Reading Statistics

Leigh Wood and **Peter Petocz**, Department of Mathematical Sciences, University of Technology, Sydney
Leigh.Wood@uts.edu.au Peter.Petocz@uts.edu.au

Introduction

There has been a substantial increase in the cultural and academic diversity of commencing tertiary students over the previous decade. From 1990 to 2000 the total number of students in higher education increased by 43% (to just under 700,000), while the number of overseas students increased by a factor of four (to just under 100,000), raising the ratio to one-in-seven students (Department of Education, Science and Training, 2002). With this increase in number and cultural diversity comes an increase in their academic diversity. At the same time, changes in the nature and scope of professional work are placing an increasing demand on the range of skills, linguistic and numerical, that are needed by a successful graduate. A challenge for mathematics and statistics educators is the development of curriculum that addresses the language-related difficulties of language minority students, the numerical difficulties of students with diverse mathematical backgrounds, and enhances the learning outcomes for all students. This paper describes our approach to this challenge, based on our research in student conceptions of statistics and the language needs of professionals in the mathematical sciences, and embodied in the learning materials that we are currently developing.

Australian government and professional bodies have recognised the importance of this area. A recent review with a scope of 'the 15 years from 1995–2010', finds 'unequivocal evidence that, as an economic and social instrument, advanced mathematical services relying on the mathematical sciences are critically important to Australia' (National Committee for Mathematics, 1996). Recent government initiatives have targeted declining interest, standards and resourcing in mathematics (see for example Thomas, 2000). Similarly, universities are moving towards the integration of 'generic skills' within the curriculum, loosely equating statistical study with a higher-level 'numeracy'.

Tertiary students in a wide range of areas will have need of statistics as a tool in their professional life. Many of them will find their first statistics course to be quite a shock, not only because it represents a completely new way of using numbers and language, but even because some of them had no idea that statistics would be a component of their studies. Yet, future researchers and professionals in many areas will need at least a working knowledge of the meaning of statistical outputs, and some may need to develop sophisticated understanding of statistics. The first statistics course has been much studied by statistics educators. Research on students' learning in statistics has focused on the educational effects of approach, learning environment, materials and assessment (e.g. Roiter and Petocz, 1996; Petocz, 1998b; Garfield and Gal, 1999; Keeler and Steinhorst, 2001). Some research looks at the effects of students' attitudes towards the subject (e.g. Gal, Ginsburgh and Schau, 1997), or their statistical ideas, particularly in the area of probability (e.g. Wild and Pfannkuch, 1999; Chance, 2000). A few studies have looked at students' own conceptions of mathematics (Crawford et al., 1994) or of statistics (e.g. Reid and Petocz, 2002) and how this influences their learning.

Other research has focused on communication needs of future professionals in the mathematical sciences (Wood, Smith and Baynham, 1995; Coutis and Wood, 2002) and the development of appropriate curriculum to enhance students' language abilities in this area (Wood and Perrett, 1997). The theoretical basis for these studies can be found in the ideas of critical discourse analysis (see e.g. van Dijk, 1998). The notion of helping students develop their language skills in the context of a particular subject area such as statistics is not new. However, what is new is the linking of our

research into learning statistics with a theory of the relation between discourse and social factors. Moreover, this approach can be applied in any other area of science, and is not limited to statistics.

The research background

Our approach to the challenge outlined in the introduction is based on four theoretical frameworks. The first arises from a study of students' conceptions of statistics carried out by Petocz and Reid (2001, 2002) based on the phenomenographic approach (Marton and Booth, 1997). They found that statistics major students have qualitatively different ways of understanding statistics and learning in statistics, ranging from limiting to expansive views. Students who describe the most atomistic and limiting views seem only to be able to focus their attention on fragmented and unrelated components in their learning environment. Conversely, students who describe the most integrated and expansive views are able to make use of a wide range of learning approaches to further their already sophisticated understanding. Reid and Petocz (2002) introduce the abstract notion of the 'Professional Entity' – a way of thinking about students' (and teachers') understanding of professional work (based initially on studies in music, see Reid, 1997). It consists of three different levels: the *extrinsic technical* level describes a perception that professional work is constituted as a group of technical components that can be used when the work situation demands it; the *extrinsic meaning* level describes a perception that professional work is about developing the meaning inherent in discipline objects (e.g. data, in the area of statistics); and the *intrinsic meaning* level describes the perception that professional work is intrinsically related to a person's own personal and professional being. The significance of the Professional Entity is that there are specific conceptions of teaching and learning associated with each of its levels: a particular way of viewing the world of professional statistics corresponds to a particular approach to teaching and learning.

Moreover, teachers can help students move beyond the more limiting conceptions towards the broader conceptions. Reid (1997) has shown that teachers' approach to their teaching and the sort of learning environment that they set up in their classes can encourage students who identify with the lower, fragmented levels to engage with their learning at a higher level. However, this can also work the other way if a teacher sets students tasks that are best carried out using the more fragmented conceptions of learning (Reid, 2000).

The second framework on which our work is based is the theory of critical discourse analysis, particularly the ideas of Fairclough (1992, 1995). Critical discourse analysis 'studies the way social power abuse, dominance and inequality are enacted, reproduced and resisted by text and talk in the social and political context … critical discourse analysts take explicit position, and thus want to understand, expose and ultimately to resist social inequality' (van Dijk, 1998). Within the overall aims of critical discourse analysis, there are a diversity of theoretical frameworks. In the British context, the writings of Fairclough focus on various dimensions of power. He (and others) argue that there has been a large-scale restructuring of employment with major implications for the linguistic demands of work. The modern workplace is requiring more interpersonal communication skills, as the emphasis shifts from isolated workers to teams. A transformation is also occurring within the professions, where clients are no longer expected to adapt to the professional discourse: rather, the professionals are adapting to the language needs of their clients. In our experience, the situation seems no different in the Australian setting. We have found it useful to consider Fairclough's three dimensions of critical discourse analysis (1992, page 11):
(a) description of the text (with 'text' interpreted widely, and including spoken words);
(b) interaction with the text, involving processes of producing and interpreting the text; and
(c) explanation of the interaction with the text, by referring to its social and discipline context.
This defines three levels at which students can work with text. We have used these levels in designing our learning materials.

Another research framework that informs the design of our learning materials is the increasing emphasis on graduate profiles, professional competencies and generic skills (see e.g. Bowden and

Marton, 1998). Universities and professional societies are agreed on the importance of fundamental professional skills, or 'graduate competencies', that help to prepare students for an increasingly uncertain future. The development of academic and professional discourse skills ('communication skills') accords well with the capabilities needed by all graduates, but is sometimes lacking in graduates of quantitative disciplines. The siting of the language of the professions within informal language when dealing with clients, and within formal language when dealing with colleagues places extra importance on the diverse communication skills needed by graduates.

The fourth framework that we have used connects the ideas of equity, equal opportunity and non-discrimination which have become an explicit part of teaching and learning at university. For many lecturers, these are principles to which they have always adhered. However, the changes have been in the legislative and social acceptance of these principles. It is widely accepted that universities are no longer only for an elite, and importance is given to teaching and learning initiatives that are inclusive and that assist students to reach their full academic potential whatever their background. An extract from the University of Technology, Sydney's Equity Plan 2000-2003 (UTS, 2002) states: 'UTS is committed to the right of all students to study and access services in a university environment which is equitable, free from discrimination and harassment, and in which everybody is respected and treated fairly. A central objective of the UTS Mission Statement is *to improve educational provision for students from a diversity of backgrounds*'. We believe that good curriculum design that develops academic language skills and statistical skills meets the requirements of such an Equity Plan.

Curriculum design

Our focus in this paper is on enhancing language, numeracy and communication skills in culturally and academically diverse student cohorts, using the results of our research on student learning and communication needs. We have designed a flexible curriculum that uses real sources (published journal articles, conference papers, academic subject notes, e.g. Barron, 1997; Hunsaker and Ramsey, 1995) from the disciplines of the participating students. In our learning resource, *Reading Statistics*, we have examples from the areas of tourism and sport, environmental science, medicine and the health sciences, music, physical sciences, engineering, education and orthodontics. In each example, the source material is the basis of a series of questions focusing on the language of the article and the statistical aspects of the study. Although our questions do not neglect the lower-level skills, they are designed to encourage students to use the highest level of the taxonomy of discourse, and to view the subject material at the most expansive and holistic level statistically. These teaching and learning experiences can be adapted to any situations where students need to interpret and understand statistical material – the typical situation that many students in 'servicing statistics' courses will find themselves. They are encouraged to develop critical reading skills and understand the statistical content of research papers. They are also supported in making connections between the topics of the articles and their own personal and professional life.

Previously, we have been involved in preparing a range of learning materials that aim to extend students' ideas about the nature of statistics and mathematics, and to develop their communication skills in these areas. Such materials include textbooks (Petocz, Petocz and Wood, 1992; Wood and Perrett, 1997), video packages (Petocz, Griffiths and Wright, 1996; Wood, Petocz and Smith, 2000) and laboratory materials (Petocz, 1998a). In discussing the preparation of *Reading Statistics*, we are making explicit the theoretical background on which our approach is based, showing how we use our and others' research to prepare materials that will enhance the skills of our diverse groups of students. We are also allowing for the possibility of designing a whole statistics course that is built around the use of a series of readings in applications of statistics (see e.g. Roiter and Petocz, 1996).

Examples from *Reading Statistics*

We will give examples of the structure of the material in *Reading Statistics*. Each of the sources or readings is followed by a set of questions that direct students' learning, organised under two main headings, 'reading and comprehension' and 'statistics'. This is for convenience only, and it is not our intention to divorce the two aspects. The introductory questions are the same for all the readings, and these are followed by questions focusing on specific aspects of the source document. The questions for the reading sections were adapted from Wood and Perrett (1997) and are attributed to Perrett. In general, the introductory questions for each reading cover the descriptive and technical aspects of the text and the statistical analysis. The specific questions address higher order skills: they ask students to generate text or analyses, and place them within a wider context, in their own discipline. (Note that the layout of the questions has been condensed for this paper.)

Reading and comprehension

Do these pre-reading activities: this will save time and help you get the most out of your reading.

1. Identify the background of the article: Who are the authors? What is the title? What is the name of the publication it appears in?
2. Set a timer for 5 minutes and skim through the article: Skim reading techniques help you deal with large amounts of material in a short time. Pay particular attention to the title, abstract, headings, diagrams and the first and last paragraphs. Get as good an idea as you can of what it is about in the time limit. Summarise the article in 3-5 dot points. In a work or study situation, you may not wish to proceed further as the article may not meet your needs at the moment. By having the 3-5 dot point summary, you will be able to locate the article quickly if your needs change.
3. Aim and audience: Now read the whole article carefully and answer the following questions. What is the authors' major aim in writing the article? What audience are the authors writing for?

Statistical aspects

Do the following activities to help you identify the reasons why the author has used the particular research design and statistical techniques.

1. Identify the research question: Write down the research question. How is it presented? Why has the author presented it this way?
2. Identify the research methodology used: Write down the research methodologies used. Is it an observational study or an experimental study? What sampling techniques are used (if any)?
3. What data are given in the article? How are the data presented or described?
4. What statistical techniques are used and why? List the statistical techniques used. Give a reason for using each of them. What clues do you get from these about the aim of the whole text?

Specific questions on 'Images of Hospitality' (Barron, 1997)

1. The author identifies three reasons why high attrition rates in hospitality courses are a problem. List these three reasons.
2. Barron presents the main results from his study in the form of graphs and tables. Write down some of the good features of the graphs and some of the features that could be improved. Use your ideas to prepare a graphic showing the information in one of the tables.
3. The editor of your university newspaper has asked you to write a 300 word review of this article, addressing the following questions: What did you learn from this paper? Are any of the conclusions surprising? Who has benefited most from the study, and why?
4. *Work in groups for this question.* Are there any possible ethical problems involved in asking students to fill in a questionnaire in formal class time under the supervision of the lecturer/author? Does it depend on the context or the subject of the questionnaire? What ethical guidelines does your institution have for questionnaires in this situation, and do you think they are reasonable? Discuss these questions from various points of view in your group. If you are working in a class situation, different groups could present different viewpoints and the whole class could debate them.
5. Do you think that you and your fellow students have realistic and positive views of working life in your chosen area or industry? Design a short (one page) survey either to find out the views of students in your area, or to find out what extra experience or information students would like about working in this industry.

Specific questions on 'Trumpet Playing' (Hunsaker and Ramsey, 1995)

1. List the reasons why the authors of the current article believe that previous studies were flawed. How have the authors set up their study to minimise the problems of previous studies?
2. The article mentions the 'popular instrumental literature'. List five features of popular literature as opposed to research literature, and give a brief example of each.

3. Let's look at some of the details of the t-tests used in this article. First, use the information presented in Table 2 to carry out the independent samples t-test comparing the heart rate increase for younger and older musicians (how many?). Write down the null and alternative hypotheses. Why have the authors used a one-sided test? Do you think a two-sided test would have been better, worse, or just as good? Give reasons for your answer. Now show how to calculate the mean difference between the two groups and the standard error of the mean difference. Then show how to find the t-value for the test, and the p-value that summarises the result.
4. Now look at the paired t-test in Table 1. It was carried out to compare the resting and playing heart rates for a group of trumpet players (how many?). Write down the null and alternative hypotheses. Discuss why you think the authors used a one-sided test. Show how the mean difference was calculated. What about the standard error of the mean difference? Can you show how to find the t-value for the test, and the p-value that summarises the result? You may find that you can't do this, or that you get a different result to the one given in Table 1. Can you explain what the problem is?
5. Hunsaker and Ramsey write: '*The mean heart rate during trumpet playing was found to be significantly higher than when resting. Also, when compared by age groups, younger players had a greater increase in heart rate than older musicians.*'. Think about the first of these results in terms of your own music making (or some other activity). Can you suggest a more useful research hypothesis than the one that the authors used? Is there a simple explanation for why younger musicians increased their heart rate more than older musicians? Again, can you suggest a more useful research hypothesis than the one used in the paper?

Conclusion

In this paper, we have described an approach to designing curriculum that results in learning materials and corresponding teaching methods that combine a focus on real sources from the students' own discipline areas with a flexible and varied approach to their learning. We have done this in response to the increasingly diverse linguistic and academic backgrounds of our students and the increasing demands placed on them as graduates in professional areas. We have also discussed the research framework that has informed our development of such learning materials: research on students' conceptions of statistics and learning statistics based on a phenomenographic approach, notions of the increasing importance of communication skills in the workplace from work in critical discourse analysis, the increasing emphasis on graduate profiles and generic skills, and the greater visibility of notions of equity in tertiary education.

A criticism sometimes levelled against phenomenographic research is that, while it yields a description of the range of ways of viewing a phenomenon (an 'outcome space'), it does not result in any practical outcomes. This paper provides a clear counter-example – a phenomenographic study extended to yield a practical outcome that can influence the course of student learning. While we have used this approach in the discipline area of statistics, the same approach can easily be applied to a range of subject areas.

When we were preparing questions at the highest levels of both the hierarchy of conceptions of statistics and the taxonomy of discourse, we often came up with very similar ideas for questions that focused on language and those that focused on statistics. Although there is no evidence that the theories underlying the two approaches are related, and the fact that they each have three levels is simply coincidental, they can result in the same types of high-level questions. When you consider the descriptions of the highest levels of discourse and statistical conceptions, this is not surprising since they both focus on placing the student in the context of their discipline and their personal connections with society. In this context, it is interesting to note that early studies using the phenomenographic method (e.g. Marton and Saljo, 1976) focused on different ways of understanding written text. This research lead to the identification of 'deep' and 'surface' approaches to learning, described in detail in Marton and Booth (1997).

References

Barron, P. (1997) An analysis of Australian students' images of the hospitality industry: a focus on new recruits. *Australian Journal of Hospitality Management*, **4**(2), 13-20.

Bowden, J. and Marton, F. (1998) *The University of Learning*. London: Kogan Page.

Chance, B. (2000) Components of statistical thinking and implications for instruction and assessment. *Proceedings of the American Educational Research Association*.

Coutis, P. and Wood, L. N. (2002, in press) Teaching statistics and academic language in academically diverse classrooms. *Proceedings of International Conference on Teaching Mathematics, ICTM2*, Wiley.
Crawford, K., Gordon, S., Nicholas, J. and Prosser, M. (1994) Conceptions of mathematics and how it is learned: The perspectives of students entering university. *Learning and Instruction*, **4**, 331-345.
Department of Education, Science and Training (2002) [Online] Available: http://www.detya.gov.au/highered/timeseries/ [2002, March 3].
Fairclough, N. (Ed.) (1992) *Critical Language Awareness*. London: Longman.
Fairclough, N. (1995) *Critical Discourse Analysis: the Critical Study of Language*. London: Longman.
Gal, I., Ginsburg, L. and Schau, C. (1997) Monitoring attitudes and beliefs in statistics education. In I. Gal and J. B. Garfield (Eds) *The Assessment Challenge in Statistics Education*. IOS Press.
Garfield, J. B. and Gal, I. (1999) Assessment and statistics education: current challenges and directions. *International Statistical Review*, **67**(1).
Hunsaker, L. and Ramsey, D. (1995) Cardiac arrhythmias observed during trumpet playing. In R. R. Pratt and R. Spintge (Eds) *MusicMedicine Vol 2*. MMB Music, Saint Louis, MO, 253-260.
Keeler, C. and Steinhorst, K. (2001) A new approach to learning probability in the first statistics course. *Journal of Statistics Education*, **9**(3).
Marton, F. and Booth, S. (1997) *Learning and Awareness*. New Jersey: Lawrence Erlbaum.
Marton, F. and Saljo, R. (1976) On qualitative differences in learning: 1-outcome and process. *British Journal of Educational Psychology*, **46**, 4-11.
National Committee for Mathematics (1996) *Mathematical Sciences: Adding to Australia*. National Board of Employment, Education and Training and Australian Research Council, Canberra.
Petocz, P. (1998a) *Statistical laboratory exercises using Minitab: A guide to understanding data*. Jacaranda Wiley.
Petocz, P. (1998b) Effective video-based resources for learning statistics. In *Statistical Education – Expanding the Network, Fifth International Conference on Teaching Statistics*, ISI, IASE, Voorburg, The Netherlands, 985-991.
Petocz, P., Griffiths, D. and Wright, P. (1996) *Statistics for quality – Using statistics in Australian industry*. Video, 33 mins, booklet of exercises, Summer Hill Films, University of Technology, Sydney and University of Wollongong.
Petocz, P., Petocz, D. and Wood, L. N. (1992) *Introductory Mathematics*. Melbourne: Thomas Nelson.
Petocz, P. and Reid, A. (2001) Students' experience of learning in statistics. *Quaestiones Mathematicae, Supplement 1*, 37-45.
Petocz, P. and Reid, A. (2002, in press) How students experience learning statistics and teaching. *Proceedings of The Sixth International Conference on Teaching Statistics, ICOTS6*.
Reid, A. (1997) The hierarchical nature of meaning in music and the understanding of teaching and learning. *Advancing International Perspectives*, **20**, 626-631.
Reid, A. (2000) Self and peer assessment in a course on instrumental pedagogy. In D. Hunter and M. Russ, *Peer Learning in Music,* 56-62. Belfast: University of Ulster.
Reid, A. and Petocz, P. (2002) Students' conceptions of statistics: a phenomenographic study. *Journal of Statistics Education*, (submitted and accepted subject to revisions).
Roiter, K. and Petocz, P. (1996) Introductory statistics courses: a new way of thinking. *Journal of Statistics Education*, **4**(2).
Thomas, J. (2000) *Mathematical sciences in Australia: Looking for a future*. Federation of Australian Scientific and Technological Societies, Occasional Paper 3.
UTS (2002) Equity Plan. [Online] Available: http://www.equity.uts.edu.au/facunits/eplan.html [2002, March 12].
van Dijk, T. A. (1998) Critical Discourse Analysis. [Online] Available: http://www.hum.uva.nl/~teun/cda.htm [2002, March 13].
Wild, C. J. and Pfannkuch, M. (1999) Statistical thinking in empirical enquiry. *International Statistical Review*, **67**, 223-265.
Wood, L. N. and Perrett, G. (1997) *Advanced Mathematical Discourse*. University of Technology, Sydney.
Wood, L. N., Petocz, P. and Smith, G. H. (2000) *Terror, tragedy and vibrations – Using mathematical models in Engineering*. Video, 26 mins, booklet of exercises, University of Technology, Sydney.
Wood, L. N., Smith, G. H. and Baynham, M. (1995) Communication needs of mathematicians. *ICMI Regional Conference on Mathematics Education*, Monash University, Melbourne, 657-666.