One potato, two potato, three potato, four: the use of *Hot Potatoes* software in science language comprehension

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Introduction

Our paper concentrates on innovation in teaching two 'hard' sciences, namely Genetics and Statistics. Reform in the teaching of Statistics moved through the higher education sector in Australia in the 1990s. Emphasis was placed on statistical thinking and active learning rather than recipes and derivations. New-style textbooks and laboratory manuals were published that employed teaching techniques from a variety of disciplines, but not from language teaching. Teaching in Genetics, generally, is in a transmissive style and as the language of Genetics is as foreign as a foreign language, texts written become inaccessible to many students. An earlier study (Zhang and Lidbury 2006) has examined a range of language techniques in the teaching of tertiary Genetics and Molecular Biology, and has recently focussed on language learning via the *Hot Potatoes* software. For this original study, *Hot Potatoes* was used as one of a suite of language-centred teaching approaches, so its full value has not, thus far, been individually assessed. Anecdotally, *Hot Potatoes* was a great tool to revise genetic language from previous lectures, and was appreciated by motivated students who wished to explore extra voluntary online exercises, or use the Hot Potatoes exercises as study tools. This study in Statistics will focus primarily on *Hot Potatoes* and assess it as a tool through which to teach statistical language.

Languages issues in Statistics

In Statistics, as in Genetics, ordinary English words such as 'normal' have a similar restricted meaning. For example, a student wrote that 'The whiskers of the boxplot are normally spaced' to describe a boxplot with whiskers of equal length.

A second common problem in Statistics is the 'scattergun' approach to answer questions. In other words students often seem to throw two or three statistical terms into a sentence (without understanding them) and hope for the best. For example, a student was asked to select either the mean or median as a more appropriate measure of location, based on a boxplot. The student wrote, 'I would like to describe the location with the median, because there are not too many outliners and though median appears to sit lower on the scale even in the interquartile range.' Notice that in this answer a range of statistical terms was used, such as the 'median', 'scale', and 'interquartile'. But as an answer to describe location with the median, from 'median' on, the sentence is basically nonsensical. The non-statistical term 'outliner' was also used instead of 'outlier'.

Online support issues in Statistics

Recently, research has been done to compare online approaches to teaching Statistics with that of traditional way of teaching Statistics (Dutton and Dutton 2005; Utts, Sommer, Acredolo, Maher and

Matthews 2003). The findings of these studies suggest that students prefer a combination of face-to-face and online methods of delivery because online delivery provides them with more interactivity control and flexibility.

While the findings cited above are extremely informative, they were not studies conducted to investigate language issues in the study of Statistics. As far as we know, no study (that we are aware of) has been done to investigate these issues. However in implementation of language oriented strategies, we will heed the recommendation provided by Utts et al. (2003) that students' need to interact with the knowledgeable instructor is not diminished. Our students will be provided with multiple methods of support, ranging from the usual lectures, tutorial questions, discussion questions posted on *WebCT* through to the innovative use of *Hot Potatoes* for language support.

Hot Potatoes software

The *Hot Potatoes 6* (http://hotpot.uvic.ca/) software was created by the Research and Development team at the University of Victoria Humanities Computing and Media Centre in Canada and is free for educational institutions to install. We chose this software because of it is freely available and we would like to investigate its application in the sciences. Example exercises from *Hot Potatoes 6* are shown below:

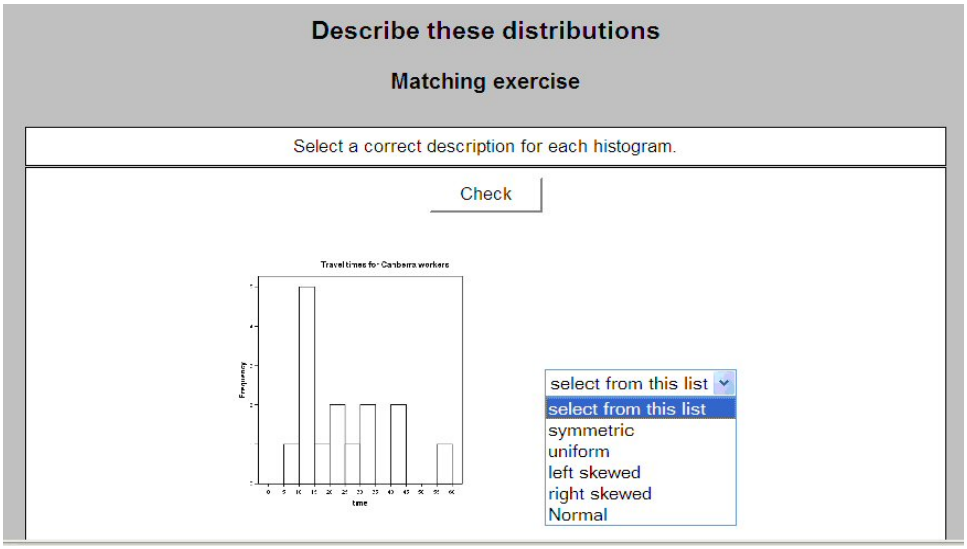
Examples

In the examples below, we have taken data from Moore (2007, p. 37) and adjusted it for local conditions. Students are provided with the sample of 15 travel times to work, in minutes, for a sample of 15 Canberra workers.

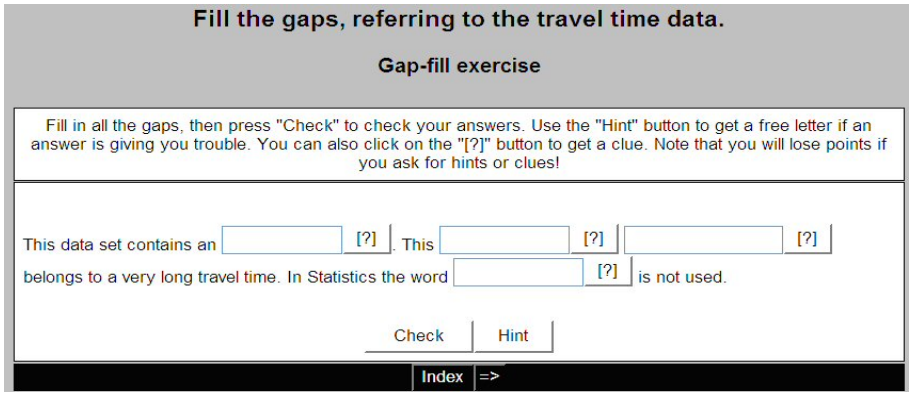
30 20 10 40 25 20 10 15 60 40 5 30 12 10 10

The real-world question posed initially is 'Does the data support the claim in the *Canberra Times* last week that Canberra workers spent an average of 10 minutes travelling to work?'

Matching: A *Hot Potatoes* exercise matching concepts in hypothesis testing to their definitions is shown at http://www.mathsnet.net/asa2/modules/s24hyptest.html. Our example below is designed to assist students with one of the first steps in answering the question above, namely matching terms for describing histograms to the histogram shapes.



Cloze: Highly specialised statistics software utilises the cloze or gap-fill approach, hence our use of it provides an additional educational benefit in preparing students for future study. In particular, the *Bioconductor* software package (Gentleman et al. 2004) has a report-writing package *affyQCReport* (Parman and Halling 2007) which generates a report on a data analysis by filling in the gaps in a standard report structure. *Hot Potatoes* open that sort of technology to students of introductory statistics as well as providing a tool for statistics students to learn the language of statistics. Here we show a cloze exercise commenting on an unusual aspect of the distribution of the travel times.

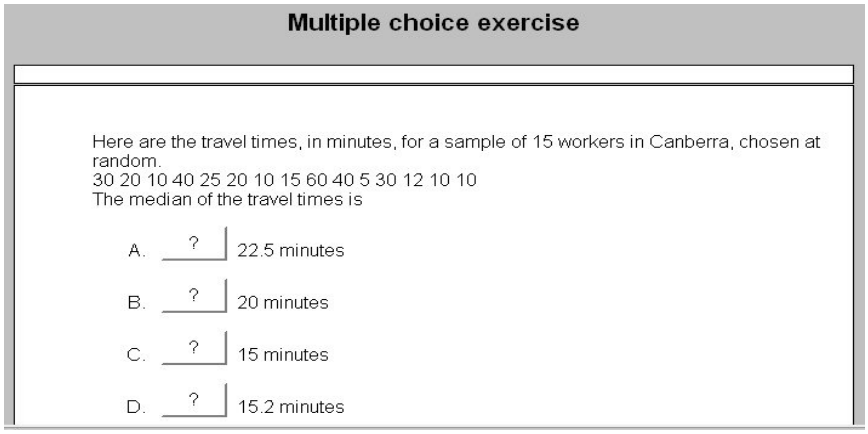


The [?] buttons define provide [hints] for the missing words as follows.

- This is a noun which describes a value which is a long way from the bulk of the values.
- This adjective goes before the noun and refers to a value which is a long way from the bulk of the observations.
- This noun refers to a number in the data set (observation/value).
- This noun refers to a tool for drawing around the edge of a picture.

The meta-language used here such as ‘nouns’, ‘adjectives’, ‘verbs’ and so on are a way of establishing a common language that students can use in future discussions on the nature of words used. For instance, without such language, it is not possible to explain to someone the difference between ‘outlier’, ‘outlying’ or ‘outliner’. An answer that simply states that using ‘outliner’ is wrong is not sufficient to equip students with tools for self-monitoring of their own progress in future studies.

Multiple-choice. Multiple choice testing is of course widely used in many fields including Statistics. Diagnostic help can be added to the multiple-choice answers in *Hot Potatoes.* The multiple choice question shown belongs to the next phase of answering the question posed. It tests the ability of students to correctly calculate the median.

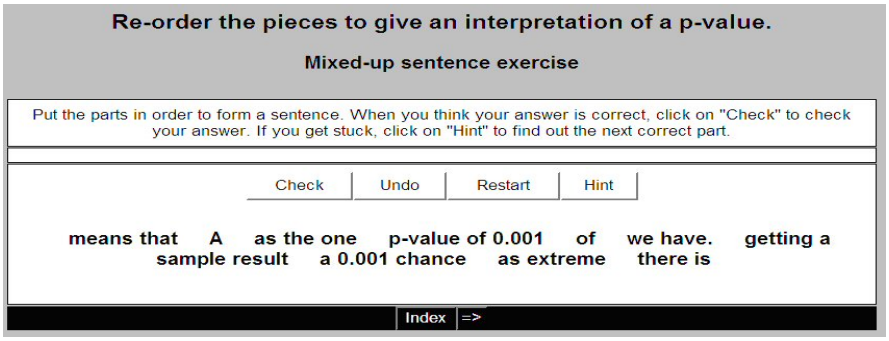


The four diagnostics are:

A. No: you have calculated the mean
B. Correct: order the values and select the middle one
C. No: you need to order the values from smallest to largest first.
D. No: you have calculated the standard deviation, which is a measure of spread.

An outlier can render the results of a t test invalid. For the purposes of this paper, we will now omit the outlier in the travel times data and proceed with a t-test of the claim above. When we teach, we would of course discuss the effect of outliers on the validity of t-tests. We would also teach the students how to take the real-world question and turn it into the statistical hypotheses H_0: $\mu = 25$ minutes against H_a: $\mu \neq 25$ minutes.

Jumbled-sentence: Quantitative researchers in many fields are familiar with the p-value of a hypothesis test, which is defined as the probability of getting a sample result as extreme as the one observed. Thus a suitable sentence for jumbling is, 'A p-value of 0.007 means that there is a 0.007 chance of getting a sample result as extreme as the one we have.' This is broken into the pieces: A, p-value of 0.007, means that, there is, a 0.007 chance, of, getting a sample result, as extreme, as the one, we have.



To close the loop in this example, we would have an exercise in returning to the real-world question. In this case, the p-value was very small and the hypothesis of a mean travel time of 25 minutes is rejected.

Experiences and intentions

Zhang and Lidbury (2006) implemented a range of language specific educational techniques so that students could learn more actively in molecular biology and genetics. Results of Zhang and Lidbury's study (2006) suggested that students favoured the use of group work to acquire difficult and abstract genetic concepts and overwhelmingly welcomed the provision of online language oriented exercises, assessment and teaching materials. Many students felt that these strategies helped them in other courses and that they had become much more independent in their study. Apart from the positive impact of these techniques reported in the qualitative data, the significant correlation of the students achieving a Distinction grade in Genetics with their past performance (GPA) offers evidence that language centred teaching in Genetics benefited the high GPA students most (Zhang and Lidbury 2006). We hope to achieve similar benefits in Statistics.

Small group work is also one of the practices under examination. The benefits of small group work have been established for a wide range of applications in science (see Fagen 2003 for a review). In connection with vocabulary problems, Wellington and Osborne (2001) suggest that time needs to be spent discussing and explaining the meaning of the words by the students, themselves (in small

groups), rather than relying on the meaning of the words to be 'caught' haphazardly; leading Wellington and Osborne to say that 'meaning has to be taught, not caught – preferably in an interesting and humane way' (p. 18). In the second semester 2007, we plan to pre-test students to ascertain their level of understanding of terms such as 'observation', 'value', 'sample', 'population', 'mean' and 'median'. This constitutes baseline data. Every week, in the lecture, at least half of the time will be spent carrying out activities in which students have a voice and participate actively. For instance, instead of the lecturer providing a list of definitions for terms such as 'observation', 'value', 'sample', 'population', 'mean' and 'median', small group activities will be carried out so that students will have opportunities to speculate what these terms might mean. At all times, they are encouraged to draw graphs or diagrams to communicate their thoughts. Then, we will hear from them first on their interpretation of these terms before the correct definitions are given to them. In order to encourage out of class activities, we will provide the definitions and class notes on *WebCT* as well as *Hot Potatoes* which test the recall and application of such terms. Students might be provided with an unseen graph and asked to point out the 'mean' and 'median' in relation to the graph but most importantly, what these mean in real world terms related to the context of the data in the graph.

These exercises serve as revision and also preparation for the next week's class. Feedback will be provided at the beginning of each class before introducing new terminology and materials. In lectures and tutorials, emphasis will be placed on providing students opportunities to discuss what they have learned in small groups actively and topics will always start with real-world problems and will always end with answering the same real world problems. The idea is to convey to the students that statistics are tools to find solutions to real world problems which cannot be answered easily. The lecturer's role is not only to provide content but also to facilitate small-group discussions about how to approach the problem. As a test of application, students are also encouraged to come up with a similar problem in their own discipline to the real-world problem posed in class.

Conclusion

In our opinion, *Hot Potatoes* are excellent tools for supporting Statistical learning. However, for them to be effective, they necessarily have to be combined with an approach to teaching which involves small group activities. It is through such small group work that a privileged opportunity for the contextualization of concepts, which is to say the organization of concepts into holistic schema can be carried out. Specific tasks which have been designed to encourage 'system thought' and awareness of the generic features of Statistics by means of group discussion are preferred to lecturing. This approach to teaching Statistics can provide a very important opportunity for students to attune their new found Statistical understanding to their intuitive understanding of their own disciplines.

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