Statistics—worse than a poke in the eye?

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Introduction

The majority of students studying statistics are not majoring in that subject: they are taking a service course in statistics as part of their studies in another discipline to prepare themselves for a career where statistics will be a professional component tool. Many of them find such a course difficult or even distasteful. A recent advertisement put up at Macquarie University by someone offering tutoring services began: 'If you think statistics is worse than a fork in the eye, then you need help!' We have previously reported on conceptions of statistics held by statistics major students (Reid and Petocz 2002). In this paper, we extend that study by looking at the views of statistics held by students taking service statistics courses in various areas of science. We also investigate their expectations of their use of statistics in their future studies and profession. The students' views were obtained using an anonymous, open-ended questionnaire, and we have analysed the content of the responses using our previous theoretical framework. Based on the results obtained, we discuss teaching and learning approaches and materials that can help such students to engage with the ideas of statistics and to develop an appreciation for its possible uses in their future professional lives.

Service statistics courses

Many tertiary students in a wide range of disciplines will have need of statistics as a tool in their professional life: they will be introduced to the subject in a 'service' course in statistics. Such service courses have been much studied by statistics educators, and are a continuing theme in forums such as the on-line *Journal of Statistics Education* and the four-yearly *International Conference on Teaching Statistics* (or *ICOTS*). Research on students' learning in statistics has often been oriented around investigations of learning approach and environment (Boyle 1999; Martinez-Dawson 2003), the educational effects of assessment (Garfield and Gal 1999), the impact of students' attitudes towards the subject (Gal and Ginsburg 1994) and students' statistical ideas of specific topics, particularly in the area of probability (Pfannkuch and Brown 1996; Keeler and Steinhorst 2001). Garfield (1995) lists aspects of the learning environment that seem to encourage student learning of statistics, including activity and group work, use of interactive computer software and computer simulations, and investigation of statistical 'misconceptions'. There have been several reports on the topic of enhancing statistics education for scientists by using case studies, applications and projects (Zetterqvist 1997; MacGillivray 2002). Other reports write of the positive effects of teaching using industrial collaborations, settings and applications (Morris 2000; Davies 2002).

Relatively few studies include an emphasis on students' understanding of statistics (such as Gordon 2004). Yet, focusing on students' learning, rather than on the lecturer's ideas of important content or pedagogical method, is an essential step to encourage students to develop mature approaches to learning, and an appreciation of the possible role of statistics in their professional life. We have been carrying out a project in just this area, based initially on a series of in-depth interviews with students majoring in statistics, and then extended to include students who are studying statistics as a 'minor' component of their professional studies. We have also surveyed a much larger number of students in service courses in various areas of science. An analysis of these survey results is presented later, but to provide an appropriate theoretical framework we first summarise students' conceptions of statistics from the initial interview study.

Statistics major students' conceptions of statistics

In a previous paper (Reid and Petocz 2002), we have reported on the conceptions of statistics held by students who were majoring in statistics. The conceptions were identified from a phenomenographic analysis (Marton and Booth 1997) of interviews with 20 students from first- and third-year classes in statistics, focusing on their responses to the question 'What is statistics?' or 'What do you understand statistics to be about?' The 'outcome space' is presented in Table 1 without supporting quotations from the transcripts (which can be found in the cited reference). The first three conceptions focus on techniques, mathematical and then statistical, individual and then a collection. Students holding conceptions 1 or 2 have a limited and fragmentary understanding of statistics, which is somewhat broader in conception 3 as techniques are accumulated. The next two conceptions focus on using data: conception 4 shows a view of analysing a set of data to understand the meaning hidden in it, while conception 5 explicitly includes the context of the analysis. Students describe statistics using the techniques characteristic of conceptions 1–3, but consider these techniques to be part of a coherent whole, and aim to be able to analyse and interpret a complete set of data. Conception 6, the broadest, focuses on meaning. Students use statistical methods to develop their own thinking, create new interpretations of data, and actively relate their statistical understanding to their personal and professional life. In common with many other phenomenographic outcome spaces, the conceptions are hierarchical and inclusive. They are listed in the table from the narrowest and most fragmentary to the broadest and most holistic. Moreover, students who express the broader conceptions are also aware of the narrower conceptions, and can make use of any or all of the characteristics of the previous conceptions, if their perception of the situation demands it. It is for this reason that we as educators favour the broader, most expansive conceptions over the narrower, more limiting ones.

Table 1. Statistics major students' conceptions of statistics (after Reid and Petocz 2002)

Focus	Conception of Statistics	Brief Description
Techniques	1. Numerical techniques	Limited and fragmentary understanding, statistics is a type of mathematics that uses 'boring calculations', 'numbers' or 'probability'
	2. Individual statistical techniques	Statistical rather than mathematical fragments, individual techniques used to look at data, eg graphing, line of best fit, collecting data, regression
	3. Collection of statistical techniques	Statistics is a collection or 'stockpile' of a range of techniques, accumulated by students and listed as a description
Data	4. Analysis and interpretation of data	Statistics is interpreting or making sense of a complete set of data, analysing and drawing conclusions about it
	5. Understanding using statistical models	Statistics is a way of understanding situations by examining statistical models, analysing sets of data and testing appropriateness of conclusions
Meaning	6. Making sense of the world and develop personal meaning	Statistical methods are used to understand and make sense of wider aspects of reality, develop creative and critical thinking, create new interpretations of data and life

While this model of students' understanding of statistics is interesting theoretically, it can also be used practically as a basis for developing effective pedagogical approaches. Firstly, students often believe that everyone else in the class shares their way of looking at the subject and are surprised to hear that there are alternative viewpoints: those students who previously held more limiting views are thus encouraged to consider broader conceptions of their subject (see Ho, Watkins and Kelly 2001). Students' conceptions of their own learning and the role of their teacher can also be discussed (see Petocz and Reid 2003). Secondly, we can provide activities and assessment that encourage students towards the broader conceptions. For instance, rather than simply asking students to carry out a statistical technique, we can set the problem in a real-life context and in addition ask students to explain the *meaning* of the results to a colleague or a client: this moves students' focus from facts and techniques towards the broader conceptions of statistics as a way of understanding the world. An example of such a pedagogical approach in action is given in Reid and Petocz (2003) in the context of a class in regression analysis.

The questionnaire and data collection

The background to the data collection was our desire to make practical and immediate use of results that we had obtained from the interviews with statistics major students. We wanted to discuss the range of conceptions of statistics with our other classes, and in order to provide a basis for starting a discussion we asked students to think about their ideas of statistics and how they might use it. Using an anonymous open-ended questionnaire, students were asked to write replies to the questions: What is statistics? What part do you think statistics will play in your future studies? What part do you think statistics will play in your future professional work? The replies formed the basis for general class discussions and with our students' permission we collected their responses for further analysis. We have responses from 122 students, two groups of students from sports science (one undergraduate, one honours), a group of masters students in orthodontics and two groups of masters students in human nutrition. These responses were analysed together due to the relatively small samples.

Service students' conceptions of statistics

Although enough space was left for longer responses, most people just wrote a short definition of statistics for the first question. Many responses were concerned with mathematical techniques (the study of numbers, application of mathematical formulae, calculating, a form of maths) or their application (finding probabilities, calculating reliability, correlations or trends, using mathematical methods to find results, using numbers to work out significance). Another large group of responses focused on compiling or collecting data, using data or samples and analysing, evaluating or interpreting data. Also mentioned were finding significance of results or confirming/denying a hypothesis and drawing valid conclusions. Finally, there were some isolated comments that focused on the positive aspects ('A subject helpful in research') or negative aspects ('Glorified guesswork', 'Science designed to prove that all our work is wrong'), or made comments on respondents' attitudes to statistics ('Complicated', 'A struggle for those who dislike maths').

The responses can be analysed using our previous theoretical framework and the results are shown in Table 2. Using the inclusive nature of the outcome space, each response was classified at the broadest level shown, so for instance if a student wrote 'The collection of data and the use of it', the response would be classified as conception 4 (since it showed evidence of interpreting or using the data) rather than conception 2 (collecting data as an individual statistical technique). Since there is no chance for respondents to amplify their written responses, the classification is 'generous'.

Table 2. Service statistics students' conceptions of statistics

Focus	Conception of Statistics	Freq	Example
Techniques	1. Numerical techniques	14	A lot of numbers and graphs everywhere/ A form of maths/ Maths calculations/ The study of numbers
	2. Individual statistical techniques	9	A way of displaying information in numerical format/ Studying relationships between values and data/ The measurement of a specific phenomenon with a group of subjects (or objects)
	3. Collection of statistical techniques	19	The study of probabilities and the significance of results/ Standard deviation, are the results statistically significant?/ ANOVA, Wilcoxon rank sum test, but can't remember detail
Data	4. Analysis and interpretation of data	66	Analysing numerical data and then putting them to some use/ Analysing data and making sense of it/ The collection of data, making sense of the collected data
	5. Understanding using statistical models	5	The collection and organisation of data so that it can be understood and give meaning to a particular situation/ Analysing numbers to make sense of the results of experiments
Meaning	6. Making sense of the world and develop personal meaning	0	

Table 2 shows that conception 4, analysis and interpretation of data, is the most common (and in fact was the most common in each of the three sub-groups). It is not surprising that the short written responses from this group did not display the broadest conception of statistics as ‘an inclusive tool to make sense of the world and develop personal meanings’. The following extract from an interview with an honours student in sports science shows the problem. Joe’s first statement, early in the interview, would indicate conception 4, statistics as analysis and interpretation of data. However, his response to a question at the end of the interview implies the broadest conception 6 of statistics:

> Joe: [Ok, can I start then by asking you, what you think statistics is?] I would think stats is about investigation of data. It can be any kind of data and it can be used for anything, but pretty much working to formulate anything they want really. /…/ [What do you think the main things are from what you have learned here in stats that you take with you when you leave?] The whole way of thinking about things differently, you know, ideas of formulation that I would have never had come up with before that maybe I could lay things out a little bit differently so it works, that I may not have thought of previously. It will just make my life easier basically. /…/ I think differently now because I can see now that it’s much wider and can be used for a much wider range of things, as previously I may have been a bit more closed minded, thinking it was just nerdy stuff that we don’t need to know. But now it’s like, oh this really applies to everything. You know I can work out this, and whack these things together. Just thinking differently, thinking more advanced.

Service students’ ideas about their use of statistics

The responses to the questions about the use of statistics in future studies and professional work are considered next. Students from the first interview study who were majoring in statistics had no doubt that they would use statistics in some form in their professional life, and some of them were already using it professionally. By contrast, the students in the service groups had less clear expectations. The most common responses for both study and work were concerned with reading and understanding research articles or results and actually carrying out research assignments or projects. This focus is not surprising given that more than half the students were enrolled in coursework masters degrees, but it was also apparent in the undergraduate group in sports science. Many respondents gave specific examples, such as sports coaching or evaluating sporting performance, investigating public health or the nutritional status of a group, or developing better dental materials. There were a small number of comments related to a broader use of statistics, for example: ‘Understand better the industry where I will work’ and ‘It helps to derive conclusions from observations kept in everyday work in the clinic.’ Despite this, there was a minority who believed that statistics would have no role, or were unsure about the role it might play, writing comments such as ‘Unsure of what I’m doing, so I’ll have to wait and see.’ The responses are summarised in Table 3: a response could contain several ideas, so the frequencies do not sum to the total number of respondents.

Table 3. Service students’ ideas of future use of statistics in their studies and work

Use of Statistics		Studies	Work
Unspecific:	- no role	3	3
	- unsure of role	9	12
	- some role	5	7
	- large role	12	9
Specific Example:		17	33
Research Use:	- organise and present data	2	4
	- analyse data, evaluate results	10	2
	- read and understanding research	28	30
	- carry out own research	48	27
Professional Use:	- explain to clients		1
	- understand the industry	1	
	- support professional judgement	2	3
	- further studies (PhD, Honours)	4	

Conclusions

Our analysis permits us to draw several conclusions concerning effective pedagogy for service classes in statistics for science students. We have already mentioned the strategy of helping students become aware of the various conceptions of statistics and the fact that other students may think differently about the subject. Given the large numbers of students who viewed statistics as isolated mathematical techniques, there seems to be potential for broadening their views of the statistics and learning statistics. However, it is important to remember that it would be as important that they expand their conceptions of their own area of science. We have also pointed out the benefits of providing learning activities and assessment that direct students towards the broader conceptions of statistics. Such an applied approach is vital even in an introductory statistics course, rather than the traditional focus on the development of basic statistical techniques. Given the large numbers of students who were aware of the role of statistics in understanding research results or carrying out their own research, this would be an obvious source of examples and assessments. The many reports of pedagogy involving projects selected in the students' own areas of interest attest to the success of this approach (e.g., MacGillivray 2002; Yesilcay 2000).

These research outcomes can be used as a basis for developing effective learning materials. As examples, we can refer to the laboratory exercises in Petocz (1998) that ask students to engage with the meaning and context of various sets of scientific data (e.g., Rayleigh's measurements of 'standard volumes' of nitrogen that led him to the discovery of argon in 1894), the video case studies in Petocz, Griffiths and Wright (1996) that take students behind the scenes of problems in statistical quality management (e.g., the problem of trichloroanisole in the corks at the Rosemount winery), and the book *Reading Statistics* (Wood and Petocz 2003) which encourages students to 'read' statistical papers, articles and research in a variety of areas of application (e.g., effects of T'ai Chi on balance), with the aim of looking beyond the data to the real life meanings. These examples fit into the problem-based learning model that has been successfully used throughout the sciences: the winning presentations at the last three UniServe Science Symposia are good examples (Kirkpatrick, McLaughlan, Maier and Hirsch 2002; Meyers, Nulty, Cooke and Rigby 2003; Batmanian, 2004). Another statistical example: we recently read a fascinating imaginary conversation with Florence Nightingale about the use of statistics in evidence-based medicine that would be an ideal resource for a medical statistics class (Maindonald and Richardson 2004). With such learning materials, the focus of the learning shifts to the broader conceptions of statistics, and supports students' own learning rather than statistics itself, or the basic techniques of the subject.

Traditionally it is assumed that science students learn about professional competencies such as statistical skills through real-life problems or experience in laboratory experimentation. However, their lecturers may have limited industry experience and thus prepare students for professional work from an institutional academic orientation (Evans 2001). This standard approach reflects a lack of appreciation of the way in which students understand the situated nature of their learning and the professional tools that are integral to their intended profession. 'Telling' students, and providing activities purporting to reflect professional work simply do not enable students to challenge their own beliefs about their learning focus and their work. Providing a space where *students* can explore their own perception of professional work and the way in which other subjects can be appreciated as component tools for scientific work enables educators to more effectively enhance the situation of learning and the students' own connections between institutional and professional learning experiences (Trigwell and Reid 1998). Another quote from an interview with another student in sports science points to the importance of changing students' conceptions:

> Karin: [What do you think might be the main things you take away with you from your stats learning when you leave university?] More understanding of it, before I thought statistics was very dry and useless. Something for academics to keep them busy. But it actually has a purpose: I changed my mind. [Why?] Because I guess I realized I might use it in the future.

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