THE GETTING OF WISDOM: EDUCATING STATISTICIANS TO ENHANCE THEIR CLIENTS' NUMERACY

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One often hears that "data are not information, information is not knowledge, knowledge is not wisdom". But what will turn data into information, information into knowledge, and knowledge into wisdom? The first two facets of this question are at the core of every university course in statistics. They provide a motivation for understanding statistical description and statistical inference, respectively. It is the third facet, the getting of wisdom, which adds depth, resilience and realism to that understanding, yet its importance is often underrated in professional statistics programs. Crucial to the getting of wisdom in this context is a competence to argue back to a statistic and to criticise a statistical argument. Imparting this competence should be a vital concern in designing the program syllabus. In this paper I argue that, by adding a little to the syllabus, such a program can also aid the statistician in opening up for his/her client the client's own path to statistical knowledge and wisdom. Such a move constructively addresses an abiding social issue: the need to enhance the level of numeracy in our alarmingly innumerate society.

INTRODUCTION: THE PROBLEM OF INNUMERACY IN SOCIETY

"Data are not information, information is not knowledge, knowledge is not wisdom."
(Anon.).

"Wisdom is the principal thing; therefore get wisdom"
(Proverbs, iv, 7).

Every society today values a literate citizenry and strives to eliminate illiteracy. We can distinguish *total* illiteracy from *functional* illiteracy. Someone who is totally illiterate does not know how to read or write words: such a person "misses the message". Someone who is functionally illiterate does not well comprehend or express logical arguments in words: such a person "misses the meaning in the message". It is, of course, total illiteracy that every society aims to eliminate, through an elementary education for all. Functional illiteracy is a longer-term challenge to educators. A person's functional literacy grows only gradually, generally in proportion to length and level of education and/or extent of involvement in the world of words.

Every society today ought also to value a numerate citizenry and to strive to increase the functional numeracy of the population. So say more and more people, aware of the expressive and persuasive power of numbers, and of their inseparable association with the ubiquitous computer. How shall we understand "functional numeracy"? We need only replace "(il)literacy" by "(in)numeracy" and "words" by "numbers" in the previous paragraph, and the task is done!

It is important to make it clear that, just as one can be highly functionally literate without being a journalist or a *littérateur*, so one can be highly functionally numerate without being a mathematician or a quantitative analyst. Indeed, it is not the mathematical manipulation of numbers (or symbols representing numbers) that is central to the notion of numeracy. Rather, it is the ability to draw correct meaning from a logical argument couched in numbers. When such a logical argument relates to events in our uncertain real world, the element of uncertainty makes it, in fact, a statistical argument. *I am defining "functional numeracy" broadly in this paper as a competence to understand, and argue back to, a statistic and to draw accurate meaning from, and criticise, a statistical argument about the real world*. Some writers refer to "functional numeracy" in this sense as "statistical literacy" and I shall use these two expressions synonymously.

It is a remarkable phenomenon that, until very recently, even economically-advanced societies appear to have prized far less the goal of achieving a functionally numerate citizenry than one that is functionally literate – for example, on the situation in the UK see Moore (1990), and for the USA see Steen (1990). Such relative neglect of numeracy is becoming steadily more unsupportable, particularly in a democratic society. There are now many controversial situations where statistical evidence and argument have a central role in the decision process and the

decisions that are made have profound social implications, e.g. allocating public funding for education and health care. For further examples see Wallman (1993). In such situations it is no longer adequate (if it ever was!) for statistical evidence and argument to be accepted uncritically by an uncomprehending lay community. The need for enhancing statistical literacy in the community is today a pressing social issue – so much so, indeed, that it is declared as the overarching theme of ICOTS 6!

In the next 2 sections of this paper I look more closely at the problem of innumeracy in the community and at some current approaches to its solution. In the following section, I detail a different (and complementary) approach to a solution, namely, *to enhance the functional numeracy of the clients of professional statisticians through the informal educational efforts of the statisticians.* This approach is shown to have some advantages over existing approaches. The fruit of this approach is to enable clients to gain sufficient statistical knowledge for their needs and, ultimately, to acquire a measure of wisdom about quantitative evaluations of the real world. Knowledge will turn into wisdom if it is found to be reliable, that is, realistic and resilient to critical scrutiny. How is all this to be achieved for the benefit of statisticians' clients? In the final section, I trace the implications of my proposal for the structuring of professional education in statistics. In the remainder of this paper, all mentions of numeracy should be read as referring to *functional* numeracy.

SOME DIMENSIONS OF INNUMERACY

How do people who are strongly innumerate react to a challenging statistic? Assuming that their sense of involvement with the matter is sufficiently strong not to ignore it altogether, then experience suggests they will be more likely to accept the statistic on trust than argue back to it. Why this happens so consistently is not self-evident, but it is not difficult to hypothesise.

Firstly, many people have a vestigial recollection from their earliest arithmetic lessons that anything expressed in numbers is precise, and that there can be no doubting a precise number. However, the significant issue in reality is usually not whether a number is *precise*, but rather whether it is *accurate*. The confusion of accuracy with precision runs deep within society.

Secondly, where mathematics is concerned, many people suspend their otherwise natural skepticism in favour of a regressive obedience to argument from authority. While at school, many people learned their maths by rote without ever understanding things fully. Numerical results were meaningful because the teacher said they were meaningful. In later life, when faced with a challenging statistic such people do not need much urging to accept it as meaningful if the source of the statistic says (or implies) it is meaningful.

Nowadays, in an era of accountabilities of every kind, quantitative criteria of performance have taken on a life of their own. As a result, a yet more pernicious conditioning force on society has emerged: any "official" measurement of performance (e.g. television audience "ratings", book "bestseller" rankings) gains credibility in an innumerate society simply from having been stated, never mind what it really means (or whether it means anything at all!).

And how do strongly innumerate people respond to a statistical argument? Here again, one may hypothesise the residual influence of the school mathematics experience. Children learn mathematical theorems and, at the same time, they learn that (under given assumptions) these theorems are always true. But, surprisingly, they are rarely taught *why* these theorems are always true, namely because they rely on deductive logic – which is, moreover, only one of an array of logics of systematically lesser reliability (deduction, induction, analogy, intuition …). Not knowing that statistical arguments are inductions, statistically illiterate people assign to such arguments the same status as the deductive theorems of their school days, and thus hold the conclusions to be beyond question. Clearly, such people will be hard pressed to turn knowledge into wisdom.

How are matters different with people who have some grounding in statistical principles? If they never had more than an imperfect understanding of these principles, or if their recollection is hazy, they are likely over time to have transformed their initial learning into an amalgam of partial truths and plausible, but incorrect, beliefs. Such a hotch-potch has been whimsically (and disparagingly) called "intuitive statistics" or, more bluntly, "bad statistics". One can encounter "intuitive statistics" everywhere – even among people who interact with statisticians regularly.

Here, for illustration, are some propositions that will give the general flavour of "intuitive statistics": (i) a frequency distribution is always adequately characterised by a measure of central tendency alone – average daily temperature in New York is, thus, as informative a measure as average daily temperature in Singapore; (ii) the "law of averages" governs the determination of probabilities by relative frequency; (iii) sample representativeness is more important than sample randomness when seeking to draw generalisable results from surveys; (iv) the findings from a survey are substantive in themselves – the response rate is not a factor; (v) in determining the reliability of an inference, the proportion of the population that is included in the sample is more relevant than the absolute sample size; (vi) a 99% confidence interval is always more desirable than, say, a 90% confidence interval (and a 100% interval would be best of all); (vii) pairwise comparisons of means can always be validly made by means of a t-test, whether the variables are continuous or discrete, and regardless of the forms of distribution of the parent populations; (viii) statistical significance implies practical significance; (ix) the higher a pairwise correlation the more plausibly it implies a causation; (x) statistical methods can prove an empirical hypothesis to be true or false.

Further propositions of this kind may be distilled from the examples of misused statistics in Campbell (1974), Jaffe and Spirer (1987), and Best (2001), and on the "bad statistics" Web page of Fred Worth (2002). An added worry is that "intuitive statisticians" often do not formulate clearly the propositions they misconceive. Evidently, statistical arguments presented (or judged) on intuitive principles are unlikely to generate worthwhile knowledge, let alone transform it into wisdom.

CURRENT APPROACHES TO ENHANCING NUMERACY

What are the currently-established approaches to enhancing statistical literacy in the workplace (in particular) and in the community (in general)? Each of the two current approaches is a response to an aspect of the problem of innumeracy. The first response says, in effect, *we must do something at once for those whose school days are behind them – hence we need a suitable course in statistics for adult learners*; the second says *we must make a long-term attack on the problem – hence we need a suitable course/program in statistics for schools*. Both responses, it should be noted, call for formal teaching of statistics.

Difficulties may arise when the proponents of such formal teaching seek approval or sponsorship from accrediting authorities for their proposed courses. Accrediting authorities (e.g. State Education Departments, Community Colleges) have their own agendas. Specifically, they may prefer to see a formal course in statistical *methods* rather than a course in statistical *literacy*. What then eventuates may be an unsatisfactory compromise between conflicting conceptions.

At school level, there is a further obstacle to be surmounted. Ideally, a program in statistical literacy will be most effective if presented "across the curriculum". The inexorable reality, however, is that anything to do with numbers and calculation is usually regarded as the sacrosanct preserve of the Mathematics Department. Statistics is thus channelled into the mathematics curriculum, where it is taught in a way that is often quite out of line with the ideals of those who seek the enhancement of statistical literacy. In community education for statistical literacy, there is also a further obstacle to success, and that is the limited time available to many adult learners in full-time employment.

What of the universities? In Australia, at least, much of university education in statistics, whether as a minor or a major, is devoted to students' acquisition of technique, rather than to enhancing students' statistical literacy through a focus on the interpretation of results or a critique of limitations. And the topic of effective communication between the statistician and the non-numerate or quasi-numerate client does not generally get special emphasis.

There are now (as a result of initiatives by, among others, the Royal Statistical Society and the American Statistical Association) well-designed curricula and substantial print and electronic resource materials on which to base courses in statistical literacy. However, it is apparent that, while there may be constructive teaching to this end in scattered locations, on the whole progress on a broader front is required to advance statistical literacy in our society. Now may be the time to try another tack, one that I believe has growing potential in the coming years.

A NEW APPROACH: STATISTICIANS TO ENHANCE THEIR CLIENTS' NUMERACY

We have seen in the previous two sections where some of the difficulties and obstacles lie, in devising and implementing a broadly-based program to enhance numeracy in the workplace and in the community. With insight into these impediments, how can we establish a program that *can* be effective? Let us use the following criteria. Firstly, the program must not be sidetracked from its objective. Secondly, it must be implemented by someone who is both committed to the objective and who possesses the knowledge and temperament to achieve it. Thirdly, it should be readily available at the point of need and tailored to the wishes of those in need.

Who is better placed to meet all three of these criteria than the practising statistician him/herself? In saying this, I do not mean to imply that a practising statistician has not enough to do already, in both breadth and depth of responsibility. Nor do I suggest that *every* practising statistician will be drawn to contributing in this way. Rather, I am encouraging consideration of the idea that statisticians who choose to enhance their clients' numeracy – by explaining to their clients the meaning, strengths and limitations of their solutions to statistical problems posed by those clients – can have in this activity a new source of professional satisfaction.

I intend the broadest definition of a "client". In the workplace, the statistician, whether an employee or a consultant, has of course *paying clients* (the charge being either an actual or a notional amount). But – in the foreseeable future – the statistician may also acquire non-paying "clients" in the broader community. Such "clients" I shall call *pro bono clients*. Where will such pro bono clients come from? Just as many cities already offer a free community legal service, I envisage the evolution in many places over the coming decade of a free community statistical service (CSS). A CSS (most likely to be run by a professional Statistical Society) could be primarily Internet-based, with face-to-face consultation offered when and where appropriate.

The activities of a CSS would include answering statistical queries from the (more-or-less innumerate) public and offering informal small-group presentations to the public aimed at enhancing statistical literacy. It could also take upon itself to respond professionally to controversial or erroneous media statements on statistics-related matters.

As already mentioned above, it has not been common for a university education in statistics to devote attention to ways of advancing the statistical understanding of non-numerate or quasi-numerate clients. If practising statisticians are to contribute in future to enhancing statistical literacy in the workplace and in the community, it will clearly be important to prepare them thoughtfully for this role. Whether they will be dealing with paying or with pro bono clients, statisticians will need, in the course of their education, to acquire three kinds of skills:

(a) the skill to foster an open and productive two-way communication between statistician and client – a fundamental skill which *every* professional statistician needs.

(b) the skill to explain technical matters at varying levels of sophistication, depending on the client's knowledge of statistics and interest in understanding the statistician's input.

(c) the skill to discern in dialogue when the client is under some misapprehension of the "intuitive statistics" kind (as described above), so that a gentle correction may be offered – a skill that represents something novel in the repertoire of a statistician.

EDUCATING STATISTICIANS FOR THIS INNOVATIVE ROLE

I need not say anything here about the first of these three skills, building a good general communication with clients, since this matter has already been comprehensively discussed in the statistics education literature. Boen and Zahn (1982) and Kirk (1991) give very useful accounts.

Skill in the art of explaining technical matters to non-specialists in statistics is often advocated in the consulting literature of statistics but rather less discussed in the education literature. A probable reason for there having been relatively little attention paid by statistics educators to development of this skill in past years is that it was assumed that the client was generally not interested in the technical details of the statistician's work. Today this may or may not be generally true of clients, but in an era of tightened professional liability laws and propensity to litigation, it is certainly in the statistician's interest to put the client into the picture as fully as possible concerning analyses that have been performed.

How can skill in the art of explaining statistical work to non-specialists be developed during university studies? As with so many other learned practical skills, this one grows with practice. Here is one approach. Teachers ask students doing assignments always to include in the report they submit for assessment a "client letter". This letter presents to a supposed client an account of analyses done. By specifying, in different assignments, different levels of statistical literacy of the supposed client, students will gain practice in explaining their work to a wide range of types of clients. (I would go so far as to say that this facet of university education could, with benefit, be formalised in many disciplines as a desired graduate attribute: *the ability to explain effectively to a layperson the meaning and results of standard analytical procedures*.)

The teacher could go a step further and, playing the role of the client, engage students in dialogue. The purpose of such dialogues is to give the student statistician the experience of responding to a client's searching questioning. When the student is able to demonstrate that his/her statistical analysis is resilient to the client's challenges, the student's own confidence in the techniques used will be heightened. Knowledge will begin to turn into wisdom.

In order to satisfy the array of challenging questioners they will encounter in professional life, student statisticians need a sure understanding not only of the mechanics of techniques, but also of their strengths and, most particularly, of their limitations. These are, in the philosophical sense, methodological issues. Involving senior students in debate on methodological issues during their studies has, in my experience, a further merit: it is a powerful way of generating intellectual excitement (see Sowey (1995), section 4.2).

There is no shortage of suitable material! Methodological issues and controversies abound in statistical work – from puzzles about appropriate procedure in designed experiments (as wittily highlighted by Zidek, 1986) to the ambivalence of attitudes towards data mining (as described, for instance, by Greene, 2000); from the uncertain robustness of parametric inferential procedures in the face of "dirty" data to the elusiveness of a specification testing procedure in regression, in the absence of a "true" model. And so on.

Given that it is valuable to prepare students to explain statistical techniques even to non-numerate clients, the question arises: what sorts of examples are best for this purpose? For an answer we may take a lead from the daily newspapers and look to social, economic and political issues – all matters of popular interest. Excellent statistical examples from among such issues can be found in Moore (1997), and in Dorling and Simpson (eds) (1998). Further aspects of building student skills in explaining statistical work to non-specialists are addressed constructively by McCulloch, Boroto, Meeter, Polland and Zahn (1985) and Busk (1993).

We come, finally, to developing skill in discerning when the client is thinking in terms of some faulty principle of "intuitive statistics". The essential prerequisite in developing such skill is to know how people with low statistical literacy get things wrong about statistics. To understand this well is an issue in meta-learning, which perhaps accounts for its absence from the syllabus of most educational programs for professional statisticians.

Coming to grips with this issue will be assisted by having a taxonomy of misuses of statistics, such as can be found in Jaffe and Spirer (1987). Next it will be useful to probe the solidity of students' own statistical wisdom on each of these kinds of misuses, as well as on the basic principles of thinking statistically. There can then be discussion of effective ways of explaining to a statistical layperson how to turn various conceptions that are "bad statistics" into corresponding ones that are "good statistics". In this regard we are at the forefront of research on conceptual understanding of statistics (see, for example, Hirsch and O'Donnell, 2001), and research-based guidelines are as yet sparse.

CONCLUSION

Nearly a century ago, a US statistician recommended that practitioners should "seek to enable the layman, whether in public life or private business, to better understand the results obtained by the statisticians" (Huebner, 1909 quoted in Billard, 1998, p.322). And today the call is still the same: "…one of the roles of the consultant statistician should be as a teacher, educating the researcher [as client] in statistical methodology" (Hand and Everitt, 1987, p. 4).

While the call to statisticians to explain statistical analyses to a collaborating researcher from a different discipline may be being heeded, it seems that, nowadays, the idea of doing the

same for a layperson is languishing. If the layperson is statistically illiterate, the task may indeed seem intimidating. But, as this paper has suggested, the (non-monetary) rewards of attempting the task are many and their distribution is wide.

The statistician is rewarded because commitment to explain, especially if to a challenging questioner, entails an obligation to be not only knowledgeable but also wise in the choice and use of techniques, and in the interpretation of results. The statistician's pursuit of wisdom elevates his/her professionalism and self-regard. The statistician is further rewarded by the pleasure of enlightening a receptive client and also (one may hope) by the client's return for consultation on a future occasion and enthusiastic word-of-mouth recommendations to colleagues.

The client is rewarded because his/her wish for information has been met, demurring questions answered, and misconceptions set right. The client's knowledge is extended and, depending on the circumstances, the client's path to his/her own wise conception of statistics may be opened up.

And, not least, the community is rewarded by enhancement of the numeracy of its members, something that can bring benefits on many fronts. The advance of social justice in a democracy is just one (not insubstantial!) example. While this way of reaching the goal of a numerate society may seem slow and roundabout, I believe it will be at least as successful in the longer run as the alternative (and complementary) approaches currently in use. Moreover, if developments in the direction of community statistical services mature, the effectiveness of the approach I am here proposing will be accelerated.

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