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 what motivate the description and inference topics in every statistics course. The third facet, the getting of wisdom, progresses as the student's understanding of these topics grows in depth, realism, and resilience, yet its importance is often underrated in statistics courses. Crucial to the getting of wisdom is a competence to argue back to a statistic and to criticize a statistical argument. Imparting this competence should be a vital concern in designing the course syllabus. By adding a little to the syllabus, such a course can also aid the statistician later to open up for his/her client the client's own path to statistical knowledge and wisdom. This can be valuable for advancing numeracy in our alarmingly innumerate society.

KEY WORDS: Statistical literacy; Statistical misconceptions; Statistical reasoning; Statistics and society; Teaching statistics; The statistician in the community.

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

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

1. INTRODUCTION: THE PROBLEM OF INNUMERACY IN SOCIETY

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 words: such a person "misses the message." Someone who is functionally illiterate does not well comprehend logical arguments expressed 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 with length 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 both of the increasing use of quantitative evidence in public policy debates and of the bewitching power of numbers on the general public. 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!

One can be highly functionally numerate without being a mathematician or a quantitative analyst. 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 article as a competence to understand, and argue back to, a statistic and to draw accurate meaning from, and criticize, 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.

Remarkably, until very recently even economically advanced societies have prized far less the goal of developing a functionally numerate citizenry than one that is functionally literate. On the situation in the UK see Moore (1990), and for the U.S. see Steen (1990). Even in these societies it will be a huge task to redress existing deficiencies!

Here are some troubling data for the U.S. from the most recent national survey of quantitative literacy (defined somewhat more broadly than statistical literacy) among adults, which was carried out in 1992. The survey data reported achievement on five (it might be thought, fairly basic) levels of quantitative competence, with level 5 being the most demanding. The cumulative percentages of approximately 27,000 respondents performing adequately at each level were: (1) 99%, (2) 77%, (3) 54%, (4) 21%, (5) 4% (National Center for Education Statistics 1992).

Neglect of numeracy is becoming steadily more unsupportable, particularly in a democratic society. There are now many situations where statistical evidence and argument are central to decision making on controversial matters having profound social implications, for example, allocating public funding for education and health care. For further examples see Wallman (1993) and Quantitative Literacy Design Team (2001). 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. Enhancing statistical literacy is today a pressing issue.

In Sections 2 and 3 of this article I look more closely at the problem of innumeracy in the community and at some current

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approaches to its solution. In Section 4, I propose 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 advantages over existing approaches. In Section 5, I trace the implications of my proposal for the structuring of professional education in statistics.

Knowledge of statistics cannot take us far in the real world without wisdom—the wisdom (among other things) to choose lines of analysis appropriately and to interpret findings aptly. Knowledge will turn into wisdom as it develops in depth, realism, and resilience to critical scrutiny in the light of experience. Aiding statistics students and their eventual clients in the getting of wisdom lies at the heart of the proposals in this article.

2. SOME DIMENSIONS OF INNUMERACY

How do people who are strongly innumerate react to a challenging statistic? Assuming that they do not ignore it altogether, then experience suggests they will be more likely to accept the statistic on trust than argue back to it. Why? It is not difficult to hypothesize.

First, many people have a vestigial recollection from their school days 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* (i.e., *exact*) but rather whether it is *accurate* (i.e., *correct*). The confusion of accuracy with precision runs deep within society.

Second, where mathematics is concerned, many people suspend their instinctive skepticism in favor of a regressive obedience to argument from authority. While at school, many people learned their math by rote. 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, performance measurements 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 hypothesize the residual influence of school mathematics. Children learn mathematical theorems and 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 can be whimsically 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 flavor of "intuitive statistics":

- a frequency distribution is always adequately characterized by a measure of central tendency alone—average daily temperature in New York over the year is, thus, as informative a measure as average daily temperature in Singapore;
- the "law of averages" governs the determination of probabilities by relative frequency;
- sample representativeness is more important than sample randomness when seeking to draw generalizable results from surveys;
- the findings from a survey are substantive in themselves—the response rate is not a factor;
- 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;
- a 99% confidence interval is always more desirable than, say, a 90% confidence interval (and a 100% interval would be best of all);
- 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;
- statistical significance implies practical significance;
- the higher a pairwise correlation the more plausibly it implies a causation;
- 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), Spirer, Spirer, and Jaffe (1998), and Best (2001).

An added worry is that "intuitive statisticians" often do not formulate clearly the propositions they misconceive. Evidently, statistical arguments derived (or judged) on intuitive principles are unlikely to generate worthwhile knowledge, let alone transform it into wisdom.

3. CURRENT APPROACHES TO ENHANCING NUMERACY

What are the currently established approaches to enhancing statistical literacy in the community? 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 channeled 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 (see, e.g., Scheaffer 2001). For adult learners in full-time employment there is also a further obstacle to success, and that is the limited study time that these people have available.

The American Statistical Association (see Mulekar and Haven 2002) and the Royal Statistical Society (see Hunt, Jolliffe, and Davies 2002) are two leaders, among professional organizations worldwide, in the design and trialing of curricula and resource materials for courses in statistical literacy at both school and university levels. It is apparent from the two very current survey articles just cited how broad these constructive initiatives are and how enthusiastically they have been received. And there are also, of course, many individual initiatives, piloted by foresightful statistics educators around the world, as may be seen from the Proceedings of all the six International Conferences on Teaching Statistics held since 1982.

It is my impression, however, that even in developed societies formal teaching aimed expressly at enhancing statistical literacy is still a fledgling enterprise, offered only in scattered locations and to relatively few people. This is even more true in the case of adult learners than it is for young people. Progress on a broader front is required. Now may be the time to add in a new approach, one that I believe has growing potential in the coming years.

4. A NEW APPROACH: STATISTICIANS TO ENHANCE THEIR CLIENTS' NUMERACY

We have seen in the previous two sections where some of the obstacles lie, in devising and implementing a broadly based program to enhance numeracy in the community. With insight into these impediments, how can we establish a program that can be effective in reaching out to the many people who do not have access to formal education in statistical literacy? Let us use the following criteria. First, the program must not be sidetracked from its objective. Second, it must be implemented by someone who is both committed to the objective and who possesses the knowledge and temperament to achieve it. Third, 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 practicing statistician him/herself? In saying this, I do not mean to imply that a practicing statistician has not enough to do already, in both breadth and depth of responsibility. Nor do I suggest that *every* practicing 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. This need not be a time-consuming task: much can be achieved cumulatively with a commitment of just an hour a week, especially if many statisticians rise to the challenge.

I intend the very broadest definition of a "client." Statisticians have, as we know, a rich variety of workplaces. And in every workplace, the statistician, whether an employee or a consultant, has *paying clients* (the charge being either an actual or a notional amount). Thus, the industrial statistician's clients can be found among operations managers and production workers, the biostatistician's clients come from an array of health professions, the psychometrician's clients include clinical psychologists and executive placement agencies, and so on.

In addition—and within the foreseeable future—the statistician may also acquire nonpaying "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 would most likely be staffed by volunteers from among the membership of a professional statistical society. Appropriate safeguards would be in place to protect volunteers against both the risks of public liability and the possibility of conflict of interest with the requirements of their employers. A CSS 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 non-numerate) public and offering informal small-group presentations to the public aimed at enhancing statistical literacy. In the public interest, it might also take upon itself to pronounce, by way of professional opinion(s), on statistically-flawed aspects of official reports or media statements.

It has not been common for university programs in statistical theory and methods to devote attention to ways of advancing the statistical understanding of non-numerate or quasi-numerate clients. If practicing statisticians are to contribute in future to enhancing statistical literacy in the community, it will clearly be important to prepare them thoughtfully for this role.

5. EDUCATING STATISTICIANS FOR THIS INNOVATIVE 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:

- The skill to foster an open and productive two-way communication between statistician and client—a fundamental skill which *every* professional statistician needs.

• 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.

• The skill to discern in dialogue when the client is under some misapprehension of the "intuitive statistics" kind (as described in Section 2), so that a gentle correction may be offered—a skill that represents something novel in the repertoire of a statistician.

I need not say anything here about building the first of these three skills since this has already been comprehensively discussed in the literature. Boen and Zahn (1982) and Kirk (1991) gave very useful accounts.

Fostering skill in the art of explaining technical matters to nonspecialists in statistics is often advocated in the consulting literature of statistics, but teaching programs have in the past been rather unresponsive. A probable reason for this lack of responsiveness is that clients were generally assumed not to be 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 nonspecialists be developed during university studies? As with so many other learned skills, this one grows with practice. In line with the aim of aiding students in their getting of wisdom, here are three approaches designed to increase students' knowledge in depth, realism and resilience.

• *A "client letter."* The teacher asks 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 realistically wide range of types of clients.

Given that it is valuable to prepare students to explain statistical work even to non-numerate clients, the question arises: what sorts of assignment contexts are best for this particular purpose? We may take a lead from the daily press and look to social, economic, and political issues—all matters of popular interest. Excellent examples on which to model assignments can be found in Moore (2001), and in Dorling and Simpson (1998).

• *A simulated client interview.* Playing the role of the client, the teacher engages each student in dialogue about his/her assignment. The purpose of such dialogue 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 deepened.

• *Attention to methodological issues in teaching statistical techniques.* To be able to satisfy the array of challenging questioners they are likely to encounter in professional life, student statisticians need a deep 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 has, in my experience, a further benefit: it is a powerful way of generating intellectual excitement (Sowey 1995, sec. 4.2).

There is no shortage of suitable material! Methodological issues and controversies abound in statistics. Consider, for instance, the ambivalence of attitudes towards data mining, the uncertain robustness of parametric inference in the face of "dirty" data, and the dilemma whether to trade off consistency against increased efficiency in choosing an estimator for a nonclassical model.

Methodological discussion need not be "heavy" or tedious. Here (quoted from Zidek 1986, p. 9) is a powerful point about appropriate procedure in designed experiments made via a witty anecdote: "An industrial worker told his newly appointed statistical advisor of his plan to put four different soap powders [under comparison] into four successive washing machines, 1, 2, 3, 4. 'You mustn't!' said the statistician, explaining about possible machine effects and the need to draw the numbers out of a hat one-by-one at random to get a randomized order. The industrial worker drew the numbers, 1, 2, 3, 4 and on seeing the result exclaimed 'I can't do that!' 'Yes you must!' shrieked the statistician." Zidek asks "how would you explain the statistician's position to the student?"

Further aspects of building student skills in explaining statistical work to nonspecialists have been addressed constructively by McCulloch et al. (1985) and Busk (1993).

We come, finally, to developing skill in discerning when the client is thinking in terms of some erroneous 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.

One can come to grips with this issue, I suggest, in three sequential steps:

• Assemble, as a reference base, a taxonomy of misuses of statistics and of kinds of incorrect statistical reasoning. Such taxonomies have been proposed, for example, by Spirer, Spirer, and Jaffe (1998, chap. 2) and Garfield (2002).

• Next, probe the solidity of students' own statistical knowledge on each of these categories of error. One way to do this is to challenge them to detect such errors, and then to explain them, in some specially devised case studies.

• Then, working with the students' explanations, discuss with them how these explanations could be adapted to be meaningful to a statistical layperson. I should point out that there are no "right answers" in this regard. Indeed, we are here at the forefront of research on conceptual understanding of statistics (see, e.g., Hirsch and O'Donnell 2001 and Garfield 2002), and research-based guidelines, too, are still sparse.

6. CONCLUSION

Nearly a century ago, a U.S. 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 by 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 daunting. But, as this article suggests, the (nonmonetary) 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 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 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 contributing to 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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REFERENCES

Best, J. (2001), *Damned Lies and Statistics: Untangling Numbers from the Media, Politicians and Activists*, Davis, CA: University of California Press.

Billard, L. (1998), "The Role of Statistics and the Statistician," *The American Statistician*, 52, 319–324.

Boen, J. R., and Zahn, D. A. (1982), *The Human Side of Statistical Consulting*, Belmont, CA: Wadsworth.

Busk, P. L. (1993), "Improving Statistical Literacy Among Consultants and Clients," *Proceedings of the Statistical Education Section*, Alexandria, Va: American Statistical Association, pp. 239–246.

Campbell, S. K. (1974), *Flaws and Fallacies in Statistical Thinking*, Englewood Cliffs, NJ: Prentice-Hall.

Dorling, D., and Simpson, L. (eds.) (1998), *Statistics in Society: The Arithmetic of Politics*, London: Arnold.

Garfield, J. (2002), "The Challenge of Developing Statistical Reasoning," *Journal of Statistics Education*, 10; online at http://www.amstat.org/publications/jse/v10n3/garfield.html.

Hand, D. J., and Everitt, B. S. (1987), "Statistical Consultancy," in *The Statistical Consultant in Action*, eds. D. J. Hand, and B. S. Everitt, Cambridge: Cambridge University Press, Chapter 1.

Hirsch, L. S., and O'Donnell, A. M. (2001), "Representativeness in Statistical Reasoning: Identifying and Assessing Misconceptions," *Journal of Statistics Education*, 9, online at http://www.amstat.org/publications/jse/v9n2/hirsch.html.

Hunt, N., Jolliffe F., and Davies, N. (2002), "The Royal Statistical Society and Statistical Education," in *Proceedings of the Sixth International Conference on Teaching Statistics (ICOTS6)* on CD-ROM [ISBN: 0855907827], The Hague: International Statistical Institute.

Kirk, R. E. (1991), "Statistical Consulting in a University: Dealing With People and Other Challenges," *The American Statistician*, 45, 28–34.

McCulloch, C. E., Boroto, D. R., Meeter, D., Polland, R., and Zahn, D. A. (1985), "An Expanded Approach to Educating Statistical Consultants," *The American Statistician*, 39, 159–167.

Moore, D. S. (2001), *Statistics: Concepts and Controversies* (5th edition), New York: Freeman.

Moore, P. G. (1990), "The Skills Challenge of the Nineties," *Journal of the Royal Statistical Society*, Series A, 153, 265–285.

Mulekar, M. S., and Haven, M. (2002), "The Role of the American Statistical Association in Statistics Education," in *Proceedings of the Sixth International Conference on Teaching Statistics (ICOTS6)* on CD-ROM [ISBN: 0855907827], The Hague: International Statistical Institute.

National Center for Education Statistics (1992), "Adult Literacy in America: Overview of 1992 Results," Web document (accessed 25 February 2003) at http://nces.ed.gov/naal/resources/92results.asp.

Quantitative Literacy Design Team (2001), "The Case for Quantitative Literacy," *Mathematics and Democracy*, ed. L. A. Steen, Princeton, NJ: National Council on Education and the Disciplines, chap. 1; Web document (accessed 25 February 2003) at http://www.woodrow.org/nced/001-22.pdf.

Scheaffer, R. L. (2001), "Quantitative Literacy and Statistics," *AmStat News*, November; also online at http://www.amstat.org/publications/amstat_news/2001/pres11.html.

Sowey, E. R. (1995), "Teaching Statistics: Making it Memorable," *Journal of Statistics Education*, 3, online at http://www.amstat.org/publications/jse/v3n2/sowey.html.

Spirer, H. F., Spirer, L., and Jaffe, A. J. (1998), *Misused Statistics* (2nd ed.), New York: Dekker.

Steen, L. A. (1990), "Numeracy," *Daedalus*, 119, 211–231.

Wallman, K. K. (1993), "Enhancing Statistical Literacy: Enriching our Society," *Journal of the American Statistical Association*, 88, 1–8.

Zidek, J. V. (1986), "Statistication: The Quest for a Curriculum," in *Proceedings of the Second International Conference on Teaching Statistics (ICOTS 2)*, The Hague: International Statistical Institute, pp. 1–17.