Activating multiple senses in learning Statistics

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Abstract: *Introduction to Statistics at the University of Canberra (UC) is a service unit taken by students from a variety of disciplines. However, it is common for students to dislike and under-perform in Statistics. We sought to address these issues by redesigning the way that Statistics is taught. Given the importance of acquiring statistical language to learning Statistics, we decided to employ language learning techniques in Statistics classes. The project brought together a statistician and an educational expert to reconceptualise the syllabus, and focused on developing different methods of delivery. New teaching materials including online exercises and new ways of delivery involving multiple senses of hearing, speaking and moving were designed and produced, placing greater emphasis on applying statistics and interpreting data. Two cohorts of students were evaluated, the control cohort (CG, 2007 Semester 1) with a traditional teaching style, and the experimental cohort (EG) taught with non-traditional methods, as summarised above (2008 Semester 1). Students in EG showed a greater improvement in defining key concepts such as population and standard deviation and have improved attitudes towards the role of statistics to their disciplines and performed significantly better in class tests and examinations.*

Background

Students in introductory statistics units generally have varied academic backgrounds and it is increasingly clear that teaching statistics in a traditional didactic way neither engages the students nor meets their needs. One of the problems is that the language of Statistics presents a barrier to comprehension. Overcoming the language barrier in the learning of science subjects has recently been addressed in molecular biology and genetics (Zhang and Lidbury 2006). Specialised meanings for English words are common in Statistics, and misuses of Statistical language by students can arise from the traditional transmissive model normally used for teaching statistics. This model means that lectures are instructor centred, with the lecturer talking most of the time, often at a rapid pace. Students do not usually work in cooperative groups during the lecture. In a week of lectures (three hours with one hour of tutorial/laboratory) covering regression, for example, 20-30 new terms are covered. However, in the traditional model of delivery, there is no time for students to reflect on the concepts and the relationship between concepts, nor is there time for the lecturer to check the students' understanding. As a result, while many students do well in introductory statistics courses, it is not clear that they retain the information for very long or that they are able to make use of it in their studies.

Table 1. Proposed language-oriented techniques to be implemented in the project

1. Small group work in tutorials using guided questions	6. Attaching sound files to vocabulary so that better understanding can come from 'the human voice behind the words'
2. Students are provided with a list of terms and, through the process of group work, place these terms in relation	7. Breaking down long words to aid memory by identifying prefixes and suffixes, and exploring the roots and origin of words
3. Giving students opportunities to put forward their points of view in groups	8. Using warm up activities such as matching scientific terms to definitions for revision purposes
4. Using online language exercises such as crosswords, gap-fill (Cloze) exercises and simplified scientific readings	9. Using of flashcards for vocabulary revision
5. Providing stimulus questions for lecture and tutorial materials on WebCT thus encouraging students to prepare before the lecture	10. Role playing: students practise conveying complex scientific discoveries to the public

At UC, we decided to redesign the introductory Statistics unit by incorporating some of the strategies used in Zhang and Lidbury's (2006) study which used language learning strategies to improve teaching in Molecular Biology and Genetics. These pedagogical methods, as outlined in Table 1, have resulted from interdisciplinary negotiations between the fields of Applied Linguistics and Molecular Biology, but are practices which could assist students in the Statistics discipline.

Educational setting

Introduction to Statistics at UC is a service unit that consisted of three hour lectures and one hour tutorial per week. Although no extraneous mathematics was introduced with the statistical concepts, the unit contained a significant amount of theory and formulae. There was some attempt to contextualise the learning however students often failed to acquire the Statistical language appropriate for application in their education and future professions. We recognized this as a key area for improvement and following a successful bid for institutional teaching and learning development funds, we set about revamping the way in which statistics was taught, in order to make the subject more successful for the students by utilising some language learning strategies.

Method

Project description

The project was concerned with redesigning the delivery of statistics to first year undergraduates and postgraduates with no prior Statistics study. In line with Garfield's (1995) recommendations we initially concentrated on what it was that we felt students needed to know and be able to do following the teaching sessions. The goals of the project were to:

- ensure that students were equipped with skills in interpreting data that would enhance their future performance in their chosen field of study;
- improve students' ability to use data to inform their practice in their chosen area of study, thus arriving at greater understanding of the underlying statistical principles;
- increase the amount of learner-centeredness in appreciating the role of statistics; and
- develop online materials that allowed students flexible access, and more opportunities to interact with materials at their own pace.

This project concentrates on benefits that students perceive and display over one semester only, and a future longitudinal study could address benefits over longer periods of time.

Group work in lectures and tutorials

In order to cater for different learning styles and preferences as well as a diverse student body, we incorporated the use of multiple senses in the learning process through the application of language learning strategies listed in Table 1 above and online support. During the lectures, we incorporated small group work as a normal part of the lecture through initiating group discussions on statistical concepts and encouraging students to talk about statistics themselves in small groups (Table 1, strategy 1). In tutorials, we used multiple senses such as visualization, listening and moving (Table 1, strategies 8, 9 and 10). Some strategies are not discussed here as they are weakly related to the concept of visualisation (Table 1, strategies 2, 3, 4 and 5) while other strategies were thought to be less directly relevant to Statistics compared to other discipline such as Genetics (Table 1, strategies 6 and 7).

There is no doubt that it might be argued that visualisation is the mainstay of statistics but there is a difference between letting students learn by constructing new knowledge based on their prior learning and using visualisation as a mere illustrative or graphical tool. For instance, in a topic such as simple linear regression, traditionally, students are usually provided with scatterplots which have been drawn already in order to introduce a series of concepts such as 'intercept', 'outliers' and ‘influential points’. However, the difficulty for students is knowing, after having plotted points on a graph, which points on the scatterplot should be used to estimate a line of best fit. Knowing the formula y = a + bx does not help if students do not know where to start. Traditionally, at this point, the rule of least squares regression might then be introduced, but this only compounds the situation as the students are still wondering what points they should connect on their scatterplot and now they add an additional question ‘what least squares?’

In the new model of teaching linear regression, we first divided the students into cooperative small groups and asked them to brainstorm about which points to be used to estimate a line of best fit. Then we ask them to share this information with different groups. It was through this discussion that we introduce the principles of constructing a least-squares regression line by confronting them with their misconceptions through visualization. The aim of this activity is to enable students to draw a line of best fit themselves and knowing what to minimise when estimating a least-squares regression line. Ideally, at the end of receiving modelling of lines of best fit from the lecturer during a lecture, students would be given opportunities to test their skills of drawing lines of best fit based on real world examples and to check that they have done this correctly by using a statistical package such as SPSS.

Active learning strategies

Attending three hours of lectures on a topic does not guarantee that students know how new concepts are related to each other. Therefore during the one hour tutorial, instead of working through worksheets, we created a set of flashcards to carry out a ‘living concept map’ activity (Table 1, strategy 9). On each flashcard, a concept such as residual is written. Students were divided into groups of three or four and they were asked to put these flashcards into some sort of order. After 15 minutes, each group was asked to walk around and check out other students’ constructions. There is a great deal of research on the use of concept maps in science with most the studies from the teaching of biology (Novak 2001; Wallace and Mintzes 1990; McClure, Sonak and Suen 1999). In this new model of teaching, the use of ‘living concept map’ was used as an authentic assessment which involved self, peer and teacher feedback (Kaya 2008). Not only was it fun to do, it also promoted conceptual understanding in a student-centred approach firstly by encouraging them to listen to their fellow students, providing them with a chance to talk through the relationships between the different concepts and providing instructors about the students’ understanding of these concepts. For instance, on the topic of linear regression, it was through this process that students realised the relationship between y, $\hat{y}$ and residuals.

Online support

In order to cater for different learning styles, lecture notes before the lecture and after the lecture with student questions and lecturer-written explanations, along with lecture recordings, were uploaded onto the learning management system at UC. This also included online quizzes (such as multiple choice, matching, crossword questions) created using *Hot Potatoes*. From the lecture notes after the lectures, we are able to create a bank of student questions that can be used as stimulus questions in future unit development.

Evaluation

In order to evaluate the new teaching approach and compare it with traditional teaching styles, three forms of evaluative mechanisms were used.

- An evaluation questionnaire was distributed to students in CG and EG at the end of the each teaching session in 2007 and 2008. As it was regarded as a teaching evaluation in line with standard departmental teaching policy and full ethics approval was not deemed necessary. Every student who attended the final statistics session for both cohorts was asked to fill in the evaluation questionnaire and hand it in as they left the lecture theatre. The questionnaires were all anonymous and completion was not compulsory.

- Students in EG were also asked to complete an attitude survey about their beliefs and attitudes to the unit at the beginning of and at the end of semester (Schau, Stevens, Dauphinee and Del Vecchio 1995). These beliefs were measured on a 5-point Likert-type scale, from to strongly disagree to strongly agree. In the second part of this attitude survey they were also asked to define Statistical terms including 'population' and 'standard deviation'.
- Both CG and EG students were assessed through four 45-minute tests and a 3-hour examination.

Results

Evaluation questionnaire

Only relevant questions concerning students' opinions related to statistics learning have been included in Table 2: other questions referred to the organisation of the unit.

Table 2. End of unit evaluation scores on a scale of 1 to 7 for CG and EG

Statements	1/07 (CG) median	1/08 (EG) median	p-value (Mann-Whitney test)
3. The unit made an important contribution to my major area of study.	5	5	0.531
4. The unit assumed too much previous knowledge.	3	2	0.367
13. To do well in this unit all you really need is a good memory.	4	3	0.123
14. I developed the ability to solve problems in this field.	5	5	0.849

The medians and nonparametric tests do not give strong results with small sample sizes, however we can see that students in EG recognise that the unit began where they needed it to, and that there is more to Statistics than memorising formulae.

Table 3. Attitude data for students in EG

Statements	pre-unit median	post-unit median	p-value (Mann-Whitney test)
1. I think I will enjoy/have enjoyed taking a statistics unit.	4	4	0.526
2. Statistical skills will make me more employable.	4	4	0.317
3. Because it is easy to lie with statistics, I don't trust them at all.	2	3.5	0.029 *
4. Understanding probability and statistics is becoming increasingly important in our society, and may become as essential as being able to add and subtract.	4	3	0.356
5. Statistics is not particularly useful to the typical professional.	2	3	0.241
6. You need to be good at mathematics to understand basic statistical concepts.	3	3	0.786
7. To be an intelligent consumer, it is necessary to know something about statistics.	4	3	0.198
8. Statements about probability (such as what are the odds of winning a lottery) seem very clear to me.	3	4	0.161
9. I can understand almost all of the statistical terms that I encounter in newspapers or on television.	3.5	4	0.086
10. I could easily explain how an opinion poll works.	2	4	0.001 *
11. Given the chance, I would like to learn more about probability and statistics.	4	4	0.882
12. I often use statistical information in forming my opinions or making decisions.	3	3	0.878
13. I feel insecure when I have to do statistics problems.	3	2	0.153
14. Statistics should be a required part of my professional training.	4	4	0.382
15. When buying a new car, asking a few friends about problems they have had with their car is better than consulting an owner satisfaction survey in Choice.	3	4	0.405

EG Attitude survey

In the first part of the attitude survey, students were asked 15 questions (see Table 3). It can be seen that seven of the fifteen statements showed movement in the mean in a "positive" direction i.e. further towards the responses that would be expected from students who have studied introductory statistics. Furthermore, two of the statements showed movement that was significant at the 5% level. The small number of responses (n = 7 post-unit) probably reduces the number of significant results. Nonetheless, these results as a whole suggest that the unit as a whole has positively influenced students' attitudes towards statistics.

In the second part of the attitude survey, students were asked to provide definitions for terms including 'population' and 'standard deviation'. This part of the survey was not distributed to the students in CG. Tables 4 and 5 show how a selection of students has improved their ability to define these concepts thus demonstrating a better understanding of these concepts.

Table 4. Improvement of the definition of 'population' for students in EG

Student	Pre-unit definitions	Post-unit definitions
1	-	the whole group which is being investigated contains all individuals
2	A group of people used to gather data e.g. 5 University lecturers would be the population	University employees / or ppl generally who drive to work
3	Total number of number of [sic] University lecturers	A total number of people / objects from which a sample was drawn or a total number of people / objects being studied
4	The size of something to be measured	The total no. of subjects that make up the group
5	A defined group most likely w/ some unifying factor e.g. location	The entire group you are concerned about

Table 5. Improvement of the definition of 'standard deviation' for students in EG

Student	Pre-unit definitions	Post-unit definitions
1	How far the lowest + highest numbers vary from the mean	s = 10.46 – used to describe the distribution of results around the $\overline{X}$
2	Don't have an idea	A variation between observations
3	[blank]	The variability
4	I think it's ~ 60% of data fit into 1 SD on either side of the mean. Can't remember details, basically means most data are within that amount either side of the mean	The spread of the data around the mean – an indication of how much it varies from observation to observation
5	A statistical term, relating to a value's position in relation to the mean	A measure of spread

Tests and examination

The final piece of evidence demonstrating the efficacy of the new teaching model is provided by the four tests taken by both groups of students. Table 6 showed that while the means of CG and EG for test 1 and 2 are not significantly different, for test 3 the differences in means are significant at the 5% level. For test 4, the means are significantly different but EG scores lower than CG. This may be due to the fact that there were two significant errors in the EG paper, and furthermore different topics were tested in the two groups: two-sample hypothesis tests and regression in EG and regression and analysis of variance in CG.

Table 6. Comparison of test marks for CG and EG

Tests	CG Group Mean (SD) (n=38)	EG Group Mean (SD) (n=23)	p-value
Test 1	20	22	0.162
Test 2	19.56	20.20	0.665
Test 3	15.33	18.78	0.041 *
Test 4	24.34	20.5	0.007 *

Table 7 shows the distribution of grades in the final examination for CG (n = 34) and EG (n = 20), after eliminating students who passed the unit on in-term assessment and chose not to attempt to improve their grade by sitting the examination. A χ^2 test shows that there are significant differences (p = 0.019 on 4 degrees of freedom) between the grade distributions for CG and EG. The main departures are in Credit (fewer Credits in EG than expected) and in Pass and Distinction (more Passes and Distinctions in EG than expected). This suggests that the methods employed both assisted borderline students to pass, and helped competent students to perform better. Data on UAIs and GPAs for these students was too sparse to be able to confirm whether credit-level students were achieving at a Pass or a Distinction level in this unit.

Table 7. Examination grade distribution (%) for CG and EG

Group	Fail	Pass	Credit	Distinction	High Distinction
CG (n=34)	17.6	32.4	26.5	17.6	5.9
EG (n=20)	5.0	40.0	5.0	35.0	15.0

These examination results, along with the positive trends demonstrated in both the end of semester questionnaires and the attitude data, can be interpreted as evidence that the new teaching model promotes learning in students.

Discussion

We have described above a project that brought together experts from language teaching and statistics to produce a new teaching/learning model for beginning students. We evaluated this new approach and demonstrated that we have made a statistically significant difference to students' performance in tests and examinations, improved their understanding of some key concepts and their ability to view statistics in relation to their professional practice. It is this multi-sensory approach to delivery that we would recommend to others. A caveat is that the groups of students involved in this project were fairly small (EG = 20). Consequently, we need to act with caution if we are to apply these new teaching strategies to a larger group of students, say, of size 200. Admittedly, the size of the student cohort might make group work more difficult but with attention paid to management issues related to a larger size group, it is still possible to implement such group work. For some group work management ideas, see Ebert-May, Brewer and Allred (1997).

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