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Enhancing statistical education by using role-plays of consultations

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Summary. Role-plays in which students act as clients and statistical consultants to each other in pairs have proved to be an effective class exercise. As well as helping to teach statistical methodology, they are effective at encouraging statistical thinking, problem solving, the use of context in applied statistical problems and improving attitudes towards statistics and the statistics profession. Furthermore, they are fun. This paper explores the advantages of using role-plays and provides some empirical evidence supporting their success. The paper argues that there is a place for teaching statistical consulting skills well before the traditional post-graduate qualification in statistics, including to school students with no knowledge of techniques in statistical inference.

Keywords: Professional entity; Statistics profession; Student attitudes

1. Introduction

Recently published papers on statistical education advocate that greater concentration should be put on statistical consulting skills. This trend is not driven by opinions that mathematical or theoretical statistics is not important, but by recognition of the need for balance between theory and practice. Here statistical consulting skills refer to those skills that are required by most statisticians in addition to knowledge of statistical techniques (such as regression) and the theory behind them. Anderson and Loynes (1987), section 2.2, provided a detailed list of these skills with 25 points ranging from generic skills such as communication through to statistics-specific skills such as recognizing which statistical techniques are appropriate.

The views of practising statisticians are essential when discussing the teaching of statistics if we are to preach what we practise. For example, Chatfield (2002) observed

> 'I spend an increasing proportion of my time in problem formulation as opposed to data analysis and note the importance of asking (many) questions, of finding out about any prior knowledge and looking at any prior data, and ensuring that any necessary background information is understood'.

This suggests that students should be trained in areas such as problem formulation, questioning skills and the use of background information.

The purpose of this paper is to suggest that a viable strategy for teaching statistics is role-plays, where one student plays the role of a statistical consultant for another student who plays the role of a client requiring statistical advice. Although it is not the same as a real consultation with a real client, role-plays have many advantages. For example, they are extremely easy to

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implement and are sufficiently close to a real consultation to involve the skills of professional statisticians, and aspects of the consultation such as the level of statistical methodology that is required can be controlled to make them suitable for students at several levels of statistical education. This results in positive implications not only for the teaching of good statistical practice but also for the teaching of statistical techniques. Furthermore, they can be used successfully with young students, including students with no knowledge of inferential techniques. This has a positive influence on the attitudes of students towards statistics and the image of statistics and the statistics profession.

This paper is structured as follows. The rest of this section discusses past literature under three major themes: teaching statistical skills such as statistical thinking, statistical consulting courses and the image of statistics and statisticians. Section 2 describes role-plays in detail and Section 3 provides some empirical evidence in favour of role-plays, which has been obtained via feed-back from students and teachers who have participated in role-plays. Section 4 contains a list of advantages and disadvantages of role-plays based on the author's experience with role-plays since 1999 and Section 5 contains some concluding remarks.

1.1. Teaching statistics

Recently a new pedagogy has impacted on statistics education:

> 'In practice, the new pedagogy asks us to change what students do from listening and reading to active participation'

(Moore, 1997). Moore also quoted the National Research Council of the USA (1991):

> 'What is needed is a variety of activities, including discussion amongst pupils, practical work, practice of important techniques, problem solving, application to everyday situations, investigational work, and exposition by the teacher'.

Similarly,

> 'There is a need for much more holistic assessment with things such as open-ended questions, discussions of issues, short essays, questions requiring more than simple or technical answers and items relating the data to a real issue in a context'

(Holmes, 2003). Pfannkuch and Wild (2000) challenged statisticians to develop teaching that incorporates the dimensions that practising consultants suggest are required by a statistical consultant because these dimensions are not covered in standard statistical methodology courses.

Recent challenges to the traditional emphasis on mathematics in statistics education by many can be summarized with the belief that

> '... statistics is not a subfield of mathematics, and that in consequence, beginning instruction that is primarily mathematical, or even structured according to an underlying mathematical theory, is misguided'

(Moore, 1997). MacGillivray (2005), however, called for more research on the relationship between mathematics and statistics and suggested that mathematical and statistical thinking have important similarities and that 'emphasis on formal statistical procedures in schooling can be detrimental to development'.

The literature now contains numerous activities and advice addressing these issues in a variety of ways to implement this new pedagogy in statistics education. For example, Stuart (1995) argued for teaching statistics from a problem solving paradigm and Scheaffer *et al.* (1996)

contains activities that were collected from experienced statistics teachers to illustrate statistical concepts. Chatfield (1995), chapter 10, and Derr (2000) contain tips and further references on consulting and collaboration, and Derr (2000), chapter 5, devoted a whole chapter to simply 'Asking good questions'. Cobb (1993) has documented American projects to improve activity-based learning in statistics under three themes: analysis of archival data, production of data and simulation. Garfield (1993) advocated using co-operative learning and Giraud (1997) presented evidence that this approach was superior to using standard lectures. Having students work co-operatively in small groups is argued to have advantages, including students learning from other students who are more competent than they are (or view concepts from different perspectives), self-evaluation and immediate feed-back from others.

The practical, activity-based project is generally advocated as beneficial in terms of student learning of statistics, non-statistical skills such as communication and motivation. These projects can vary in form considerably, including activities or problems presented with a full context (Nolan and Speed, 1999) and statistical consultations with clients (see Section 1.2).

Despite reported successes with projects (Yesilcay, 2000), they can degenerate into extended pieces of traditional homework questions. du Feu (2003) suggested that projects in schools are often 'little more than collections of calculations and charts which may gain points but show no underlying statistical coherence' and owing to a lack of time students often complete only one project, so they are used more for assessment than for learning. Wild and Pfannkuch (1999) suggested that the usual solution to teaching statistical thinking, 'let them do projects', was insufficient. In this paper we suggest that the variable success of projects could be due to the variable understanding by teachers and students of what it means to be a professional statistician (see Reid and Petocz's (2002) 'Professional Entity', section 1.3), and other methods are required to convey this meaning when it is lacking.

1.2. Consulting courses

The literature on teaching statistical consulting skills concentrates on post-graduate students in statistics and ranges from articles defining necessary skills for statistical consultants through to preconsulting courses and courses involving students performing consultations. Examples include Cox (1968), Watts (1970), Cox (1977), Hunter (1981), Boen and Zahn (1982), Zahn and Isenberg (1983), McCulloch *et al.* (1985), Anderson and Loynes (1987), Hoerl *et al.* (1993), Hand (1994), Chatfield (1995), Derr (2000) and Cabrera and McDougall (2002). Although generally aimed at post-graduate students in statistics, this is not always essential. Sahai and Khurshid (1999) have provided a bibliography on statistical consulting and training.

Cox (1977) discussed teaching his eight important points for the strategy of statistics to post-graduate students and suggested that

> 'these topics are not suitable for more than at most an extremely brief mention in undergraduate work, even in degree courses with a strong statistical content'.

Although more recent lists such as Anderson and Loynes (1987), section 2.2, define statistical consulting skills more broadly, the emphasis in the literature remains on teaching statistical consulting to post-graduate students. Indeed, there is understandable logic behind requiring a prerequisite of statistical methodology for any statistical consulting course. Not only are good communication skills of little value if you do not know the technical details of the topic that is under consideration, but also statisticians are generally all too familiar with the problems that are associated with statistical techniques being applied inappropriately by people who lack sufficient knowledge of the techniques.

More recent literature suggests that

> 'More courses in statistical consultancy are needed. And these should begin at the beginning—before the statistical question has been formulated'

(Hand, 1994). For example, the Statistical Society of Australia plans to accredit degree programmes in Australian universities as part of their accreditation of graduates as Graduate Statisticians and lists statistical consulting along with nine other topics such as linear models that (undergraduate) degrees must substantially cover to be accredited.

Some researchers have described courses on statistical consulting for undergraduate students, including Bentley (1991), Bentley *et al.* (1998), Rangecroft and Wallace (1998), Jersky (2002) and Taplin (2003). These range from courses emphasizing consulting skills such as communication and teamwork through to consultations with external clients and are typically aimed at advanced undergraduate students.

Although the above literature on consulting courses is important, this paper proposes that the teaching of statistical consulting to students who are already committed to a career in statistics is 'better late than never'. It suggests that the benefits of using statistical consulting to teach high school students and lower university students who are not yet proficient in statistical techniques, and may even be ignorant about the existence of a statistics profession, should not be ignored.

We explicitly ask the important question 'Where should statistical consulting be taught, and does this include high schools?'. Perhaps the statistical consulting courses at the post-graduate level assume that the aim is to produce competent statisticians at the end of the course. If this is so, then the prerequisite of statistical methodology skills is understandable. This paper, however, suggests that the teaching of statistical consulting to younger students, possibly with little statistical knowledge, is not inappropriate if the aims include recruiting students to the statistics profession, improving attitudes to statistics, motivating and enhancing the learning of statistical techniques and statistical thinking, and teaching more generic skills such as technical communication.

1.3. Attitudes to statistics and the statistics profession

Gal and Ginsburg (1993) argued that statistics educators should pay more attention to the emotions of students: their attitudes to statistics and feelings concerning their statistical education. These emotions are important for many reasons, including the influence that they can have on student learning within statistics courses and the influence that they can have on both the use of statistics generally and on the future of the profession through recruitment of future statisticians.

Professions such as medicine, law and forensic science partly owe their high profile to popular television shows, even if these shows deal more with people and their interactions with each other than with the technical aspects that are central to these professions in reality. For example, television shows about lawyers tend to display lawyers interacting with clients and making speeches in courts rather than researching past cases, studying books or completing paper work. Statisticians in contrast are more often associated with solitary activities involving calculators, computers or mathematical formulae. This suggests that the image of the statistics profession may be improved by placing more emphasis on the human side of statistical work.

Hunt (2000) interviewed nine statisticians and from analysing their statistical stories tried to understand why people become statisticians. None of these statisticians went to university to train as statisticians. She noted that

> 'Statistics as a career at present does not appeal to many people-centred folk although it must be emphasised that most of those interviewed took pleasure from their contact with clients'

and suggested that the presentation and teaching of statistics may turn away students who are suitable for careers in statistics. Finally, she concluded that

> 'Perhaps if some of the satisfying elements of statistical work quoted earlier were emphasized more in schools and universities, a wider range of people would be attracted to this worthwhile career'.

Marquardt (1987) expressed concern with the visibility of statistics as a discipline. He suggested that most people had a narrow view of statisticians as 'compilers of data' rather than the wider view of 'problem diagnosis and solution'. He saw the approach of training a small number of statisticians at the graduate level as a major problem for statistics.

Many researchers have contributed to the debate about the lack of visibility, image and even definition of statistics, including Bradley (1982), Minton (1983), Marquardt (1987), Mosteller (1988), Boroto and Zahn (1989), Wild (1994), Hoerl *et al.* (1997), Higgins (1999) and O'Fallon (2000). To many, the issue is not the removal of mathematics and computation from images of statistics but the recognition that there is more to statistics. As Evans (1994) put it

> '... there must be a spectrum of statisticians from the very mathematical to those for whom answering scientific questions is of the greatest importance. They will need training in science and in communication skills.'

Many researchers have tackled the initial problem of trying to define and measure attitudes of students towards statistics, often with Likert scale survey instruments. Examples include Roberts and Bilderback (1980), Roberts and Saxe (1982), Wise (1985), Gal *et al.* (1997) and Sorge (2001).

Gal and Ginsburg (1994) investigated the effect of students' emotions, such as attitudes towards statistics and beliefs concerning statistics, on statistical learning. Reid and Petocz (2002) used phenomenography to categorize how students perceive statistics and considered the implications for teaching statistics to such students. They argued that there is a strong relationship between learning within a discipline and how students perceive work in that discipline, referring to the latter as the 'Professional Entity'.

> 'Understanding the nature of the Professional Entity in statistics is critical. The research studies cited suggest that there is a very close relation between the way that teachers and students perceive the profession and what they then think is critical to either teach or learn'

(Reid and Petocz, 2002).

This paper suggests that a reason for negative emotions about statistics is that they are given little opportunity to experience being a statistician until late in their education, after most students have already formed attitudes towards statistics. In the language of Reid and Petocz (2002), they have not experienced the 'Professional Entity' of being a statistician, and in line with the new pedagogy of active participation (Moore, 1997) it is not sufficient for students to listen and read about this professional entity through examples and successes. Students need to experience the statistics profession actively: its value, the difficulties and challenges, personal successes and, importantly, the highs and lows of emotional energy that are associated with these experiences.

2. Using role-plays in the teaching of statistics

A statistical consulting role-play consists of students working in pairs with one student playing the role of a statistical consultant and the other playing the role of the client. To ensure that the

student playing the role of the client has a suitable problem and its context to present, they are provided with a written client sheet. This consists of two parts: an opening statement and some background notes. Appendix A contains the client sheet for the 'television marketing role-play', which is an example of a role-play that is suitable for students without knowledge of formal inference techniques. The histogram is part of the background notes and is provided on a separate piece of paper so the client can give it to the consultant without the remaining background notes.

The opening statement is read *verbatim* by the client at the beginning of the role-play. This has the advantage that the role-play sets off to a successful beginning without the two students being confused about who should speak first or what to say. It also limits the amount of context that is provided by the client to a level that is considered appropriate by the writer of the role-play. Furthermore, in a classroom situation the client sheet ensures some uniformity between role-plays that are conducted by different pairs of students, at least initially. This enhances classroom discussion after the role-play over what happened, what relevant contextual information could be extracted by the consultant, how this was extracted and possible solutions to the problem. Even if role-plays diverge from this initial statement because different students act their role of client differently, useful classroom discussions can revolve around what the consultant should do after hearing this common opening statement. For example, in the television marketing role-play, classroom discussions can involve recognizing that the lower quartile is required by the client and assessing whether the summary data that are provided in the opening statement are sufficient to obtain this quartile.

The background notes are the second part of the client sheet. These consist of contextual information concerning the client and their problem. This information is used by the student acting as the client when and if needed (usually in response to questions by the consultant). Clearly these notes cannot be completely exhaustive and the client must *ad lib*. to some extent depending on the questions that are asked by the consultant, but generally the background notes contain the details that are relevant to the statistical problem. They do not typically contain the solution because clients are rarely so confident that they know the answer. This makes it less likely for the client to give away the solution and provides an educational learning experience for the student playing the client also. For example, two statistically weak students may drop the distinction between client and consultant and work together to solve the problem. The information that is contained in the background notes is important because requiring the consultant to extract relevant contextual information is an important part of the process. Students must not only be able to extract the relevant information (consulting skills) but also to have a deeper understanding of the statistical techniques that may be applicable to recognize what contextual information is crucial for that technique. For example, in the television marketing role-play consultants should recognize that means and standard deviations are of limited value when determining the lower quartile (unless assumptions such as normality can be justified), and so asking for the data is appropriate in this situation.

At least two, and typically four, role-plays are performed per session so that both students in a pair can be a consultant and a client. For most simple role-plays such as those in Appendices A and B a minute or two is sufficient for the client students to read their client sheet and to familiarize themselves with their role (for realism, we do not expect clients even to understand fully their problem!). Both students in each pair read their respective client sheets at the same time in silence before the two role-plays are performed in succession. Anywhere from 2 to 20 minutes are typically allocated to the actual role-play. Experience has shown that students who have not performed role-plays in the past often struggle with what to do initially, and having students

conduct brief 'dummy run' role-plays is quicker and more effective than trying to explain the procedure.

A good role-play mimics a real consultation in that there are multiple layers of questions that can be addressed. This ensures that both weak and strong students are challenged and capable of making some progress during the role-play and encourages the applied skill of determining the precision that is required for an answer. For example, the television marketing role-play has the relatively straightforward objective of determining a lower quartile. Another issue is whether the data are required to determine an exact value of the quartile, whether an estimate is sufficient and how to obtain an estimate from the histogram (answers to such questions typically depend on a student's definition of the quartile and whether they are aware of the numerous alternative definitions which in itself is a useful topic for discussion after the role-play). Furthermore there are other issues for this role-play such as the relevance of the data, informal inference and the fact that the client wants only a numerical answer to put in their report.

The issues that students need to consider for the television role-play are diverse and address the elements of statistical numeracy that were described in paragraph 781 of the Royal Statistical Society (1979) submission to the Committee of Enquiry into the Teaching of Mathematics in Schools:

> 'Statistical numeracy requires a feel for numbers, an appreciation of levels of accuracy, the making of sensible estimates, a common-sense approach to data in supporting an argument, the awareness of the variety of interpretation of figures and a judicious understanding of widely used concepts such as mean and percentages. All these are part of everyday living.'

Most examples and exercises, including examination questions that are currently found in high schools and universities, are easily adapted into role-plays as long as they have some contextual information. Apart from differences in presentation, the key decision is which context information should be in the opening statement and which belongs in the background notes of the client sheet. These decisions are largely driven by the desired level of difficulty for the role-play.

Appendix B contains client sheets for further examples of role-plays at different levels of difficulty and covering a range of activities that are performed by professional statisticians. In the 'Remedial scores' role-play the student client provides the boxed material on a separate sheet of paper during their opening statement. The distinction between correlation and causation is central to this role-play but student clients are not informed of this in the notes. It is easy for student consultants to miss this distinction, especially when confronted with a 'real' person demanding a convincing argument for a plausible but unsupported conclusion. Dealing with this situation is not only part of the 'Professional Entity' but also requires a deeper understanding of statistical concepts. Classroom discussions after the role-play about how to recognize this issue and how to convince the client can also be useful learning experiences. Similarly, the 'Rainfall' and 'Remedial scores' role-plays can be considered by students with no knowledge of inference and are simply role-plays involving the suitability of a mean and the suitability of a simple regression equation respectively. The 'Lunch' and 'Potting mix' role-plays require simple experimental design and inference techniques that are typically taught at university and the 'Toys' role-play involves inference for a problematic situation and is suitable for more advanced university students.

3. Empirical support for the use of role-plays

In this section we present some empirical evidence supporting the use of role-plays. This evidence comes from three sources. First qualitative feed-back from university students over many

years of development and use of role-plays is summarized. Second, the responses of high school students to small written questionnaires that are held immediately before and after a role-play lesson provide some quantitative evidence. Finally, the responses of teachers after attending a professional development evening on role-plays are summarized.

3.1. University students

Role-plays have been used by the author as a teaching strategy in his 'Introduction to statistical consulting' course (Taplin, 2003) for second- and third-year university students since 1999. Students volunteer to participate (substituting for other assessment tasks such as a project) and need only to have completed an introductory first-year statistics course. Fewer than half the students participating are statistics majors. As part of the assessment for this course, students must review audiotapes of their role-plays and critique their performance, including what they did right, what they could do better and what they thought and felt about the role-play. Although intended to assist students' reflection and learning, their comments provide some qualitative insights into role-plays.

Many students indicate that they are initially scared of performing the role-plays, especially as the consultant. These fears are partly driven by fear of the unknown and of failure, and partly by personality. It was for these reasons that role-plays were introduced before real consultations, as they are useful learning experiences and enable students to find and practise their skills and to gain confidence before the potentially intimidating experience of consulting with a real client. After completion of the first role-play most students indicate that once the role-play had started it was not as bad as they had expected. Most students eagerly look forward to the next role-play. Reasons for this include satisfaction that they successfully overcame the challenge, a desire to see whether they can improve on their previous performance and enjoyment at being able to put their knowledge into practice to help someone.

Many students comment that the aspects that they found most difficult were not what they expected. For example, having previously passed statistics courses covering the techniques that are required in the role-plays, they underestimated the difficulty of remembering and applying their knowledge. They also found communicating their thoughts orally more difficult than the written communication which they are more familiar with from their statistics education. Both generic skills such as oral communication and their inclusion in the statistics context are often seen by students as benefits of participating in role-plays.

The role-plays stimulate interest in working as a statistician. Even students who major in mathematics and statistics often have little idea what working as a statistician may involve but the role-plays provide this experience. The role-plays are relatively close to statistical work, and the problems that students encounter while acting as consultants motivate discussion of both the practical application of techniques and other issues such as professional ethics. Having experienced the role-plays for themselves, students are more likely to initiate these discussions.

Students majoring in other subjects such as science and commerce often comment that, having experienced the role of the statistician through role-plays, they have a better appreciation of the statistics profession and how they will interact with statisticians from within their own profession.

It was this qualitative feed-back from many students over many years that led to the use of role-plays in high schools for students without knowledge of inferential techniques. Feed-back from university students suggested that the initial objective of training students in statistical consulting skills was overshadowed by the change in knowledge about, and attitudes towards, statistics and the statistics profession. The second- or third-year statistics courses, where the

relatively few students are already committed to statistics, are not the ideal place to be changing attitudes.

3.2. High school students

Some of the role-play sessions that the author has conducted in schools contained written questionnaires and these are described below. These lessons were conducted in nine classes in four Western Australian schools (two Government and two non-Government) during 2004. The duration of each class varied between 35 and 55 minutes, depending on the length of the timetabled lessons in the different schools. All students were in their final year of high school and currently studying 'Applicable mathematics', which is the middle of three tertiary entrance mathematics subjects and consists of approximately 60% elementary statistics (descriptive statistics, probability and random variables, but with no inference). All students completed two role-plays as consultant and two as client, the initial role-plays ('Remedial scores' and 'Rainfall' in Appendix B) being deliberately short practice 'dummy runs', followed by the 'Television marketing' (Appendix A) and 'Grow young achiever pellets' (Appendix B) role-plays.

All lessons followed the following basic structure (with approximate times for a 40-minute lesson):

(a) introduction—the existence of a statistics profession and what statisticians do, and an initial questionnaire (it includes a brief description of the role of the client and the role of the consultant during a role-play); organize students into pairs (6 minutes);
(b) initial role-plays (two) (3 minutes each);
(c) solutions and discussion of the initial role-plays (2 minutes each);
(d) second role-plays (two) (5 minutes each);
(e) solutions and discussion of the second role-plays (4 minutes each);
(f) questions and second questionnaire (6 minutes).

There were a total of 156 students although 11 students completed only one questionnaire.

Approximately 64% of the students were males, 49% were studying calculus (the most difficult high school mathematics course) as well as 'Applicable mathematics' and 30% had English as their second language. The initial questionnaire administered near the beginning of the class also contained several questions requiring responses on a five-point Likert scale (strongly disagree, disagree, neutral, agree and strongly agree). A summary of the results after ignoring the strength of agreement or disagreement is as follows: 69% of students believed that statistics is useful (3% disagree) but 34% believed that it was boring (20% disagree); 89% believed that it is important for a statistician to be good with numbers (1% disagree) but only 50% believed that it is important for statisticians to be people orientated (10% disagree); 16% would consider working as a statistician (60% would not); 37% believed that their future career would involve statistics (18% did not). Compared with how many statisticians might view their profession, the trend is that these students see statistics as boring, to be avoided and to a degree avoidable in the future, even if they acknowledge that it is useful. Winning the battle of having students believing that statistics is *useful* is rather hollow if students do not perceive that they will actually *use* it.

These students are not taking the weakest tertiary entrance mathematics course and are expected to gain entry to the full range of university studies such as engineering, science and commerce. They have had 12 years of basic statistical education through the chance and data stream of the mathematics curriculum. The trends are that they accept that statistics is useful but find it boring and cannot see their future careers requiring it: one student giving a neutral

Table 1. Response rate by students to the role-plays†

Statement	*Strongly disagree*	*Disagree*	*Neutral*	*Agree*	*Strongly agree*
I enjoyed the role-plays‡	3	14	19	51	14
The role-plays were helpful for learning statistics	3	11	16	58	12
The lesson was helpful for learning about the work of professional statisticians	1	3	11	67	19
I liked being the consultant better than being the client‡	10	26	30	26	9
I was able to communicate my ideas easily	5	24	48	20	3

†$n = 152$ students responded.
‡$n = 151$ students responded.

response wrote 'Engineering?', suggesting that they knew that they would be an engineer but did not know whether statistics was relevant. With regard to the statistics profession, these data are consistent with the view of statisticians as 'calculators of numbers' or sports statisticians. Very few would even *consider* working as a statistician.

Table 1 summarizes the responses by students to statements concerning the role-play lesson. These questions formed part of the final questionnaire that was administered at the end of the class and the responses give some indication of the reaction of students to the class. All the summaries in Table 1 suggest a trend towards the role-plays being received favourably by most students.

65% of the students indicated that they enjoyed the role-plays and only 17% indicated that they did not. Since it is unlikely that any classroom activity will be enjoyed by every student, these results are promising. Having statistics classes that are fun is a worthwhile objective because, despite the impressions of some, we do not set out to make life dull and boring for our students. If our primary objective is good statistical education, however, then having statistics classes that are enjoyed by students is only a means to this end because we expect that students will respond more positively towards reaching this primary objective if they are having fun.

70% of the students indicated that they found the role-plays useful for learning statistics and only 14% indicated that they did not (Table 1, second row). Responses to this question were highly correlated with responses to the earlier question concerning enjoying the role-plays ($r = 0.6$, with 56% of students providing exactly the same response to both questions). Although we do not have a direct measure of whether the role-plays were helpful, the fact that students believe that they are useful is encouraging.

One of the objectives of this role-play lesson was to inform students about the statistics profession and 86% of the students indicated that the lesson was helpful in this regard (Table 1, third row). Since the lesson focuses on students performing role-plays, with some introductory description of the role of a client and consultant and only brief mentions of the existence of careers in statistics and professional societies, this suggests that having students role-play as statistical consultants and clients is an effective way of promoting the statistics profession. A hypothesis of this paper is that having students experience the 'Professional Entity' through activities such as role-plays is an important part of advertising the existence of careers in statistics and professional statistical societies. Although job advertisements and glossy posters from statistical societies may also help, role-plays can be an informative mechanism. There are obvious analogies with students acting as lawyers, judges or politicians in the classroom.

Table 2. Mean changes in student responses (final – initial response) for $n = 144$ students

Statement	*Mean increase (standard error)*	*p*
I would consider working as a statistician†	0.30 (0.08)	0.001
My future career will involve using statistics†‡§	0.33 (0.07)	< 0.001
It is important for a statistician to be good with numbers†‡	−0.73 (0.09)	< 0.001
It is important for a statistician to be people oriented	0.71 (0.08)	< 0.001
Statistics is useful	0.21 (0.06)	0.001
Statistics is boring	−0.19 (0.08)	0.029

†Significantly different means between schools.
‡One school with 13 students displayed a mean with a different sign from that of the overall mean.
§$n = 143$ students responded.

As expected from the likely future careers of these students, there were mixed responses concerning whether students preferred being the consultant or client (Table 1, fourth row). Nevertheless, since 34% of students preferred being the consultant (and almost no students choose to major in statistics at present) there appears to be an opportunity to recruit students into a profession that they are likely to enjoy (only 16% of students indicated that they would consider a career in statistics at the beginning of the lesson). Presumably these students at least take away a positive attitude about professional statisticians and the work that they do.

The last row of Table 1 indicates that students are not confident that they communicate their ideas. This was included because communication is an objective of 'Applicable mathematics' but is often given little or no emphasis compared with the mathematical and statistical content. Nevertheless, it is arguably an important skill for a statistical consultant to have and students who are excellent communicators have a place in the statistical profession as well as excellent mathematicians.

Table 2 summarizes the changes in responses to six key questions concerning the role-play lesson. Values of 1, 2, 3, 4 and 5 were assigned to the Likert scale responses of strongly disagree, disagree, neutral, agree and strongly agree, and the difference (final questionnaire minus initial questionnaire) was computed for each student who answered both questions. For each question, Table 2 reports the mean change (with standard error in parentheses) and two-sided p-value testing the hypothesis of a mean difference of 0. Note that these results potentially overstate the statistical significance since students were not included independently but on the basis that classes within schools were willing to participate in the lesson. Although there were significant differences between schools for three questions, the means for all schools on all questions were consistent with the overall trend direction except for the second and third questions, where one school with only 13 students displayed mean changes with a different sign.

The first two rows of Table 2 indicate a trend towards students being more likely to consider working as a statistician and more likely to believe that their future career will involve statistics. Although statistically significant, this effect is not large in magnitude but was achieved in a single lesson with multiple objectives. Approximately one in three students responded more favourably after the lesson than before the lesson, with most students indicating no change.

The second and third rows of Table 2 demonstrate a large shift away from the notion of statistician as a 'calculator of numbers' without people skills. Although statisticians generally regard their mathematical skills as essential, this raises the debate on both the relative importance of number *versus* people skills (and no doubt other skills) for statisticians. This debate prompts consideration of what most statisticians require and how broadly we define a statistician. It also

requires consideration of what public perception of statisticians is desirable, especially since most people will be in contact with applied statistical consultants or people in other professions with statistical abilities, rather than theoretical (mathematical) statisticians. On average, students placed approximately equal importance on number and people skills after the role-play lesson.

The final two rows of Table 2 indicate small but statistically significant trends towards students finding statistics more useful and less boring after the role-play lesson.

Information was also collected on whether the students believed that key parts of a solution to the role-plays were covered. Although this information was primarily for quality improvement of the role-plays, it did indicate that students generally struggled to find solutions to the role-plays. For example only half the students indicated that it was clear that the lower quartile was required for the television marketing role-play in Appendix A and only a quarter made an estimate of the lower quartile from the histogram. Similarly, for the 'Remedial scores' role-play about half the students interpreted the correlation coefficient as a strong positive relationship but only a quarter that correlation does not imply causation. Although students had less than 5 minutes to perform these role-plays, and some students may go off on tangents considering other aspects of the problems, these are straightforward concepts for 'Applicable mathematics' students.

Despite the limited success by students in finding solutions to the role-plays they still found the role-plays fun and valuable for learning statistics. This suggests that even failing students can find statistics fun. Furthermore, students are indicating that they learn from their mistakes (students' responses to enjoying the role-plays and finding them helpful for learning statistics were not significantly correlated with their ability to provide solutions to the role-plays). Role-plays provide an environment where students can learn from their mistakes in a fun and safe way. They also illustrate the need for role-plays rather than consultations with real clients, where mistakes could be embarrassing and demoralizing for students, and costly to clients. Nevertheless, the evidence that is presented relates directly to students' attitudes and opinions rather than the learning of traditional statistical content.

A few students wrote comments on the post-questionnaire, such as 'erased many misconceptions', 'an excellent lesson' and 'this was a lot more fun than doing Applicable Mathematics'.

3.3. High school teachers

In addition to delivering the role-play lesson to 'Applicable mathematics' students in schools, the lesson was also delivered to approximately 50 mathematics teachers at a professional development evening at Murdoch University. Teachers attending this evening are likely to be the relatively dedicated teachers who are willing to give up an evening outside school time to participate. The lesson was the same as the lesson that was delivered to schools except that teachers only performed two role-plays and some results from the student questionnaires were discussed.

A voluntary questionnaire using the same five-point Likert scale was available for teachers to complete at the end of the evening and 18 teachers completed this questionnaire. All teachers responding to the questionnaire indicated that they enjoyed the role-plays, believed that they were helpful for learning statistics and that they will try using role-plays in their teaching (no strongly disagree, disagree or neutral responses).

Teachers also indicated that they found the evening useful to learn about the work of a statistician. Even teachers who are trained in mathematics often have little appreciation for the work of a statistician and have experiences that are limited more to the mathematical content of the techniques or exposure to the statistical ideas in the media. Although these experiences can enable teachers to demonstrate the general usefulness of statistics they can be insufficient to impart knowledge of the statistics profession and the use that is made of statistics by other

professions ('Professional Entity'). Owing to the difficulty of having teachers complete work experience as statisticians, participating in role-plays that are organized by statisticians may be an effective alternative.

4. Advantages and disadvantages of role-plays

Below is a list of potential advantages and disadvantages of using role-plays based on the author's experience over many years. The list of advantages and disadvantages is provided as a catalyst for discussion and the relative importance of the issues and completeness of the list are open to debate. Most advantages of using role-plays are arguably realized early in a student's education: well before the typical statistical consulting course for post-graduates.

4.1. Advantages

4.1.1. Provide education about the statistics profession and the use of statistics in other professions

One of the most effective ways of educating students about a profession is arguably having them perform the work of these professionals. Role-plays are not real statistical consultations but they come sufficiently close to serve this purpose. Furthermore, they enable students to interact with statistics from both sides of the fence: as statistical consultant and as client. This is particularly important since most students will be future clients rather than consultants. Some students simply need to be made aware that statistical societies and professions exist but this also can be more effectively achieved by having students actively performing role-plays than by reading posters or listening to lectures.

These comments apply to many school-teachers as well as students, making role-plays a useful professional development exercise for school-teachers.

4.1.2. Promote statistical learning

Role-plays provide less focus on mathematical recipes and more emphasis on problem solving in an applied context and statistical ideas such as correlation not implying causality, randomness and sampling, and evaluating the applicability of techniques. For example, teachers can present numerous examples and set written questions where correlation does not imply causation, but these examples can be obvious when the context is explicit and also lack active involvement by the students. This can make the problems unrealistic and relatively trivial. Role-plays, however, require students to identify issues concerning correlation or causation by suitable questioning of the client over the context.

Role-plays also require students to *consolidate* their knowledge (personal communication from Professor Adrian Baddeley): to apply all their available knowledge in sensible and consistent ways, including the recognition of limitations in this knowledge.

4.1.3. Fun and encouraging a positive attitude to statistics

Students and teachers generally enjoy role-plays and this brings benefits to statistics and the statistics profession by association. Some students may enjoy the statistical aspects of the role-play, including applying their statistical knowledge, but some may enjoy non-statistical aspects such as talking or simply playing around. Ironically, even these latter students can come away with a more positive attitude to statistics because they mistake the association between statistical role-plays and fun with causality!

4.1.4. *A different activity for different people*

One of the attractions of role-plays is that they are very different from most classroom activities such as listening to teachers, completing written problems and doing projects: activities that are suited to certain types of students such as introverted thinkers. Role-plays, however, may be a preferred learning environment for extroverted students who are more motivated by helping people with their problems. Role-plays can be a very people-orientated exercise compared with most activities that are found in a mathematical subject.

4.1.5. *Teach generic skills such as communication, teamwork and asking questions*

Although most modern statistics courses will include objectives on communication, in practice this tends to mean written communication. Role-plays involve communication skills between consultant and client in a realistic way. Role-plays also promote oral communication between statisticians and other professions that many statistical consultants see as a major component of their work. These benefits extend to future non-statisticians, who may require the ability to communicate their problem.

Role-plays are also excellent for developing good questioning skills in students. Although the ability to ask a client sensible questions is an essential skill for a statistical consultant it is also a valuable skill more generally. Furthermore, the ability to ask good questions seems to require a deeper understanding of statistical concepts and assumptions. Most education systems, however, encourage and reward students who answer unambiguous questions rather than students who ask questions.

4.1.6. *High impact and motivates future learning*

Role-plays can have very high impact compared with other teaching activities. Students learn from their mistakes, especially when a person is watching and listening to their every move and feed-back concerning errors is provided to both people immediately. Most students are much happier to submit written work that they suspect contains many incorrect answers than to tell someone advice that they are not confident is correct. Furthermore, role-plays can motivate students to learn statistical content that a previously conducted role-play required. Thus role-plays can serve a similar role to the practical example that is often used to motivate a new technique, although in the role-play students actively experience first hand the relevance of the content and the consequences of statistical ignorance.

4.1.7. *Easy to implement*

Role-plays are extremely easy to implement in the classroom. Teachers simply keep track of time and facilitate discussions of the role-plays and possible solution on their completion. My experience is that little effort is required in constructing role-plays because most standard questions lend themselves to role-plays. The main issue is deciding which information is disclosed in the opening statement and which information is withheld to the background notes. Errors that are contained in client sheets, or made by students acting as clients, add realism to the role-play, as clients often misstate their problem and good consultants must identify and deal with such errors. Finally, these simple role-plays can require very little time to perform in a busy curriculum compared with more traditional activities such as projects.

4.2. Disadvantages

4.2.1. *Overemphasize non-mathematical skills*

Role-plays are not well suited to teaching standard mathematical skills. Just because we increase

our emphasis on communication skills in mathematics courses does not mean that we can expect a corresponding increase in numeracy skills in other courses such as English. Similarly, an increase in emphasis on basic scientific ideas (such as placebos and controls) may not correspond to an increase in numerical skills (such as least squares regression lines) in science courses. Mathematical skills are seen as both important generally and to the statistics profession in particular, and any deterioration in these skills is to be avoided.

4.2.2. Discourages some students from statistics

Role-plays may discourage some students from becoming statisticians or from maintaining an interest in and enjoying statistics. For example, shy students may be intimidated by the role-plays and students who are excellent at traditional mathematical skills may lose their comparative advantage in statistics over other students.

4.2.3. Requires time in a busy curriculum

Most mathematics curricula are quickly filled with many competing and worthy topics and there may be no room for role-plays. Either role-plays must be seen as a more effective teaching strategy to replace existing strategies partially to teach existing topics, or existing topics must be at least partially replaced with some objectives of role-plays.

4.2.4. Not always taken seriously

Role-plays are not always taken seriously by all students. They can be an opportunity for students to play around in class as the standard controls on students such as the authority of the teacher and the silence of students are removed. In such cases the role-plays may be fun but ineffective.

4.2.5. Initial role-plays can be ineffective

The initial role-plays that are conducted by students can be very ineffective as students are not familiar with the procedure or what is expected of them. For example, some clients hand over their client sheet (including the background notes) to their consultant to read, and some consultants are either unable to ask questions or lead the discussion away from statistical issues. Although this leads to relatively ineffective role-plays, experience suggests that it is generally only an issue after the first role-play for extremely weak students or students who are new to the English language.

4.2.6. Not as effective as real work experience

Role-plays are not the same as conducting consultations with real clients or real work experience. Although role-plays have been used effectively to introduce advanced university students to statistical consulting by providing a less intimidating and more controlled environment before real consultations they can never be a complete substitute.

4.2.7. Not examinable

Role-plays are not very compatible with most assessment procedures. In particular, most mathematics examinations are written rather than oral and concentrate on mathematical content.

> 'The philosophy of the current questions is more atomistic and encourages an emphasis on teaching and learning individual techniques in isolation and not necessarily in a practical context'

(Holmes, 2001). This can result in role-plays being seen as irrelevant, particularly for students and teachers whose primary objective is high examination marks. For example, even though the Western Australian subject 'Applicable mathematics' states the objectives 'comprehend information in oral and written forms. . . ' and 'communicate mathematical ideas and results in both oral and written forms', these are rarely assessed directly, especially the oral component.

Apart from appealing to the desire by students and teachers to concentrate on useful skills rather than exclusively on examinations, the logical solution to this problem is to modify the assessment. Teachers could evaluate the performance of students in role-plays; however, this can be relatively time consuming and is impractical for examinations. The author has also successfully used examination questions which, after providing an opening statement to a role-play, require the student to provide questions that they would ask the client and the reasons why answers to these questions are important. Although these are effective examination questions because the answers of students display much about their understanding of statistical issues, they are more subjective and difficult to mark than routine mathematical questions.

5. Discussion

Bibby (2003) claimed that

> 'We learn what we *want* to learn—motivation and content are everything, as every good teacher knows'.

Role-plays play a motivational role in learning statistics. They demonstrate the practical importance of statistics by emphasizing the context in which it is used and the fact that clients desire answers to their problems.

Hand (1994) concluded his summary with

> 'It is clear that establishing the mapping from the client's domain to a statistical question is one of the most difficult parts of a statistical analysis. It is a part in which the responsibility is shared by both client and statistician. A plea is made for more research effort to go in this direction and some suggestions are made for ways to tackle the problem.'

Role-plays emphasize this mapping and the collaboration between statistician and client, which is important not only for future statistical consultants but also to the many more students who will be the future clients. Teaching these skills appears problematic as people appear to learn these skills through practice and making mistakes. Teachers may be more effective if they do less teaching and allow students to learn by experimenting, making mistakes and thinking for themselves in activities such as role-plays. Facilitating discussions after role-plays, including mistakes, alternative approaches, ambiguities, useful questions and technical aspects of a problem, may be a more productive role for a teacher of statistics.

The idea of learning through making mistakes is not new. For example Chatfield (1991) discussed the need to avoid big mistakes, provided some ways to ensure this by using several examples and quoted the ancient Chinese proverb 'Through mistakes we can learn the truth'. Although documenting mistakes such as the space shuttle example is valuable, role-plays also make an important contribution if we accept that we learn more from our *own* mistakes than from the mistakes of others.

Many of the skills that were listed by Anderson and Loynes (1987), section 2.2, for statisticians are skills that were developed by role-plays, e.g. 'to work successfully with others', 'to

communicate clearly and efficiently, both in writing and orally', 'to appreciate the fact that in real life an answer must (usually) be found, however imperfect', 'to translate general aims into reasonably specific and realistic problems, e.g. to decide that some factors are relevant and others not', 'to recognize the limitations of one's knowledge', 'to understand what statistics can and cannot do' and 'to recognize which techniques are valid and/or appropriate'. Lists such as these are invaluable not only to determine what we desire to teach but also to characterize what it means to be a professional statistician and then to convey this 'Professional Entity' to students to promote statistical learning and a positive attitude to statistics.

The teaching of generic skills such as communication, teamwork and problem solving is also relevant to students who will not pursue careers involving statistics. As an applied, technical subject with mathematical foundations, statistics can provide a different perspective on these skills compared with other subjects such as English.

Role-plays can be an effective way to introduce statistical methodology. Rather than introducing a topic mathematically, role-plays can introduce a topic with high impact as students without knowledge actively make mistakes as they struggle to discover a solution to the new situation. When students make mistakes because they lack required methodology they can be highly motivated to learn the details of the relevant methodology, including the mathematics. Thus, with respect to the quote in section 1.1 by Moore (1997), it is the *beginning* instruction mathematically that can be viewed objectionably and not the mathematical instruction *per se*. In many cases the high school students were performing role-plays in which the central statistical ideas had not been formally covered in class. This does not appear to have detracted from the value of the role-play.

In summary, role-plays can be an effective classroom activity to introduce, teach and motivate statistical ideas and methodology, to change attitudes towards statistics, to provide a professional entity for statistics and to reinforce generic skills such as communication, teamwork and problem solving. Their use has the potential to shape the future of the statistics profession by not only informing students about careers in statistics or using statistics, but also to focus debate on what it means to be a statistician. Although these debates are not new, they are important and deserve attention from the profession in regard to how statistics is presented to the next generation. They include questions such as 'What do we believe the subject statistics entails and what does it mean to be a professional statistician?'. 'What should students learn as part of their statistics education and when should they learn this?' 'What image do we desire for statistics and the statistics profession?'

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Appendix A: Television marketing role-play

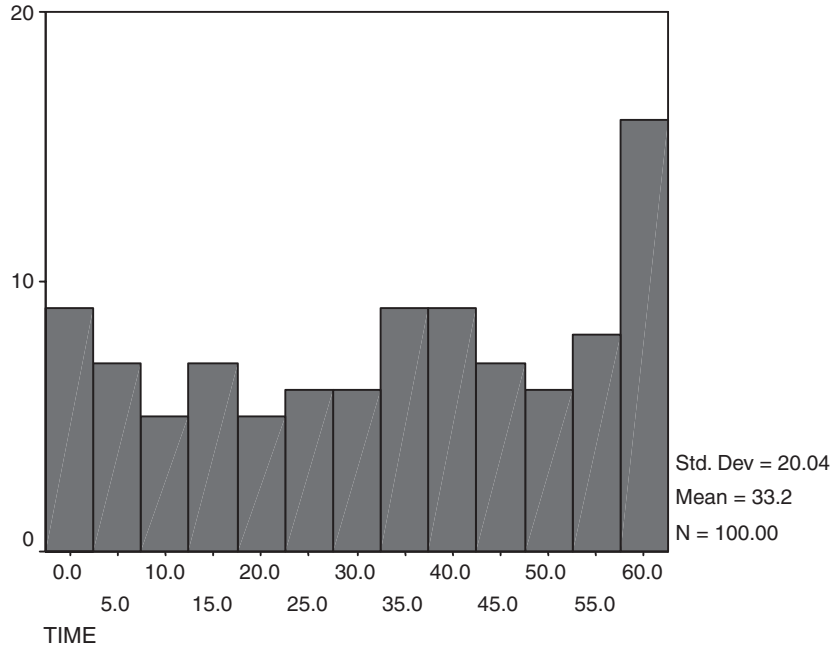
Opening statement

We have a new advertisement that our clients want to run on television. One of the requirements of our contract is that over 10% of people watching television must watch the entire advertisement. To check this

out we have had 100 people watch a television show that included our advertisement and we timed how long they paid attention to it when it came on. The average time that the people watched the advertisement was 33 seconds, the standard deviation was 20 seconds and 13 people watched the entire advertisement, so the 10% minimum requirement is met. Now our client also wants to know how far into the advertisement 75% of the people are still watching. How can we work this out?

Notes

1. The advert lasts for 60 seconds.
2. A histogram of the times is available. *Only* show the graph *if requested.*
3. The last column of the histogram shows that 16 people watched the advertisement for more than 57.5 seconds (13 watched for 60 seconds).
4. The raw data are available, but you do not have them with you.
5. The 100 people were selected from a database of volunteers.
6. The people thought that they were there to watch and comment on a new television show.
7. There is standard methodology to tell when someone is no longer watching the advertisement from their body and eye movements and this standard is accepted in the industry.
8. The 100 people are probably people who are bored, unemployed, like watching new shows etc. but you are not concerned with this. These are the types of people whom the advertisement is aimed at. All you need is the numerical answer requested to put in your report.



Histogram of times people watched the advert

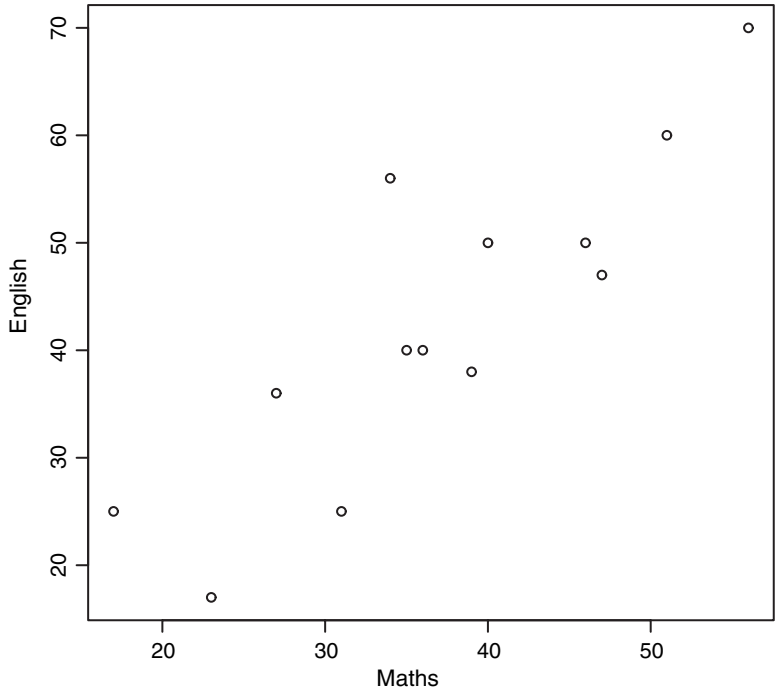
Appendix B: Additional role-plays

B.1. Remedial scores role-play

Opening statement

I am a teacher's aide—I have been brought in to teach remedial mathematics and I want to have the children taught remedial English also. Look at their English scores—you can see that poor English skills cause the low mathematics scores—it is because the children do not understand the questions. . . .

Student	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
Mathematics	23, 34, 17, 47, 35, 51, 46, 39, 31, 56, 40, 27, 36
English	17, 56, 25, 47, 40, 60, 50, 38, 25, 70, 50, 36, 40



Correlation coefficient is 0.86

These are two sets of the children's scores: one on an English placement test, and one on a mathematics test. My friend graphed the scores for me and worked out the correlation coefficient—but I do not know what it means. How can I use these figures to convince the Principal that the children's English skills need to be improved also?

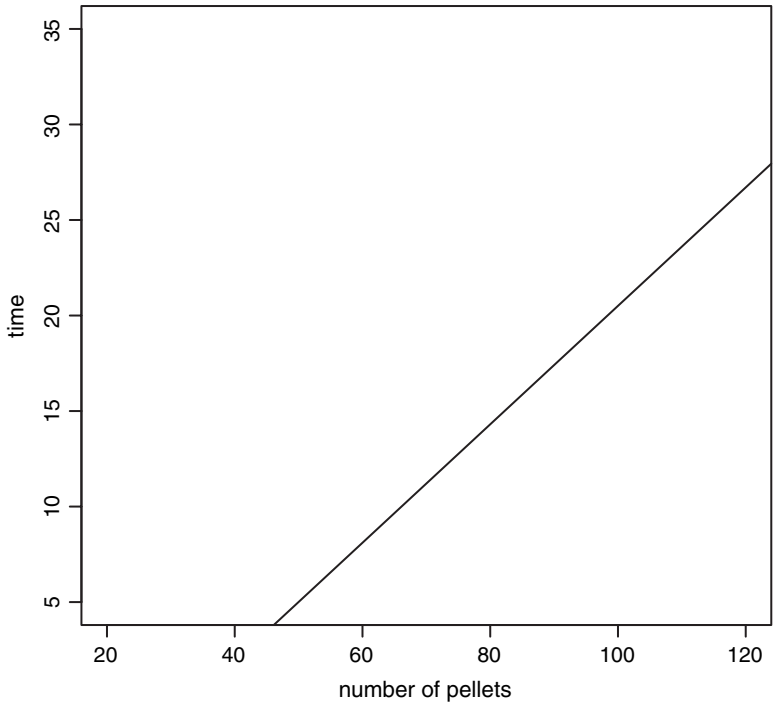
Notes

1. Scores are percentages.
2. There are 13 children. They are all in year 8 and new to the school.
3. The tests are standard tests and the results are reliable.
4. The tests were given under the same conditions.
5. There are no other test results available.
6. The children's first language is English.

B.2. Rainfall role-play

Opening statement

I have been recording rainfall for the past 10 years and have noticed a statistical trend that concerns me. The annual rainfalls that I have recorded are below average eight times in the last 10 years. It seems to me that we are experiencing a drought. Am I correct in concluding that rainfall has decreased?



Grow YA pellets: graph of regression line

Notes

1. You have recorded rainfall at the same position as the official rainfall is measured.
2. If asked, point out that rainfall data are positively skewed. That is, there are a few very high rainfall values (floods!).
3. The average rainfall at this position is 869 mm per year (calculated from rainfall figures for the past 100 years).
4. If asked, the average rainfall of 869 mm per year is an arithmetic mean (but pretend you do not know the difference between the arithmetic mean and median).

B.3. Grow young achiever pellets role-play

Opening statement

I am in the year 11 young achiever (YA) group. We have decided to sell fertilizer pellets and our slogan is 'Grow YA plants with 75 Grow YA fertilizer pellets'. We have borrowed a very expensive machine that can dispense the pellets. The instruction book for the machine only has times for multiples of 20 pellets, so we have put them in the calculator and got a regression line slope of 0.310 and an intercept of −10.494. How can we use this information to predict the time the machine has to run to dispense 75 pellets?

Notes

1. 'Young achievers' is an extra-curricular programme for school students. The students get experience in setting up and running a business.
2. The times are measured in seconds.
3. Assume that times in the instruction book are accurate.
4. Show instruction book times and graph if asked.
5. The machine is very expensive and finely calibrated, so it produces the exact number of pellets for a certain time.

6. 75 pellets are needed because of packaging and cost constraints. In addition it is the school's 75th birthday, so 75 is part of a broader theme.
7. It is too time consuming to do the counts by hand.
8. The machine is slow to start but gets faster.

Pellets	20	40	60	80	100	120
Time	1.53	1.91	3.57	8.05	17.50	34.68

Regression line:
slope = 0.310
intercept = −10.494

B.4. Lunch role-play

I am a university student and I always have my lunch at the university. However, I only have half an hour lunch break most of the time. Therefore, I need to find out which places give me a faster service. I either go to Sir Walter's Café or the Refectory.

Notes
(No notes are provided since this situation is known to students and they therefore can act the part of the client easily.)

B.5. Potting mix role-play

Opening statement
I am an avid gardener but have limited time to spend on gardening. As such, I am interested in knowing which potting mix is best for getting the best growth in seedlings grown from seed. I have done some research through local nurseries and have come up with the three most suitable potting mixes. How should I set up this experiment and how do I gauge which potting mix is best?

Notes

1. The plan is to use only one type of seed for the experiment, probably sunflower seed.
2. I shall attempt to hold all other variables such as water, sunshine, environment and whatever else constant.
3. Seeds are all to be planted at the same time.
4. I do not have a greenhouse.
5. I will be planting only one seed per pot, which is 10 cm in diameter, and intend to use approximately 15 pots.
6. As I am only interested in seedling growth, I plan to leave the seed in the pot for about 1 month before transplanting into the garden.
7. I am interested in the growth and width of the seedling, so my unit of measurement will be a single index of both height and width.
8. The measurement will be taken 1 month after planting the seed.

B.6. Toys role-play

Opening statement
I am a fourth-year Bachelor of Psychology student doing a group thesis. For our thesis we want to find out whether feminism has changed the types of toys girls and boys play with in Perth.

Notes

1. I have gone into the bedrooms of 100 5-year-old children (50 boys and 50 girls) from the Perth suburban area.
2. The rooms can only be bedrooms; otherwise we will not know who owns what toys. Therefore, we only picked kids who had their own rooms.

3. We counted the numbers of types of toys that they play with (see the data sheet).
4. The toy types are dolls, construction (e.g. Leggo), war toys, role-play, cars and dress-ups.
5. We have data from 1969 for comparison.
6. Boys' action figures are classified as dolls.
7. Families were matched with the 1969 data for socio-economic status and number of children.
8. We are going to compare the boys' toys in 1999 with the boys' toys in 1969 and the girls' toys in 1999 with the girls' in 1969.
9. We chose the children by going to pre-schools in the appropriate socio-economic status area and sent out letters asking for permission from parents.
10. We cannot categorize the toys any more than we did because we do not have that information from the 1969 data. For example, we do not know whether they are traditional boys' cars or 'Barbie' dolls' cars.

Data: average number of toys in categories from 50 girls' and 50 boys' bedrooms for years 1969 and 1999

Dolls	*Construction*	*War toys*	*Role-play*	*Cars*	*Dress-ups*
1999 males					
10	20	20	2	25	20
1999 females					
15	2	0	5	5	30
1969 males					
2	10	30	2	30	3
1969 females					
20	0	0	7	0	40

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Discussion on the paper by Taplin

J. L. Hutton (*University of Warwick, Coventry*)

I congratulate Ross Taplin on an unusual discussion paper. It is good to hear about an approach which encourages people to think more positively about statistics, both those who might consider a career in statistics and those who should collaborate with statisticians.

Integrating areas of knowledge is an important contribution that role-plays can make. It is valuable to let students explore how to use data to reach conclusions, what data to collect and how to evaluate the validity of such data. If role-plays can help to produce citizens who have a decent ability to ask questions about reports in the media, or politicians' programmes, then role-plays deserve wide use.

At university level, I think that role-plays could serve to introduce a more substantial project. They should not be seen as a substitute for larger realistic projects. Glasgow University Statistics Department has set a high standard, by expecting all students to carry out a project based on an actual consultation or request from members of the university.

Ross Taplin suggests that role-plays can help to expand the range of meanings that people give to 'statistician'. This is certainly valuable, particularly if problem diagnosis is seen as an opportunity to harness as much of the full power of mathematics as necessary.

Among the advantages that are listed for role-plays is that they are easy for teachers to implement in the classroom, but this could be a disadvantage. A very important role of the RSS Centre for Statistical Education is improving the statistical knowledge of teachers. So, my first question is, 'If a teacher knows almost nothing about statistics, will role-play provide them with more opportunities to make mistakes, or more chance of pupils questioning their remarks?'. Will role-play succeed where projects fail? Or, as asked after the National Centre for Excellence in the Teaching of Mathematics was launched: if 25% of the mathematics teachers are poorly paid non-specialists, how many years will it take to achieve success?

The second question is 'How do you think that top set mathematics high school pupils would react to role-plays?'.

This brings me to aspects of the paper which I found discouraging—the educational research which it cites. I quote:

> 'Recently a new pedagogy has impacted on statistics education: "In practice, the new pedagogy asks us to change what students do from listening and reading to active participation" (Moore, 1997)'.

My mother was a master weaver, and I acquired an interest in the warp and weft of new materials. The 'new pedagogy' is often little different from old ignorance or prejudice. Moore's statement is of the teaching of statistics and mathematics. I was not expected merely to listen and read. Mathematics text-books from over 250 years ago had exercises which the reader was expected to use to deepen their understanding and to develop their mathematical facility. Last year, I had two local educationalists insisting that children should *not* be expected actively to solve many examples for themselves.

Moore dislikes the mathematical foundations of statistics, as does almost every educationalist I have read or spoken to. Did you notice that basic statistical principles are often abandoned when indulging in educational research? For example, Hunt (2000) interviewed nine statisticians: why nine?; which nine? None of the nine went to universities to train as statisticians, but Hunt makes very general statements on the basis of these nine people. My own experience has shown me the hostility of many educational researchers to rigorous statistical design. At a joint Royal Statistical Society Medical Section and Education Strategy Group meeting, educationalists claimed that randomized controlled trials of school-teaching are unethical and impossible, despite their use in medicine. It seems rather improbable that research which is hostile to mathematics and method will help to recruit good mathematicians.

I am glad that Taplin recognizes the need to include good mathematics. Mathematics is the most powerful tool that we have, and it is folly to discard it. It is particularly foolish to disparage what is essential to your profession and way of life: mathematics underpins bridges, cars and computers.

We certainly do need statisticians to be able to communicate, but perhaps we should not be so critical of ourselves. A physiotherapy colleague who has taken several modules on Sheffield distance Masters courses told me she did not understand this fretting. She found her fellow students, statisticians, very articulate. I had three mathematically excellent second-year undergraduates working on historical data. They impressed the historians by their questions and insight, despite two being from mainland China and the data being on concentration camps in South Africa over a century ago.

Finally, thank you for taking the time to consider creative approaches to teaching, and for coming from the other side of the world to tell us about them.

It gives me great pleasure to propose the vote of thanks.

Dave Collett (*UK Transplant, Bristol*)

One of the key themes of the Society's conference in Belfast is the communication of statistics. The conference programme notes that progress in the implementation of novel statistical techniques is limited by the ability of statisticians to communicate such powerful methods to those who are responsible for their implementation. A more fundamental problem in the UK is the shortage of young people who are studying statistics at school or university. A discussion paper that addresses these issues is therefore particularly welcome.

In his cogent review of the literature in this area, the author summarizes many points stemming from papers on teaching and consultancy that have appeared in the last 25 years or so. During this time, the Society has been very prominent in the development of statistical education, most notably through the Centre for Statistical Education. However, there have been very few occasions where there has been an opportunity to discuss a paper on this topic at an Ordinary Meeting. Two exceptions were the Ordinary Meeting in 1994 on translating consultancy problems into statistical questions (Hand, 1994) and the more recent meeting that focused on teaching in schools (Holmes, 2003). Before these, there had been a discussion meeting in 1973 at which two papers were presented: one on statistical games (Mead and Stern, 1973) and one on the use of computers in the teaching of statistics (Evans, 1973). In view of the developments in this area since then, these papers and the published discussion make very interesting reading!

It was recently suggested to me that statisticians have a level of popularity that is enjoyed by time-share salesmen, but certainly some of the skills of the time-share salesman are needed in persuading others to adopt new statistical procedures. For this to be a success, statisticians must work in partnership with professionals in other disciplines, with each party respecting the views of the other. The skills mix that is needed for this cannot be learned from lectures or project work, but only through exposure to real problems and educational techniques that have been developed by Ross Taplin and others.

One of the main concerns I had on reading this paper was how sufficient time can be found for this in the already crowded General Certificate of Secondary Education syllabuses of the UK, and first-year degree programmes in the mathematical sciences. Although classroom role-plays are carried out concurrently, it is important not to underestimate the inherent management problems.

The author's descriptions and illustration of role-play envisages face-to-face contact, with the consultant patiently exploring the nature of the client's problem before arriving at a possible solution. In my own experience, medical consultancy often happens at a distance, supported by modern communication facilities. Often, substantive questions arise in discussions with clinicians or originate from an e-mail enquiry, with little opportunity to define the problem through face-to-face contact. This means that the statistician will quickly need to pick up the nature of the client's problem, specifying it more fully in a mutually understandable language via e-mail, and iteratively seeking to define the problem and the proposed method of solution fully. What skills are needed here? Certainly a broad knowledge of statistics is, but also a deep understanding of, and interest in, the context of the problem. The necessary skills for this can be developed through role-play, but this would need to be supported by more generic development of communication skills. Other necessary training includes experience of open-ended data analysis exercises that dwell on study design as well as the analysis of real data sets, and exposure to situations where statistical strategy is required.

The success of role-play depends on access to problems that are likely to motivate groups of students. These need to be real problems with real data, and so I regret that the examples of role-play that are given in Appendices A and B lack an element of realism. The development of material for role-play requires those in education to work with statisticians and analysts outside academia—and employers have a responsibility to support this. In what other ways can employers help in generating an enthusiasm for the subject and the training of statisticians? Financial support for Master of Science programmes is of course essential, but not always possible. A willingness to attend careers presentations and to provide data that can form the basis for project work and dissertations is another way forward. It is now common for General Certificate of Secondary Education students to spend a short amount of time on placement in an organization, and so this presents another opportunity for those outside the teaching profession to motivate statistics.

The paper describes one way of developing an interest in, and appreciation of, statistics. The benefits are clear, although I am not entirely convinced of its practicality in the UK education context. However, I am very pleased to be able to second the vote of thanks to the author for providing a most interesting paper, and the opportunity to discuss a topic that is of fundamental importance for the future provision of statisticians.

The vote of thanks was passed by acclamation.

Jim McNicol, Chris Glasbey, Mark Brewer, Graham Horgan, Iain McKendrick and David Elston
(*Biomathematics and Statistics Scotland, Edinburgh*)

We found this paper interesting and stimulating. Biomathematics and Statistics Scotland employs around 30 statisticians and mathematical modellers who commit between 10% and 100% of their time to consultancy in agricultural, biological and environmental research. Attracting appropriate staff and developing their consultancy skills are two challenges that we face continuously.

We would like to broaden the discussion by considering extensions to more advanced levels, which would bring several benefits in addition to those described by Taplin. If carried out in front of a mixed peer group of statisticians and scientists, these exercises will expose both groups to the challenges and benefits of interaction between disciplines. This may encourage more students, from both groups, to pursue a career in statistics and modelling, and more, as professional scientists, to pursue collaboration with other disciplines.

Consultancy exercises at this level need to incorporate the following: the importance of establishing common ground between the scientist and statistician to ease the flow of the technical discussion; agreeing the purpose of the consultation, for example whether it is a one-off or the start of a series of discussions; defining appropriate and realistic scientific objectives; defining a corresponding level of statistical sophistication; who will be carrying out the data analyses; and concluding with a summary of what has been agreed.

The role-playing exercise itself would, we feel, benefit from greater realism, e.g. by involving, as the client, a student scientist with real, but straightforward, scientific data. An alternative would be to use professionals for both roles, perhaps even practitioners from outside the university system. In either case we suggest a mixed audience of statistical and scientific students would best achieve the dual training benefits that were mentioned above. In particular, training for the two sides in the skills that are required to facilitate information flow back and forth between the scientific and statistical arenas will be most effective where there is potential for a genuine lack of understanding on at least one side. Shared experiences and background make consultancy easier: one purpose of the role-play is to teach skills on which to draw when these advantages are not present.

As potential employers we encourage the incorporation of non-technical training of this type into university courses to improve the transferable skills of potential employees and clients alike.

Chris Chatfield (*Bath University*)

Personal attributes, such as problem solving skills and an ability to communicate both orally and in writing, are at least as important as technical skills. I am therefore delighted to see a paper devoted to improving such skills. I have not tried role-plays myself, but the approach looks promising and I will be interested to hear how it works on students of varying abilities.

Alternatives to role-plays include sitting in on a real consultancy, but this is not always practicable and, in any case, the student only observes rather than actively participates. For many years, I have given a final year undergraduate course on applied statistics that is assessed 100% by course work rather than examination, and the reader may be interested in various simple stratagems, complementary to role-plays, that I have adopted to try to improve problem solving skills.

In a classroom situation, I will typically present a real problem to the students and ask for questions as well as suggestions as to what to do. Unfortunately, apart from the occasional extrovert, I usually find students lack the confidence to say anything out loud. I therefore ask them to talk together in small groups (two or three) and then to come back with questions or suggestions. This often produces some results, though still less than one would like. So I then ask each group to appoint a spokesperson to make at least one constructive comment on the particular problem.

When stating the problem or setting an individual written exercise, I sometimes try to make the problem deliberately incomplete or even wrong in some respect. This makes students more ready to ask questions, especially if you tell them at the beginning of the course that this may happen sometimes. You could, for example, provide an imprecise objective or ask them to analyse a sample size 20, but only provide 19 data points. This mimics real life where problems are typically posed in an ill-formed state and may contain errors.

When marking course work, I expect it to be written clearly and presented attractively as well as being statistically sound. I expect an attractive cover page with grammatically correct text and clear graphs and tables. I advise students to use a dictionary (to ensure good spelling) and a thesaurus. I give plenty of written feed-back, especially on the first project. I also ask all students to make an oral presentation to a small group of fellow students, in a non-threatening atmosphere, using appropriate visual aids. I like to

think that most students will be more self-confident and better prepared for the real statistical world at the end of the course, and I am sure that today's author has the same goal in mind.

Stephen E. Fienberg (*Carnegie Mellon University, Pittsburgh*)
I add my congratulations to Dr Taplin for a provocative paper and a stimulating presentation. As he notes, the idea of role-playing to emulate a consulting situation is but one instance of what has come to be known as active or activity-based learning and it has been the focus of considerable attention as part of the new pedagogy on teaching. This is an old idea of course, and statistics instructors have been using physical devices to illustrate sampling and other ideas for close to a century. Many books and articles beyond those that Taplin cites are devoted to the topic, although few deal with the role of consulting, especially in the context of introductory courses. In the hands of an enthusiastic instructor such as Taplin, and with something close to real examples, I can see how students would find the activities engaging and informative.

At Carnegie Mellon University, active learning often means computer-based exercises with real data sets, sometimes in a laboratory and sometimes not. For example, my colleagues Joel Greenhouse and Oded Meyer have worked with psychologist Marsha Lovett to develop and test an 'intelligent' statistics tutoring system, *StatTutor*, designed to help students to learn to solve data analysis problems by giving immediate feed-back flexibly, offering hints when students have difficulty and reiterating a general set of statistical problem solving steps. These 'scaffolding' tools can be reduced depending on the student's changing needs (see Meyer and Lovett (2002)).

Another kind of active learning involves projects. In an undergraduate semester long course, 'Sampling surveys, and society', students work in groups of four to do a complete survey project—beginning with the formulation of a question that can reasonably be answered by carrying out a sample survey, and moving on to questionnaire design, pretesting, human subjects approval, field implementation including follow-ups for non-response, data analysis and reporting, both orally to the class and in a written report. Groups meet outside class throughout the semester and students keep logs of their activities. This work often involves consulting with a real client and not simply role-playing.

For me the real questions of interest are

(a) do the role-playing exercises actually promote statistical learning and motivation, and
(b) if there are sufficient gains, how can we integrate the approach with other forms of active learning?

The paper reports some reactions, but largely in anecdotal form, and it is difficult to assess the claims without further systematic evaluation and assessment.

Christian Hennig (*University College London*)
I congratulate Dr Taplin for his very interesting presentation.

I am convinced that role-plays could enrich my own classes. However, I think that the use of role-plays requires a particularly open-minded attitude of the teachers.

Teachers must be willing to listen to their students properly, and they should not mainly concentrate on imparting a predefined 'correct' solution. Because reality is always much more complex than work with numbers and formulae, it is quite likely that some students will come up with surprising ideas and arguments that deviate from the predefined correct (or 'expected-as-correct') treatments of the consultation problems. To ignore or not to esteem such ideas properly can be very frustrating and the students may feel that it is just a usual statistics exercise that is wrapped up in a different way.

Therefore, teachers in general, but particularly those who use role-plays, should know and accept that in such set-ups, as in the real world, there is not just one correct answer which has to be learned, and that it is quite worthwhile to try hard to find valuable thoughts in the student's contributions from which even the teachers may learn something unexpected.

David J. Hand (*Imperial College London*)
Anything which can help to rescue the image of statistics from its unfortunate lay perception and to drive home the reality of its excitement and rewards must be a good thing. This is true for the discipline of statistics, obviously, but it is also true for those individuals who are completely unaware of this reality and who, as a consequence would never contemplate a statistical career and who would therefore miss out on so much. Opening their eyes can serve only to benefit everyone.

About 20 years ago I became interested in 'statistical strategy'—how one formulated the approach to a statistical consulting problem, including refining the question, choosing appropriate techniques and

communicating results to clients. As part of that work I recorded, transcribed and studied interviews between statisticians and their clients (see, for example, Hand (1986)). It became clear that consultancy sessions did have a structure. I think that one can then teach the steps in such a process in traditional ways (including exercises: 'what are the key things you need to know to be able to answer the client's question?'), and that this may be more effective than the inevitably largely trial-and-error approach of role-play.

The key question is whether the limited time that is available for teaching the students about the reality of modern statistics is most effectively spent in role-plays. For example, I give a 50-minute presentation to our 250 first-year mathematics undergraduates, towards the end of their first statistics course, in which I try to convey the excitement, challenge and opportunities that are available in statistical careers. As I put it in that talk, I distinguish between the foundations of statistics (what the body of the course is about) and the practice of statistics (which is what I talk about). In my 50 minutes I can cover many more exciting real examples than one could in 50 minutes of role-play. Moreover, my examples are selected and tuned—I can effectively guarantee that the students will not waste time on false trails but will be intrigued and impressed by the examples. However, I think that role-play has some advantages over lectures. For example, learning that one does not always have all the answers, and how best to cope with this, is a key skill which cannot be taught by a lecture. Perhaps we need a properly designed statistical experiment to explore the time-effectiveness of the two approaches.

David Draper (*University of California, Santa Cruz*)
Before reading this paper my view was that

(a) everybody agrees problem formulation is a key statistical skill but
(b) nobody seems to know how to teach it, except perhaps by having students watch experienced consultants in action and hoping that something clicks in their minds.

The author has made a convincing case for the value of consulting role-plays in statistical education; perhaps this is indeed one way successfully to teach problem formulation. In the spirit of sharing ideas for how to solve this difficult pedagogic problem, I offer three other suggestions.

(a) When first working with a consulting client, along with the obvious goal of ensuring that the consultant fully understands what the key questions are, it helps to make a detailed effort to *visualize the raw data* (e.g. as a matrix with rows for subjects and columns for variables in a regression setting, and with the nesting or clustering structure clearly delineated). Much successful applied statistical problem solving seems to involve two steps: keeping a library of problem templates in one's head and trying to match the current problem to a previous template, and using the best match as a starting-point in iterating towards a solution. With this in mind, once the data resources are visualized and the key questions are clear, the consultant can make a similarity judgment of the form 'This data set reminds me of something I worked on 2 years ago, with comparable key questions', and the process of template matching is off and running.
(b) I learned the last two suggestions while working with two wise old hands at the Rand Corporation, Dan Relles and Emmett Keeler. On a big consulting project that will lead to collaborative publications, it is extremely helpful to do the following.
    (i) (Relles) Set up the computing environment in anticipation that all the analyses will have to be done again two or three times before they are completely right.
    (ii) (Keeler) At *design* time, plan what the final results tables will look like in the published papers (months in the future), and simultaneously work out a data gathering programme, and an analysis plan that will successfully yield those results tables if the effects you think are there really *are* there. Of course, other findings will also arise in the analysis and you have to be sufficiently flexible to take advantage of them when they appear, but, if you have not planned from the start how to go from the initial data to the main results tables, you are in danger of gathering a data set that is incomplete or that you do not know how to analyse.

A good place to find more statistical consulting wisdom from the Rand Corporation is the illuminating volume of case-studies edited by Morton and Rolph (2000).

Douglas Zahn (*Tallahassee*)
I agree with Taplin's summary statement that role-plays have 'the potential to shape the future of the statistics profession by ... focus(ing) debate on what it means to be a statistician'. My thoughts on his three concluding questions are as follows.

What do we believe the subject statistics entails and what does it mean to be a professional statistician?
The heart of statistics is statistical thinking:

(a) all work is done in systems of interconnected processes;
(b) there is unwanted variation in every process;
(c) the key to success is to understand and reduce this variation.

A professional statistician is someone who applies statistical thinking to improve systems and/or does research to discover new applications. This person uses psychology to recognize and resolve breakdowns that are a natural part of statistical practice.

What should students learn as part of their statistics education and when should they learn this?
In their first course students should have the opportunity to discover how statistical thinking relates to their career goals. Active learning tools such as role-plays are essential if this objective is to be achieved. They should learn enough to be able to make an informed choice between becoming a statistician or becoming a professional in another discipline who will utilize statistics.

At the end of their undergraduate programme or in their graduate programme they should take a statistical consulting course that focuses on the interpersonal and intrapersonal challenges of statistical practice. Videotaped role-plays that are subsequently coached in the classroom are the heart of this course. In this way students can learn to recognize and recover from the breakdowns that they encounter. Videotaping is essential if we are to model that we value primary data over memory.

Of course, students should also learn enough statistics and mathematics so that they can be lifelong learners of statistics. The technical aspects of our profession are essential. However, asking which is more important for professional success, technical skills or relational skills, is like asking which is more important for walking: one's right leg or left leg. Both are essential if one is to complete the job!

What image do we desire for statistics and the statistics profession?
Statistics is seen as a discipline that can be used to improve any system. The statistics profession is viewed by other professionals and the public as a set of individuals who add value to every project in which they are involved.

The following contributions were received in writing after the meeting.

Herman J. Adèr (*Huizen*)
It may be argued that the term 'statistician' in the sense of 'research consultant' is a misnomer. This is, maybe unwillingly, demonstrated by the last paragraph on page 270 in Taplin's paper where Hunt (2000) is quoted as having interviewed nine statisticians, *none of whom went to university to train as a statistician!*

In many cases, a consultant's job consists in finding out what the client really wants (or should want!) by asking the right questions. As such, the trade resembles that of the old-fashioned detective. The consultant should use his or her 'grey cells' more than his or her toolbox of statistical tricks. That must be the reason why Chatfield (1995) called his book on advising *Problem Solving*.

This is not meant to belittle or restrict Taplin's important contribution: on the contrary, since the consultant's job is so much that of a problem solver, role-plays could be used in all situations where scientific thinking must be trained.

Reading Taplin's paper, I was easily convinced by his argument: maybe too easily, because I am not impartial. We tested material for Adèr *et al.* (2007) by using exactly the same kind of role-play to train students of research methods for a future role as a consultant. And we are as enthusiastic about role-plays as he is. So were the students: witness the high evaluation marks that we received.

I have two critical remarks at the end. I doubt whether the research methods that were used to provide empirical support for the use of role-plays would have passed the scrutiny of the reviewers of, for instance, the *Journal of Educational Measurement*. Specifically, my reservations concern

(a) the judgmental sampling that was used in all three studies which could lead to favourable outcomes and
(b) the construction of the questionnaires, which seem to contain leading questions.

All the same, this is an interesting paper about a highly relevant subject. I hope that the message will be heard by all those teachers who desperately try to convey the subtleties of statistics or maybe even research methods.

Penelope Bidgood and Rosie McNiece (*Kingston University*)
First, we thank the author for a highly enjoyable delivery of the paper and the opportunity to engage in the activity of role-playing, both as client and consultant.

The paper argues that role-playing of statistical consultations is useful in teaching statistical methodology, encourages statistical thinking and problem solving and helps students to gain insight into the profession. These are all worthy aims.

In the examples that were given in the lecture (which we must presume to be typical) we were given very little time to come up with a 'right' answer. The client brief and client–consultant questioning session might reflect an initial consultation, but the student consultant has little time to think through his or her response and the implication is that the student client has the right answer. Quick solutions are appropriate in some circumstances; however, in our experience, statistical consultancies generally require a more measured response.

We agree fully that students should be encouraged to think about statistical techniques in relation to the context of a problem. In the hands of skilled and experienced teachers, role-plays of statistical consultancies may be a useful addition to the variety of learning and teaching methods that students experience. This methodology could encourage students to think about the appropriate statistical techniques to use in the context of a particular scenario.

However, we are not convinced that role-playing as described in this paper would be a major pedagogic methodology, but possibly one to be used to add variety to students' learning experiences. There are many other ways in which students can gain insight into the profession, although we would not rule out role-playing as a technique that might enrich statistics teaching.

Adam Butler (*Biomathematics and Statistics Scotland, Edinburgh*)
My contribution stems from my perspective as a young statistician who has recently completed a doctorate in environmental statistics, and whose current work at Biomathematics and Statistics Scotland involves a mix of consultancy, training and applied research projects. Taplin convincingly argues that role-plays can play an important role in statistical education by prompting students to engage in statistics as an active rather than a passive activity, and I feel that, for similar reasons, there is also plenty of scope for more actively engaging undergraduate and post-graduate students in the practical difficulties of statistical work via the wider use of work placements, group work and interdisciplinary projects. Exposure to substantive applications is, in my view, a crucial aspect of this.

My own interest in working as a statistician arose initially from a period of summer work experience in an ecological research institute and was subsequently developed through working on collaborative interdisciplinary projects for both my undergraduate dissertation and my subsequent doctoral thesis. I have found two aspects of these and my current projects to be particularly stimulating and rewarding—the ability to engage with scientists who are passionately interested in their subject and the ability to work on problems that have some clear potential benefit to science, policy or society. The applied work has motivated me to learn more about the theoretical aspects of statistics and so has tended to complement—rather than to displace—the mathematical aspects of my statistical education. Such experiences have also been invaluable in providing me with many of the technical and non-technical skills that I need for my current job, although I have found that the jump from a doctorate into a consultancy-orientated role remains challenging—the task of assessing the size, difficulty and length of a potential project is an aspect that I have found particularly difficult, partly because in the context of a thesis or dissertation this is an element that has usually been dealt with in advance.

My impression is that role-plays, work placements and interdisciplinary student projects are still comparatively rare in statistics—at least relative to fields such as engineering and management science, where they seem to be regarded as an essential aspect of the educational process—and that students' enthusiasm for our subject could probably be improved through the more widespread use of these techniques.

Philip M. Dixon (*Iowa State University, Ames*)
Dr Taplin presents some intriguing ideas on long-standing and important issues. When I chat with employers about the skills that they need in their Masters or doctoral level statisticians, the top three skills are usually technical competence, problem solving ability and communication. The degree programmes that I am familiar with, mostly in the USA, spend considerable time developing technical competence, some time developing problem solving ability and very little time developing communication skills. An old and humorous illustration of poor communication is the anonymous anecdote in *Biometrics* (Biometrics,

1949). Because good communication is so essential in statistical consulting, role-plays are frequently used to train consultants. Dr Taplin shows another use: to motivate the relevance and importance of statistics to high school and undergraduate students. These are difficult groups to teach statistics to. It is much easier to teach statistical methods to graduate students who will soon design experiments, collect and analyse data, and justify conclusions in their thesis research. If role-plays do demonstrate the value of statistical thinking, reduce negative stereotypes about statisticians and increase interest in statistics as a career, they deserve a place in the curriculum. The pre-post-analysis in the paper is suggestive but it confounds the effect of role-play with the effect of novelty, i.e. doing something different in class, and the Hawthorne effect, i.e. a response simply because subjects are being studied. Finally, I want to highlight the difficulty in 'starting' role-plays. Our experience in the Ordinary Meeting was consistent with my experience in participating in and organizing role-plays. Some participants figure out the instructions and use the role-play time productively. Other participants are completely lost, even after considerable discussion of the instructions. My experience is that this diversity is characteristic of most participatory activities, but it seems especially common in role-play exercises. The suggestion to run a short 'warm-up' role-play is appealing, not only for role-plays.

Helen MacGillivray (*Queensland University of Technology, Brisbane*)
Apart from the explicit interest of the role-playing strategies and Dr Taplin's fine balance of reporting, commentary, references and reflection, there are implicit aspects of the paper that are important for the statistical profession in learning and teaching development and in linking across educational levels and across disciplines. These include linking the practice and thinking of statistics with real contexts that are meaningful to the level of the particular student cohort, a holistic approach that integrates specific and generic skills in problem tackling, the value of increased direct contact between teachers and professionals, and the importance of purpose and coherence in curricula and assessment (MacGillivray, 2005).

Dr Taplin's excellent account of his journey in developing an aspect of real statistics into a learning and teaching strategy, and adapting it for more than one educational level, has parallels in work across the statistical education community, such as the statistical investigation cycle based on Wild and Pfannkuch (1999) (`http://www.censusatschool.org.nz/resources/statistical-investigation/`), the Royal Statistical Society's international AtSchool projects (`http://www.rsscse.org.uk/activities/atschool.asp`), industry links (Martin, 2006), community outreach (Jersky, 2002; Thorne and Root, 2002), statistics in the media (Watson, 2004) and own-choice group projects in introductory data analysis (MacGillivray, 1998, 2002) and introductory probability modelling (MacGillivray, 2006).

Briefly, the own-choice group project strategies in data analysis started as a practical data learning experience, but developed since 1994 into whole semester parallel activities involving the planning, carrying out, analysing and reporting of a real, many-variabled data investigation in free-choice contexts. In introductory probability modelling, students choose everyday real stochastic situations for their data collection and assess Poisson models. The success of such strategies in student learning and effects on curriculum development are multifaceted, multilayered and far reaching, but their success in student engagement is simple—it is student ownership. However, any learning strategy 'can degenerate . . .' if it loses touch with its statistical roots and its learning objectives and becomes a pedagogical artifice. Efficient and effective management and balance of time and assessment are also essential for the fruition of the combination of strategies that are selected for the teaching and student situation. For example, the own-choice projects work excellently in large tertiary courses but need care and thought in designing the overall learning and assessment package.

As with the role-plays, certain aspects of these projects are also providing valuable strategies for schoolteachers, particularly in middle school in introducing thinking about variation. In adding to the rich armoury of teaching strategies, and interacting directly with teachers, statisticians like Dr Taplin are contributing significantly to the standing of the statistical sciences.

The **author** replied later, in writing, as follows.

I thank all the discussants for their contributions on role-plays, extensions and alternatives, and to Douglas Zahn for providing direct answers to my final three questions. These discussions on attitudes towards statistics and what statistical ideas are taught to students (and when) are important. I hope that our professional societies continue to encourage these debates and sharing of ideas. I thank the Royal Statistical Society for organizing the discussion on my paper and the audience for their enthusiastic participation in my role-plays.

I believe that Christian Hennig partially answered Jane Hutton's question concerning the use of role-plays by teachers who know little statistics. Role-plays require open-minded teachers who are willing to explore many possible solutions to ill-defined problems and who know their statistics sufficiently well to cope with a less structured or controlled learning environment. Teachers who know almost nothing about statistics are unlikely to implement role-plays successfully in their classes and having teachers trained in what they teach is a priority. Teachers can, however, gain from participating in role-plays as part of their professional development. Not only can this reinforce statistical content but teachers enjoy role-plays and they provide a professional entity.

Jane Hutton also asks whether role-plays will succeed where projects fail. Perhaps they can because they emphasize slightly different skills such as two-way oral communication compared with some project work such as the student-owned projects that were described by Helen MacGillivray. Role-plays are livelier and so appeal more to students who prefer to talk than to read or listen in class. Although I developed role-plays partly from a feeling that projects are inadequate, I continue to use projects extensively. I believe that variety in teaching is most important, but perhaps it is no surprise to hear that a statistician loves variation!

To answer Jane Hutton's second question, I have no evidence that the better high school mathematics students respond to role-plays differently. I expected them to respond less positively, if for no other reason than they may lose their comparative advantage in more theoretical mathematics. The 'Applicable mathematics' high school students responding to my survey also included students doing double mathematics (advanced calculus as well) but they did not respond to the surveys in significantly different ways.

Jane Hutton criticizes the new pedagogy. My understanding is that the new pedagogy demands activities in addition to lectures and having students reading and solving problems themselves. Unfortunately, good ideas are often bad ideas when taken to extremes. This is why I restrict role-plays to less than 5% of teaching time: any more and we know that we lose significance. I expect that we all have examples of where students either excel or fail in communication. I am more concerned with perceptions of statisticians in this regard than the reality, and Jane's physiotherapist colleague may see no problem because she interacted with the reality. I wonder what would first-year physiotherapy students who have not interacted with statisticians believe about statisticians?

Dave Collett and Philip Dixon express concern with management problems when using role-plays. I quickly discovered that attempting to explain role-plays is fruitless. People performing role-plays learn much quicker, which is why I usually allow little time for a first role-play. Unfortunately I only had time to allow the audience to complete a first role-play each when I presented my paper to the Society, and I made the mistake of overestimating how well the audience may understand role-plays from previously reading about them in the paper. I apologize to Penelope Bidgood and Rosie McNiece who desired more time to attempt the role-plays. The purpose of this presentation was not to give a 'lesson' by using role-plays, and time permitted only a taste of what they are like. Role-plays are open-ended exercises and there is no expectation of 'right' answers as these depend on directions that are taken by the consultant and client.

Dave Collett, Jim McNicol and his colleagues, Adam Butler and Steven Fienberg found the role-plays lacked realism and real data, and some discussants suggested improvements for the training of graduates. This paper specifically avoids the training of graduates and concentrates on students who have not yet committed to a career path. Although more difficult, this is where we may have more potential to influence attitudes to statistics simply because more students are exposed and form opinions about statistics at this level. Do these discussants believe that using simple role-plays with young students is detrimental or are their comments a reflection of their interest in graduate students of statistics? Role-plays based on more realistic examples may be suitable to advanced students but are likely to be unrealistic, irrelevant or simply incomprehensible to less-educated students. Realism and relevance are very different for a high school student who dreams of playing football! Some of the role-plays were simplified to concentrate on specific statistical content that is found in high school courses, and to be quick. As several discussants pointed out, this is an important feature if role-plays are to take their place in a crowded curriculum.

David Draper recognized the potential of role-plays to help to teach the important skill of problem formulation, but like me he is unaware of many other activity-based exercises for this purpose. Chris Chatfield provides strategies such as role-plays with the teacher acting as a client (see 'panel of experts' in Taplin (2003)) to improve problem solving and communication skills. I believe statisticians have plenty to offer when it comes to teaching these generic skills to students generally and not just statistics graduates. They are closely related to the statistical literacy that we desire of high school students (hopefully not to the detriment of mathematics).

David Hand is concerned with the time that is taken to perform role-plays and feels that his 50-minute lecture towards the end of a first statistics course may be more effective at conveying 'the excitement, challenge and opportunities that are available in statistics careers'. Do we not wish to convey this with activity-based learning throughout our teaching of core objectives and not just one presentation near the end of a course? Rather than students wasting time on false trails, I find educational value in their making and learning from their mistakes occasionally. Other discussants such as Douglas Zahn believe that active learning tools are essential. Role-plays are not a substitute for the lectures of David Hand, but a quicker alternative to having students be statisticians through projects or job placements. Finally, I agree that the steps in the statistical consulting process should be taught rather than relying on role-plays alone.

Philip Dixon suggests that the positive response by students to role-plays may be due to novelty or the fact that the students were being studied. I am confident that this represents a significant portion of the observed effects. With regard to novelty, perhaps this is partly why there has been a call for 'a variety of activities', and the positive responses of students is evidence that they find role-plays a very different activity. Regarding the Hawthorne effect, if the apparent improvement in students' attitudes towards statistics is due to studying students then I suggest that statisticians need to study students more!

Jane Hutton complains of the lack of statistical science in education generally, and Philip Dixon, Steven Fienberg and Herman Adèr point out that evidence for role-plays in this paper is statistically weak. So why would a statistician write this paper? My first answer concerns the aims of the paper of attitudes to statistics, what should be taught and when. The discussion has highlighted some differing opinions on not just role-plays in particular but more generally on the new pedagogy and the necessity to teach communication and other skills. These are important debates and we need to decide what skills to teach students and what attitudes we wish to promote before we decide how to achieve these goals, or to measure our success. My second answer concerns what constitutes proof that role-plays work. I believe that it is time for other people to try role-plays, because it could be something else that I do in my classes or maybe they only suit my peculiar teaching style. Different teaching strategies are effective for different teachers as well as different students. I hope that the paper encourages teachers to try role-plays, and that they let me know about their successes or failures.

I always have difficulty writing about role-plays because doing so always convinces me that they are trivial, artificial and rather silly. Nevertheless, I have had people from high school students to university professors, both students and teachers, perform my role-plays. Watching people enthusiastically participate in the role-plays and discussing issues afterwards always leaves me wondering why I ever thought that they were silly. I recommend participating in role-plays if you have the chance before passing final judgment. Regardless of this final judgment concerning role-plays, I hope that they are thought provoking and promote continuing efforts to improve statistical education and attitudes to statistics and the statistics profession, especially among younger students who are yet to choose career directions.

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