agreed with the statement '*I feel that my statistics knowledge needs to be improved*'. Only four students (7%) felt that their knowledge did not need to be improved. Interestingly, the majority of students (55%) disagreed or strongly disagreed with the statement '*I have shied away from statistics because I don't feel that I am good at maths*' however 30% of student respondents agreed or strongly agreed with this statement.

### *Current teaching provision and resources*

After assessing the students' perception of their own abilities using statistics we wanted to find out their opinions on the current provision of statistics tuition available to them as postgraduates. We asked them about the main service course as well as additional resources offered by the Postgraduate Statistics Centre (free e-learning resources, short courses, masterclasses/workshops and consultancy).

92% and 94% of respondents were not aware of the statistics tuition available through e-learning on the university website, or the masterclasses offered by the Postgraduate Statistics Centre, respectively. Similarly, 68% of students were not aware of the short courses available. When asked '*Do you think the case studies/data used are relevant to what you are studying?*' 11% did not answer the question, a further 11% of respondents said 'some of the time', 14% selected 'most of the time', 37% 'did not know' and 27% felt that the case studies/data used was 'not often' relevant to their study.

### *Problems and problem solving*

We started by asking students if they had experienced problems a) understanding and b) using statistics in their postgraduate degree, giving an even split between those who were having some problems understanding *and* using statistics, and those who were having few problems with either. Of those having 'very few problems' with understanding statistics (34 students) 65% were PhD students and 35% were Masters students. Of 62 student respondents, 54 claimed to have had problems with statistics at some stage of their postgraduate degree. We then asked the students '*If you have had any problems, have you resolved any of them?*' to which 55% said 'some', 29% said 'All' and 16% said 'few'. Lastly, we wanted to find out what the barriers were to problem solving or indeed, what helped them resolve their problems. Students were asked to type their answers into a space provided. Listed here is a selection of answers for '*How did you resolve your problems?*'; *Asking other students and peers, text books and notes including those from undergraduate degree, continuous discussion with experts in statistics, group of students approaching the module leader, spoke to postgraduate office, careful reading and re-analysing the method outlined, talked to the statistics department, internet sites, purchasing new statistics package with its own helpline and good old fashioned hard work!*

If the problems were unresolved then we asked them to explain why. Following is a selection of responses:

*Sometimes even other students aren't able to help and when I've gone to the stats lecturer for help they find it hard to explain.*

*Because I decided that it will be too much effort for too little outcome and I can use something else instead.*

*I found that explanations moved too quickly and skipped steps.*

*It is sometimes embarrassing to reveal an inadequacy in statistical knowledge/understanding at Master's level.*

*The main problem I have is knowing when it is appropriate to use statistics.*

#### *Future directions and improvements*

The final objective of the questionnaire was to gauge opinions on how the Environment Centre and the Postgraduate Statistics Centre could move forward with the current statistics provision. Encouragingly, the majority of students were in favour of an increase in the amount of statistics tuition that they receive. Only 3 people (5%) wanted to see the amount of statistics tuition decrease, whilst 19% were happy for it to stay the same. 10% did not answer this question. We then gave the students free space to write down their suggestions for the question “*Do you have any ideas to improve the way statistics related topics are taught in your department?*” Predictably, many suggestions were made, too many to list here, but below is an overview of some key/interesting comments:

- The stats courses need to be more frequent and better advertised
- Keep teaching going throughout the postgraduate degree (not just at the beginning)
- Produce fact-sheets featuring the most relevant analyses and under which circumstances you would use them
- Provide a statistics ‘clinic’/ ‘helpdesk’
- Better identification of modules where a basic understanding of statistics is required
- Relevant, practical, wide-range of examples
- Use someone in-tune with our degrees e.g. a dedicated biostatistician
- Integrate statistics more within taught modules
- Be more approachable to a non-statistician
- Prior to the service course, do a survey to see what students feel would be useful and what statistics are most relevant.
- Ensure every student on the course is up to a basic standard in statistics.
- Don’t assume too much knowledge and give clear, step-wise progression
- More practice over time leads to improvement
- An introductory short course on statistics at the beginning of the postgraduate degree before going into detail.

#### RECOMMENDATIONS

By working with students to find out about their learner experience on a service taught statistics course we are aiming to create demonstrable improvements for future learners. We have found many encouraging signs that students are engaging with learning statistics despite the fact that they find the subject challenging. Most agree that their statistical knowledge needs to be improved but are happy for an increase in tuition. This is echoed by the fact that only 4 respondents take the course compulsorily and most have *chosen* to study statistics at postgraduate level. Furthermore, many students are making real efforts (voluntarily) to solve their problems within a peer group environment and find this useful academically and socially. Our evaluation has shown that there is very little duplication in content with all sessions utilised efficiently and content is clearly defined in the module outline and is readily available online. Furthermore, students are very aware of the benefits of having a dedicated statistics lecturer and the resources and expertise that come with that.

Common problems are those of poor confidence in learners using statistics, poor advertising of statistical resources and support, the perceived irrelevance of some case studies and data used for specific disciplines and problems encountered when combining a large number of non-statisticians with a statistics lecturer. Our aim is to listen to these problems and find ways to address them in order to improve the learner experience of service taught statistics. On this basis we have made some key recommendations as a starting point for change, and we hope to develop these further in collaboration with staff from the environment centre and from the statistics department.

1. Staff continuity, enthusiasm and ability to relate and empathise with non-statistics specialists is key to producing better student satisfaction and may help statistical problems get resolved quicker.
2. Use 'real' environmental, biological and geographical data to generate a greater level of engagement and understanding.
3. We do not recommend streaming students based on ability as peer-support seems to be vital to learning. However, identifying weak areas of statistical knowledge prior to the course would be beneficial to flag up areas that may take more attention and time to teach.
4. Integrate quantitative data analysis into the subject specific modules delivered by the environment centre – practice leads to improved ability, and needs to be embedded into the student's wider learning environment.
5. Better advertise resources and support for non-statisticians.
6. Spread statistics tuition throughout the postgraduate programme, not just at the beginning of the Master's. This may be as simple as running the same course again once the students have their own data to be used for the dissertation. This should make the concepts discussed more relevant and useful.
7. Make clear at the beginning of the course why a good understanding and knowledge of statistics is important for their discipline. Pre-knowledge on the relevance and use of statistics should not be assumed. The first session of every course should be an overview on the importance and relevance of statistics, not just for statisticians.
8. Make innovative changes to teaching practice that students will find useful, e.g. factsheets.

#### NEW SERVICE COURSE DEVELOPMENT FOR 2008/2009

In response to the evaluation undertaken in 2008, the statistics service course for biologists, environmental scientists and geographers offered in the years up to 2008 was rewritten for 2008/2009. A new staff member was assigned to the course in order to rewrite it and lead it in future years, to create better consistency and reassure LEC staff and students that service teaching is an important objective of the PSC's remit. Whilst the 10-week format remained the same, the content has gone 'back to basics' placing new emphasis on basic concepts, descriptive statistics and practical, guided use of software such as SPSS. More complicated topics such as Stochastic Processes and Time Series have been replaced. In response to the perceived need for better introductory material and a session on the relevance of statistics, the first week of the new module covered the basics such as recognising different types of data and using graphical and summary methods. Lectures are now closely linked with lab work through a lab book that guides students step-by-step through the duration of the course. Helpers are on hand in lab sessions and workshops to help students in smaller groups and the marking scheme has been made more transparent. Case studies and examples used have been redesigned to suit all users and to emphasise the relevance of the course to the biological and environmental sciences. Whilst module outlines are always given to all students before the course, the revised module is described more explicitly in the module overview, and spells-out the type of things students will be doing each week as well as the type of data they will be using.

The course was delivered in spring 2009 and an evaluation was conducted. In all areas the new course has scored consistently higher. In total, 65% of students felt that the course as a whole was good/very good. Likewise, 73% of students felt the teaching was good/very good and 83% felt that the level of helpfulness from staff was good/very good. 87% of respondents agreed and strongly agreed that the course was both well organised and that the teaching staff were well prepared, and 91% agreed or strongly agreed that the course was intellectually challenging. 78% agreed or strongly agreed that the aims of the module were made clear.

#### DISCUSSION

In addition to the new course content and structure, further measures have been implemented including increased advertising of support and resources for non-statisticians which has been a key objective in raising awareness of the plentiful expertise available to assist all students with their statistics. A spatial statistics 2-day masterclass was created and delivered by the department, which was well attended by students and staff from the environment centre and

received good feedback from participants. A problem-based teaching approach to the service course is currently being piloted in response to help non-statisticians engage and understand statistics in ways that are relevant to them, and the beginning of all future courses will start with a ground-level introduction to statistics. Innovative ways are also being sought to record teaching material for future use by students who may not have understood the concepts taught in class the first time around, for example filming lectures for access online. It is hoped that the Environment Centre will continue to work with the Postgraduate Statistics Centre embedding quantitative data analysis into more modules, and will place greater emphasis on this skill in future marking schemes for course work and dissertations. Furthermore, the Environment Centre is currently working on the feasibility of pre-module questionnaires/surveys to help assist teaching staff on the baseline abilities of the student group. Whilst, this will change year on year it is hoped that a more tailored approach to service teaching can grow from identifying potential 'trouble areas' in the course content.

Postgraduate students appear to have a good sense of perception about their own learning. They are able to identify their own strengths and weaknesses and in many cases have a desire to tackle their problems with learning statistics head on. This is perhaps testimony to the postgraduate students' increasing educational maturity. However, the problems that postgraduate non-statisticians highlight show that there is still work to be done to improve service teaching for 'occasional users' (Nicholls, 2001), and our challenge within the statistics community is to tackle these problems in collaboration with students, teachers and the recipient department as a whole. Vital collaboration between all parties will help root proactive and demonstrable changes into the pedagogic approach to service teaching of statistics to users from other disciplines such as environmental science, the biological sciences and geographers.

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