TEACHING CRITICAL THINKING TO FIRST YEAR UNIVERSITY STUDENTS

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We discuss a major change in the way we teach our first year statistics course at UC. In 2008 we redesigned the course with emphasis on teaching critical thinking. The catalyst for change was recognition that most of the students take the course for general knowledge and support of other majors, and very few are planning to major in statistics. We indentified the essential aspects of a first year statistics course, given this student mix, focusing on a simple question, "Given this is the last chance you have to teach statistics, what are the essential statistics skills your bank manager/car salesmen/primary school teacher, need to have?" We have moved from thinking about statistics skills needed for a statistician to skills needed for a manager in today's society. We have changed the way we deliver the course with less emphasis on lectures and more on computer based tutorials, Excel', and computer skills testing, and written assignments.

INTRODUCTION

At University of Canterbury, Christchurch, New Zealand, we have recently undertaken a major review of our first year statistics course. This entry level course has large enrolments, with over 1000 students taking the course in any year. This number of students represents about ¼ of all first year students at the University. We outline in this paper the reason why we reviewed the course, the process we used for course review, and structure of the new course. In a companion paper, David and Brown (2009), we discuss the effectiveness of the new course.

WHO ENROLLS IN FIRST YEAR STATISTICS AT UNIVERSITY?

The entry level statistics course at University of Canterbury, like many other Universities, has a diverse student mix. We identified, through searches of enrolment records, this mix as being mostly students who did not intend to major in statistics, and did not intend to become professional statisticians. This reality is not new; many large first year statistics courses at tertiary level are the same. At University of Canterbury almost half the students who enroll in first year statistics are intending to graduate with a bachelor degree (3 year undergraduate degree) in a commerce subject, for example a BCom in economics, management or accounting. The other half enroll with the intent of graduating with a Bachelor of Science (BSc) majoring in subjects as diverse as geology, biology and the typical "commerce" subjects of economics, accounting and management science.

In our analysis it was clear that very few, in fact only one, student of the 1000 who enrolled in 2008, self identified as intending to graduate with a BSc in statistics. Analysis of past enrolment trends confirm that this student mix is typical and the norm for many New Zealand universities.

One fairly encouraging result of this analysis is that despite only one student intending to graduate in statistics on entry to University of Canterbury, each year some 30 students do graduate with a BSc in statistics so we can report impressive recruitment rates!

We also examined the level of statistical awareness, or knowledge that these students arrive with at University from secondary education institute (in New Zealand this is called secondary school). New Zealand introduced National Certificates of Educational Achievement (NCEA) as New Zealand's national qualifications for senior secondary students (http://www.nzqa.govt.nz/ncea/). Students around the age of 15 will almost all be enrolled in a secondary school class with a component of statistics. By age 17, the last year of secondary school, the most popular course is a statistics-orientated mathematics class. From this we can surmise that a student arriving at University who has completed a full secondary education is more likely than not to have taken a course in statistics.

Entry to University in New Zealand is essentially "open", students younger than 25 require some level of educational achievement but any older entry is open. We know from our experience that the 1000 students in our first year statistics class include students with full secondary

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education, and mature students with very little formal education in statistics. We also know that some international students have never had exposure to formal statistics.

The students in our first year statistics course are best described in statistical terms–highly variable. They have a very wide range of understanding and exposure to statistics, from the fearful mature student, to the brave young over-confident mathematically gifted–and everything in between.

We offer just one course at University of Canterbury despite this eclectic mix of comfort-level with statistics for the simple reason that a course designed for students who intend to continue with statistics would have very few students enrolled (essentially only the one student who arrives at University in their first year planning to major in statistics). A course designed to be more "challenging" and targeted to the more mathematically inclined would also have limited enrolments. What student would enroll for a "hard-option statistics class" under the impression they are not going to major in statistics, when the "easy-option statistics class" was available to them with, presumably, easy access to high grades. We have in fact tried to offer the challenging hard-option statistics class 5 years ago, and student behavior was exactly that. In setting up the hard-option statistics class we forgot something very simple–"almost no one intends to major in statistics when they arrive at University". We are not discouraged by this statement, because the good news is that something positive happens during the first year class and by second year at University of Canterbury we have 150 students enrolled in statistics courses.

In that decision to offer a hard-option statistics class for the students who intend to major in statistics (i.e., the 1 out of 1000) we fell into a very easy trap. We wanted the students to be just like ourselves because it is easier for us that way. I know and love statistics, it fascinates me, in my dreams I see data and I draw graphs in my mind. If everyone were like me it would be easy to design the perfect course. But the students in our course are not like me, they will not major in statistics, they have totally different plans for their careers and have different dreams at night.

In most other University subjects the design of the course can be comparatively easy since the designer knows the audience–they are one of their own. In statistics the challenge is that the students are not statisticians and probably never will be. What do these students need to know? And how did we get the whole teaching team to reach the realization that the 1000 statistics first year students do not intend to become statisticians?

WHAT DOES A STUDENT IN A FIRST YEAR STATISTICS CLASS NEED TO KNOW?

To define what the student needs to know we thought about where the students go on completion of their undergraduate University degree. Almost all the students in the first year statistics course graduate with an undergraduate degree in a commerce or science related field.

Where do the students end up? Rather than answer this question directly we used an exercise where we thought about all the people who we encounter in our day, or those who, in some way, shape our lives. Who of these people will have had first year statistics at University?

Let's start off with an ordinary week day. The marketing manager who branded the cereal box on the breakfast table probably took first year University statistics (and nothing more). The newspaper sales manager who decided on the morning paper's design enrolled in first year statistics (and nothing more). The accountant who decided on today's price of petrol from the local garage, the education manager who recommended the size of the class your son is attending this morning, the bank manager who is overseeing the mortgage on your house, and so on, all took first year University statistics (and nothing more).

All these managers, administrators, scientists, service workers have taken a first year course at University in statistics (if that). We then posed the question:

> Given this is your last chance to teach statistics, what do they need to know? What does your school manager need to know? What does your bank manager need to know? Do they need to know the formula of a binomial distribution or is it more important for them to know the difference between a discrete and continuous variable. Do they need to know the formula for a confidence interval or do they need to understand the concept of uncertainty and estimation? What is important for them? What is important for you because these people shape your life?

This exercise was the key link in allowing the statistics teaching team to focus on what a first year student needs to know and away from what they, as statistics academics want the students to know.

The statistics team at University of Canterbury is a group of 10 staff and tutors who are all involved in the teaching of the course and the statistics program, or who represent major disciplines in subject the students are majoring in. We include in the team the statistics academics who are not actively teaching first year courses because they will come in contact with the students on advice days, and they teach the higher level program. Their involvement in the first year course redesign was critical to ensure the entire team was in agreement. They were able to reshape their 2nd and 3rd year courses on the basis of having a better understanding of what students arrive with at these levels from the first year course.

Not surprisingly the shift in mindset for the team from teaching first year statistics as a base for graduate-level statistics to teaching statistics for non-statisticians was not easy and in fact painful for some. We used group management techniques, with regular and sometimes slow meetings, facilitated initially by an external advisor, and group exercises to build the confidence of the team and to agree to a common goal.

WHAT IS THE NEW AIM OF OUR FIRST YEAR STATISTICS CLASS?

With this shift in paradigm from teaching first year statistics to future statistics majors, to thinking about what our students really need to know, we were then able to introduce the concept of statistical literacy (Ramsey, 2002; Gal, 2000; Wild & Pfannkuch, 1999). Statistical literacy is based on the idea of understanding about collecting data, understanding how to examine data, understanding how to interpret analysis in context, and having appropriate communication skills.

We used the concept of critical thinking to help define what a first year statistics student needs to know (Browne & Keeley, 2007). We want the students to be able to look at data and see patterns and trends, to be able to interpret analysis and critically examine it, to be able to interpret graphical displays of data and infer relationships, and be able to communicate these ideas and concepts.

Why these skills? My local school manager or my bank manger, or whatever other role in society these students go on to, need these competencies. They may not be the ones doing the statistical analysis but they will be reading analysis and making decisions based on it. They need to be able to think critically.

Given this common understanding, as a group we identified what were the learning objectives. The exercise was surprisingly simple because we build from a common base and agreement on who the course was for and the aim of critical thinking. If there was any doubt about a learning objective we simply asked the question “Does our bank manager, accountant etc need to know this?”

Learning objectives were grouped as: understanding data, probability, estimation and inference. More details and the complete list of objectives are available from the authors. Each group was defined into subgroups leading to (approximately) one learning objective for each lecture.

Learning objectives were defined in the construct of a description of what the student will be able to do, the conditions under which the student will perform the task, and the criteria for evaluating student performance. For example, “Given a set of data (condition), the student will be able to compute the standard deviation in EXCEL and using a calculator (behavior) and the number computed will be correct - this is implicit in this example (criteria).

THE STRUCTURE OF THE NEW COURSE - ASSESSMENT

Once we had defined learning objectives we focused our attention on assessment. The final assessment mix includes online (computer based) quizzes, written assignments and a final exam. The traditional final exam is still an essential part of the course for two primary reasons–it provides the summative piece of assessment, and because it is done in a secure environment motivates the students to study.

The written final exam with short answer questions is an opportunity to encourage students to develop communication skills. In contrast the traditional mid-course test was removed and

replaced with a series of online skills tests. Testing is done in a secure computing environment, and students have the opportunity to repeat tests. This repeat option is addressing the concept of mastery where students can self identify their understanding and competency.

Two project-style assignments are used to develop the concept of the data cycle (Wild & Pfannkuch, 1999). Data is collected, described, analyzed and conclusion drawn, which inform the next cycle of enquiry. The written assignments are for statistical literacy and critical thinking to be developed in context, and are a tool to develop (and assess) written communication skills.

THE STRUCTURE OF THE NEW COURSE - DELIVERY

The course delivery is now a self-directed style with student engagement being the primary focus. The responsibility for learning is with the student (Saville & Zinn, 2005) and we have designed the course to provide a range of opportunities for learning (Moore, 1997). We emphasise the range of opportunities because given the student mix, every student's learning needs differ. We offer advice and support to allow the student to use these learning opportunities to best need their individual needs. Details of the structure of the course and preliminary results are provided in the companion paper but briefly the learning opportunities are facilitated via e-learning (Bates & Poole, 2003).

We recognize that for some students traditional lectures are important, and an opportunity to engage and experience the lecturers' enthusiasm. Lectures are videoed for students who prefer to participate at different times, and for those who want to use lectures for review and consolidation. However, a video link can never provide the same impact of first hand experience of the lecturer's passion and enthusiasm and we ensure there is seating capacity for all students.

The course uses Excel and in all lectures examples are worked through using the lecture room's computer. Full notes on how to use Excel are provided for each lecture as companion material. All lecture material is available on the course website, including the PowerPoint files. Some students take their laptops to lectures and annotate these PowerPoint files during the lecture.

Lectures begin with motivational examples, preferable New Zealand based. There are many of excellent websites for this including the well resourced Statistics New Zealand website (http://www.stats.govt.nz), with access to large datasets (through the Universities link, (http://www.stats.govt.nz/methods_and_services/statistics-for-universities.aspx).

Lectures are only part of the learning experience and are not the primary means of engagement for all students (Moore 1997). We use the learning management system (LMS) from the Blackboard Academic Suite (Blackboard Inc), and more recently Moodle, the open source course management system (http://moodle.org), for interactive online examples. We use this LMS medium for the mid course assessment and skills testing. This LMS material is available on and off campus via the internet and students can work on the course when and where they like.

The physical space for learning is important for our students, and we host all-day tutor supported help classes in large computer labs, and additional regular drop-in help sessions, initiated from student feedback. The students work at their own pace on examples and tutors are available to help, guide and discuss.

CONCLUSION

In this paper we discuss the process we used to redesign of the large first year statistics course at University of Canterbury. Over 1000 students enroll in this course each year. We offer only one course for the simple reason that few students intend to major in statistics when they arrive at University in their first year.

We redesigned the course by identifying the common aim–critical thinking. We then defined learning objectives by asking the question what do the students really need to know. Do they need to know the theory or do they need to understand the concept? We then discussed assessment–why do it, what is it purpose and how best do it. And finally as the last step we discussed delivery and ways to ensure engagement, and self directed learning.

The entire statistics teaching team was involved in the redesign. The statistics teaching team includes more than those actively teaching on the course but the team of statistician who teach in the statistics program and others who are associated with major disciplines in subject the students typically major in.

Very often the statistics teachers are active statisticians and it is easy to develop a course designed to produce graduates "just like us". The approach we used was to first identify the target audience. Who are the students, what do they arrive with, and when they leave University what do they graduate with? Where do they get employed once they leave? The answer to this question on where do they get employed was "they get employed everywhere". Chances are, almost every facet of our lives is influenced or affected by someone who has taken University statistics–but only to first year.

The process we used was a one of regular team meetings where we focused on the project of developing a new course. These regular meetings were the principle mechanism we used to get common understanding.

Our natural tendency had been to begin the course redesign process by planning how best to deliver the course and what combination of lectures and tutorials we should use. Instead we used a more effective framework of defining the students, defining learning objectives and scoping assessment. We restricted course-delivery options, and any talk about "how to do it', to the final discussions.

The process has been very enriching for us all, it has clarified many misconceptions (e.g., that first year statistics has poor retention rates when in fact we have spectacular recruitment), and has given us a sense of responsibility. Students who take first year statistics go on to have diverse roles in society, but these roles affect our every day life. As statisticians teaching the first year course we need to see that we have an important responsibility for improving statistical literacy.

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