David Moore: New Pedagogy and New Content
Response by Anne Hawkins, IASE, RSSCSE

New Pedagogy and New Content: The Case of Statistics. *International Statistical Review*, 1997.

Summary: Statistical education now takes place in a new social context. It is influenced by a movement to reform the teaching of the mathematical sciences in general. At the same time, the changing nature of our discipline demands revised content for introductory instruction, and technology strongly influences both what we teach and how we teach. The case for substantial change in statistics instruction is built on strong synergies between content, pedagogy, and technology. Statisticians who teach beginners should become more familiar with research on teaching and learning and with changes in educational technology. The spirit of contemporary introductions to statistics should be very different from the traditional emphasis on lectures and on probability and inference. **Source**: www.stat.auckland.ac.nz/~iase/publications/isr/97.Moore.pdf

Anne Hawkins provided the following response (bold added) to David Moore's paper (see above).

Clearly David Moore is correct when he asserts that the teaching of statistics has undergone considerable reform. The all-pervasive nature of statistics has led to the development of many new statistical methods, and to the spread of quantification in 'user'-disciplines such as geography, economics, and the behavioural, social and physical sciences. Consequently, more and more people require statistical understanding if they are to be competent in their own work, if they are to work effectively with specialist statisticians, and if they are to fulfill their rightful roles in the societies in which they live. Moore is particularly concerned with introductory level university students, who now comprise by far the largest of our college-level audiences. He is thinking of reforms that will affect the less-specialist among our students. Much of what he says is therefore also directly relevant to school-level courses. Personally, though, I feel that specialist courses can also benefit from this kind of thinking.

Many countries of the world now espouse Statistics for All policies embodied within their mathematics curricula. We should never forget, however, that Statistics for All is not yet a universally-held premise. There remain parts of the world where statistics for all would be deemed to be politically inconvenient for the government authorities. There are also still countries where universal primary education is so tenuous that statistical education is not seen to be a priority, although mathematics education for all is treated as such. This, of course, begs the question of whether someone can be considered to have been mathematically educated if they have not also been statistically educated. As I have indicated elsewhere (Hawkins, 1996b), I remain somewhat sceptical that we should be satisfied with Statistics for All policies. **Our true objective should rather be Statistical Literacy for All,** so I must qualify as one of David's 'reformers'. Indeed, I would probably qualify as a particularly radical reformer, although not (I think) in the way that Moore describes. **My reforms would first involve a change of emphasis in our teaching objectives**, after which the appropriate synergy of content, pedagogy and technology to achieve these should be determined. I would share Moore's concern about the nature of any reforms if their source is uni-dimensional, but I would go further than him in saying that **we may not yet have determined the right framework for reform**.

The problem is that statistical education has largely evolved from a background that was significantly different from the needs and possibilities of today-in terms of the nature and practice of statistics itself; the available technology; and the students' characteristics, requirements and limitations. Reform is certainly required, therefore, but I am reminded of a traveller who, upon asking a local resident for directions to another town, receives the reply, 'Well, to be sure now-I wouldn't be starting out from here at all' !

The reform that we need must have the momentum and energy to challenge even the most fundamental and widely-held ideas about statistical education, and the ways in which these are currently manifested. Nothing should be taken for granted. We might even re-consider (notwithstanding curriculum and time constraints) whether the future of statistical education is really best served by its remaining a part of the mathematics education for most students. The reform, however, must be a process that is more than belief-based. Existing and proposed practices must be open to empirical scrutiny that can sort the 'better' or 'best' from the 'good' or the 'bad', in order to find out when and why content or pedagogy or

technology do and do not work. It must also have the wisdom and finesse to avoid 'throwing the baby out with the bath-water'. As Moore indicated, for example, there is still a place for explanation.

In fact, I strongly agree with Moore when he argues for a 'more moderate' reformist approach that encourages the use of a broad range of ways to approach the teaching and learning process. (If he is a 'content expert' then I am sure that I am a moderate radical!) There is 'no one right way' to teach statistics although there may be many 'wrong' ways! Variety of methods and materials will always benefit both teachers and students, provided we have insights into how to use the available resources. However, the development of methods and materials should start from the point of what we already know about the teaching/learning process, and **should take account of the extent to which we are aiming to produce specialists or non-specialists**.

If we concede that there is a dimension related to statistical competencies (see Figure 1) that ranges from non-specialists, maybe through para-statisticians (Peter Moore, 1990), to specialists then it is reasonable to suppose that specialists will receive more training and acquire more competencies than non-specialists. **The first point that I would make is that everyone at the outset is a nonspecialist.** Some will progress further along the dimension, however, than others. **The question is, what competencies do we want the extremes of this dimension to possess? I would argue in favour of 'Statistical Literacy for All', that emphasises understanding over facts and tools**, with specialists acquiring progressively more 'Statistical Literacy Plus', where the 'plus' possibly relates to more sophisticated/specialised techniques.

Statistics for All policies (as currently implemented), however, tend to focus on giving people the 'plus', albeit in varying amounts because if they are not fluent in the language and methods of exposition they cannot process, and therefore assimilate, as much as others. **There is a sort of tacit belief that a person will not be statistically literate unless he or she has acquired enough of the 'plus' type skills or competencies to become a 'statistical expert'.** Moore also points to the professional's fallacy, whereby the traditional language and methods of exposition are seen as essential to the process-'What was good enough for me must be the (only) way to proceed!'.

Alongside such beliefs is another assumption that 'statistical literacy' will necessarily emerge under such circumstances, i.e. that developing enough 'plus' is a sufficient condition for the acquisition of statistical literacy. 'Radical' reformer that I may be, I would argue that these assumptions can, and must, be challenged. **If statistical literacy cannot be acquired prior to the 'plus', Statistical Literacy for All may be doomed.** On the other hand, what good is a reduced collection of 'plus' without the statistical literacy to support its use**? Statistics for All, in the absence of literacy, is worthless**. If we cannot guarantee that the dosage of 'plus' administered to make 'statistical experts' will also make them statistically literate, what price their expertise? **Statistical Literacy for All must be the bread on which some may spread butter, jam, or even caviar**. Without the bread, however, there is nothing to support these optional toppings. Likewise, if we teach students a selection of the 'plus' tools and techniques rather than (or before) the principles and practical importance of statistics can be appreciated, we should not be surprised that '. . . . . .by the time a scientist embarks on a research career, much of the reluctantly-learned and poorly understood material is forgotten. Often an aversion to statistics is all that remains!' (Employer's/trainer's comment to MEANS Project, 1997,see later.)

Unfortunately, there is not universal agreement, even within the statistical profession itself, about what statistical literacy is. At one level, there is a sense in which people 'would know it if they saw it'. However, this belies the very real, and on-going, debate about the nature of statistics and, more particularly, about the statistics that can and should be taught to all students. Statistics is not 'just sums', and it certainly is not just about algebraic derivations and proofs. It is clearly not a narrow area of specialism. It encompasses many different types of activity, requiring a range of skills and understanding applied in an infinite variety of contexts. These depend on different reasoning processes from others that comprise a mathematics education. In its simplest terms, **statistical literacy can be interpreted as meaning an ability to interact effectively in**

an uncertain (non-deterministic) environment. It is not merely the possession of an ever-increasing collection of analytic tools and techniques, although this is the outcome that often results from present approaches to teaching statistics. **A statistically literate person must understand the strategies for data collection and analysis, as well as the nature of chance processes and their relevance to data collection, and the assumptions that underlie statistical reasoning.** The 'numeracy' with which mathematics educators concern themselves rarely includes thoughts of statistics and probability. The 'mathematics of uncertainty' may crop up occasionally, but not really as a major issue. 'Graphicacy', too, has a rather specialised meaning to mathematics educators, one which seems to miss the mark as far as statistical literacy is concerned. Nor does statistical literacy feature prominently, if at all, in discussions about raising the literacy of the population. It seems that **statistical literacy falls between a number of stools, and does not receive the widespread consideration that it should**.

I will therefore coin the term 'informacy', because statistical literacy clearly incorporates the whole gamut of competencies needed for dealing with information; some that would otherwise be called 'literacy', together with numeracy, graphicacy, and the ability to visualise or perceive patterns, relationships and differences in data (presented in tabular or pictorial form). To be 'informate', one requires skills in summarising and representing information, be it qualitative or quantitative, for oneself and others. Modelling cannot therefore be the preserve of the specialist, or of those who progress ('educationally') to regression techniques and beyond. Even the simplest of charts has a function of representing or modelling reality. 'Informates' are able to select an appropriate model, and perceive its strengths and weaknesses for describing reality. They, therefore, have facility in constructing, not just in manipulating, models.

'Informates' have a good grasp of the nature of chance or random events, and are therefore less prey to superstitions and misconceptions that result from erroneous subjective intuitions. They are able to formulate probabilistic models and enumerate outcomes. Hence they can assess risks and likelihoods, and make reliable predictions and reasonable decisions in the face of uncertainty. At the same time, they are sensitive to, and able to learn from, feedback that indicates that their inferences or behaviour were less than optimal on a given occasion. **They can operate in a multivariate environment**, and are not constrained to uni- and bi-variate tools for describing it. To be considered 'informate', people should be fluent in the language and principles of statistics and probability, and appreciate the inter-dependence of these two areas. **They must be able to communicate, comprehend, and critically evaluate arguments that are couched in statistical or probabilistic terms.** This is not a justification for continued, or increased, use of jargon in these areas. Rather, **a move towards statistical literacy for all should be accompanied by a move towards making statistical language intelligible to all.** If a specialist cannot talk to a non-specialist, it is all too easy to blame the non-specialist. However, in reality, failure to communicate may actually be a sign of the specialist's own statistical illiteracy, given that communication skills are by definition fundamental to (any type of) literacy. Training for 'informacy' also requires the development of a degree of computer literacy, because the use of technology is now an essential aspect of the practice of statistics by both specialists and non-specialists.

The above appears to be an extremely long and daunting 'shopping list' of skills and competencies for teachers to address. This is a challenge that statistical educators must face. It is much easier to develop a syllabus with a few statistical techniques listed (pre-defined to make for easy assessment) but this is not the way to teach real statistics. The tasks of the reformers must be to find ways of conveying 'informacy' to specialist and non-specialist students, and to convince the teachers of the merit and necessity of adopting these. David Moore argues for a balance between content, pedagogy and technology in the teaching/learning process, but points to the unwillingness of many specialists in these areas to recognise the importance of synergy between them. I agree. Many of the developments in statistical education in the past quarter of a century have been proposed from one particular perspective. Some have indeed evoked controversy. This is not to say that all such developments have been counter-productive. In general, the picture that emerges of present-day statistical education gives cause for optimism. However, there are certainly those, and I would

count myself among them, who regret that such developments have largely been made in the absence of evidence-based understanding about the teaching/learning process.

The situation that exists in statistical education today can best be described as one of Common Variance (Hawkins, 1996a) in teachers' approaches to the subject. Different beliefs about what constitutes 'basic' statistics, and about how the subject fits into the curriculum, serve to fuel the debate about how best to teach statistics. So too do differing views about the role of the 'professional' statisticians that education aims to produce. In some cases, research into statistical education has itself contributed to explaining the observed variance. For example, Piaget and Inhelder's work (1951, tr 1975) and that of Fischbein (1975) have led their followers to have very different ideas about what would constitute the appropriate treatment of probability early in the school curriculum. The whole issue of what is intellectually hard and therefore what is academically meritorious is something to which many, raised in Moore's 'peculiar culture of university faculty', pay only lip service. This is borne out by the content and style of the many texts entitled Basic Statistics. What is 'basic' to one author is clearly not necessarily 'basic' to another. A great deal of variation exists with respect to the role that mathematical explanations play in so-called 'basic' or 'introductory' texts. Likewise, there are differences between the balance struck between 'theory' and 'application', or indeed the 'theory of application'. Moore asserts that research has much to tell us about how to reform the teaching/learning process. I would agree wholeheartedly with this. However, I am less sanguine than David about the availability of that research. More particularly, even where that research does exist and is of sufficient quality, it is not always taken into account when recommendations for change are made or implemented. Shaughnessy (1992), for example, points to the gulf that exists between the findings of cognitive research and classroom research and practice.

To say that research into statistical education is guiding our progress is not strictly true at the moment. The published research is still predominantly a collection of reports of 'positive' outcomes. It does not tell us about things that did not work, and therefore about what things we should avoid. It is still rather 'development-oriented', and research into why a particular teaching approach is effective is relatively rare. Even when relevant research work has been carried out, statistical educationists are only just beginning to build upon existing studies. Gradually, we need to create a more synthesised body of literature, and better dissemination practices. Otherwise, we will continue to be prey to the prescriptive myths, fashions and 'fads' that are propagated by those with opinions about statistical education, and loud voices-the really 'radical' reformists (i.e. not me!) to whom Moore alludes. Such problems are apparently not the sole preserve of statistical education. Hart (1997), for example, highlighted the 'total lack of any research basis' that guided the introduction of, and subsequent modifications to, the UK National Curriculum in Mathematics. Ironically, of course, the greater part of the systematic instruction in statistics and probability for the UK is now conducted within that mathematics curriculum, and so statistical education is prey to all the generally undesirable results that Hart describes, plus a few more subject-specific ones. In particular, there is a 'tail wagging the dog' phenomenon. Once the statistical content is structured in a certain way within the curriculum, beliefs about relative difficulty levels within the subject matter, for example, quickly crystallise into 'facts about appropriate pedagogy' that are very hard to rectify subsequently. The issue that Moore raises about statistical education producing competitiveness rather than co-operativeness is a highly pertinent one, and one that is extremely resistant to change. Current assessment practices are major stumbling blocks to reform because they encourage competitiveness. The Royal Statistical Society Centre for Statistical Education is currently conducting a two-year project entitled Matching Education, Assessment and Employment Needs in Statistics (MEANS). One of the recurrent themes of the seminars/workshops and other network interactions associated with this project has been the mis-match to which Moore refers vis-à-vis the Motorola Company requirements of their employees.

However, what is emerging is not only a resistance on the part of the university academics to change, but also a resistance on the part of the students themselves. Even when they are available, 'team-player' skill courses may be avoided by the students in favour of more certain (less demanding? more predictable

outcome?) 'theorem-proof-theorem-. . ..-exam regurgitation-good grade' courses. The mechanism whereby this might be changed is far from simple. It requires radical adjustments in the perceptions and practices of academics, students and assessors. Such changes may well require the sort of 'leaps of faith' that are rarely, or not very readily, undertaken in the corridors of established academia. There must also be synchronous reform, because change on the part of one group will not be sustained without reciprocal changes by the others. The Public Relations exercise that is required to encourage people so fundamentally to re-think their approaches to statistics teaching will be helped by the availability of hard evidence.

A recent sabbatical visitor to the UK who travelled relatively extensively, looking at statistical education practices in higher education, went on to report that he had found only one institution which had a real commitment to changing the pattern of statistical education in its mainstream specialist statistics courses. My own experience, particularly based on responses to the MEANS project, leads me to believe that this is an over-pessimistic view of UK developments. It is certainly one that underplays the effectiveness of individual 'reformers' and their influence on the statistical education experienced by their students. However, I can believe that there may be substance to the point made with respect to departments or institutions looked at as a whole. Even those departments who give strong support to the need for reforms in statistical education are not always completely ready to examine and/or reform their own teaching practices. It is all too easy for academics to fall back on the content-driven arguments that Moore describes. In fact, these become almost a defensive reflex in the economic and competitive circumstances that prevail in today's world of academia. And how much easier it can seem to ban the use of calculators in examinations rather than change our teaching and assessment methods (Garfield, 1994) to accommodate the increases in scope and power that technology offers the practice of statistics. By limiting the use of technology, though, we seriously distort the nature of the statistics that our students can and do learn. Statistics is not a subject that can be frozen in some intermediate technology period.

We have a responsibility to provide courses that allow students to experience the real nature of today's (and the possibilities of tomorrow's) statistics. Assessment methods must reflect, not impede, this. They cannot be allowed adversely to dictate content and pedagogy. To re-think our objectives for both non-specialist and also specialist education, and to recognise and embrace new possibilities, however, will require many of us to forget old ideas. This can be an uncomfortable process, but I would support Moore in his call for reforms that exploit the synergy of content, pedagogy and technology, especially if such reforms might put us in real danger of helping our students to achieve the most effective learning. Sadly, some of our current practices do not suggest that we really want to do this, nor do they always present the synergy of skills, knowledge and understanding that represent the real and adaptable natures of statistics.

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