The Introduction of Probability into Australian Schools Interpreted Within a Broad-Spectrum Ecological Framework

John Truran
University of Adelaide

This paper argues that the two models of curriculum development currently used to interpret Australian mathematics education history—the Colonial Echo model and the Muddling Through model—are both deficient, and proposes a more complex model—the Broad Spectrum Ecological model. This considers the physical, social and intellectual forces operating within a specific environment. One small aspect of mathematics education history, the introduction of probability teaching into Australian schools, is used to illustrate the superiority of this model.

The Importance of a Sound Historical Framework

Australian educational practice has changed much in recent years, but without significant consensus and with substantial criticism and dissatisfaction. It seems to lack widely agreed principles for assessing sound educational practice, and the practice of any particular time is strongly influenced by groups influential at that time. One function of an historian is to provide frameworks which can assist all members of society to see their society more clearly so that it is easier for society to develop constructively and efficiently.

At the moment, Australian mathematics educators are more interested in social, affective and philosophical issues than pedagogic ones (Sullivan, Owens & Atweh, 1996). So the political aspects of education are highlighted, raising questions about the mechanisms which influence the nature of our society.

But such mechanisms have been poorly examined. Standard historical writing tends to describe environments and how actions conform with or fight against such environments, but tends not to examine the underlying forces which influence these actions. Blainey (1966), however, has examined the effect on the Australian economy of forces arising from transport difficulties and shown how shared original cultures can move apart when forces act differentially on the component parts. While Blainey's method does not necessarily have predictive power, it is a much more convincing explanation of events than one asserting that *X* happened because of a rise of interest in *Y*.

Educational research is concerned with both understanding and initiating change. For such research to be fully effective, an understanding of forces acting within and upon education should underpin all research. This paper is presented as a contribution towards raising the understanding of the importance of developing a sound interpretative historical framework among mathematics education researchers.

The limited debate which has so far occurred in Australian mathematics education has been mainly between the proponents of two distinct frameworks: the "Colonial Echo" model, proposed at least as early as Clements (1978) and codified in Clements, Grimison & Ellerton (1989), and the "Muddling Through" model, whose development may be traced in Truran (1991, 1994a, 1994b & 1995). The discussion below examines both models briefly before proposing and explicating an alternative model: the "Broad-Spectrum Ecological Model". It concludes by examining how well these models fit data pertaining to one small segment of mathematics education history.

The Colonial Echo Framework

Clements et al. (1989) argue that a "Colonial Echo" theory, sometimes conscious, sometimes unconscious, is sufficient to account for major events in mathematics education and for the overall uniformity of Australian schools until the mid-1970s and that it still had some validity in the late 1980s, although by then, they claim, a more mature approach had developed. They attribute such influence to the assumption that mathematics is culture-free and to many structural and social links with Great Britain, and go on to argue that this led to Australian school mathematics becoming both sexist and elitist. Furthermore, they assert that the School Mathematics Project (SMP) and the Nuffield Project, both from England, were the major inspirations for the introduction of the new mathematics into Australia, that even the criticisms of the new mathematics which arose in Australia were copies of criticisms being made overseas, and that

> it was the naive willingness of Australian educators to accept untested English ideas in the area of school mathematics which persuaded education authorities ... to commit schools to large-scale, but ill-fated, reconstructions of their primary and secondary mathematics curricula, through the Cuisenaire and "New Maths" movements. (Clements et al., 1989, p. 68)

For Clements (the name is used in this paper to include his collaborators where appropriate) the changes of the 1970s and the 1980s arose from factors like the high level of co-operation between mathematics educators in the different states, the high quality and distinctive character of recent Australian mathematics education projects, and the development of new assessment procedures (Clements et al., 1989, p. 71).

The Muddling Through Framework

Truran (1991) examined the South Australian situation in the late nineteenth century, and argued that Clements' claims were too wide, and sometimes not applicable to all States of Australia. In particular he argued that some significant changes in South Australia antedated similar changes in England, New South Wales and Victoria, and that others were successfully introduced when they had failed elsewhere. His analysis of the reasons for this significant state of affairs was inconclusive.

Later, Truran started to analyse the forces influencing the teaching of probability in South Australia, still attempting to set his findings against the Colonial Echo model. He observed (Truran, 1994a) that there were too many different overseas developments for all of them to be copied so some sort of selection had to be made and justified, and also (Truran, 1994b) that the forces for change were "idiosyncratic, poorly integrated, and poorly justified". As a result he proposed Muddling Through as a better model.

However, Truran (1995) then proposed a Broad-Spectrum Ecological Model based on Crombie (1994), which, he claimed, encompassed the Colonial Echo model and allowed for a much greater degree of purposefulness by administrators than did the Muddling Through model. The model took more account of the forces operating within education, and explained why echoing was sometimes an efficient response to a specific situation. It is a more detailed working out of this model which is discussed below.

Debate about the Two Frameworks

Some time after Truran had moved past his Muddling Through model, Clements agreed that it did accurately describe some aspects of Australian educational practice, but he also asserted that

> ... those controlling the direction of the "muddling" still look to the United Kingdom, the United States of America and, increasingly, to the discipline of economics for inspiration. In particular, policies affecting practices in school mathematics have been, and continue to be, based on decisions made by governments in the United Kingdom and the United States of America. (Clements & Ellerton, 1996, p. 141, lightly paraphrased in Clements & Thomas, 1996, p. 141)

To some extent this position puts paid to the view they expressed earlier that the 70s and 80s ushered in a new era, and the introduction of a new force—economics—suggests that the original model was not comprehensive. It is surprising that they have retained the Colonial Echo model. It is true that many recent changes in Australia have been similar to those elsewhere, and that many overseas visitors address Australians on educational matters. Such facts are not in dispute. What is in dispute is whether they are best explained by assuming that Australians "consciously" copy what is happening overseas (Clements & Thomas, 1996, p. 91, italics removed). For Clements and Ellerton (1996, p. 139) the similarities between the contents strands in nationally developed curriculum statements in Australia and the UK [sic: England & Wales is what is meant] are best explained by the Colonial Echo model, even though an explanation based on the intrinsic logic of how we perceive mathematics might be far more parsimonious.

This paper presents a model which, it will be claimed, fits more of the facts than does the Colonial Echo model. In one short paper it is only possible to support this claim by considering a very small part of Australian mathematics education history, but at this stage in the debate it seems to be more important to explicate the theory clearly.

The Broad-Spectrum Ecological Framework

There are two principles which underlie the culture of twentieth century biological investigation. One is that organisms behave in a way which optimises the balance between energy expended and satisfaction obtained. The other is that organisms operate within a competitive environment which ensures that only the most efficient survive. These principles form the basis of the model being proposed here. Educational systems may be looked at as though they are ecosystems containing individuals and groups of individuals. These organisms and groups interact, sometimes co-operating, sometimes competing. What actually happens may be interpreted in terms of the interacting forces, the mechanisms for minimising energy expenditure, and the decisions which individuals and groups make about whether to co-operate or compete.

This approach is not new. Popkewitz (1988, pp. 242 - 245) has described how some curriculum developers have proposed an evolutionary model of curriculum development, which looks for ways of introducing new items into the school practice with minimal disruption. However, he claims, they have tended to over-emphasise harmonious reconciliations, without adequately considering the tensions inherent in most situations. As a result Popkewitz proposed a more mature model which tried to reconcile these tensions and to juxtapose stability and change.

But this approach has been taken much further, and beyond traditional biology by Crombie (1994, v. I, pp. 63 - 66), an historian of science, who has proposed that historical investigation needs to consider concurrently several different aspects.

Historical ecology: which is at the level of nature, "the reconstruction of the physical and biomedical environment and of what people made of it";

Cultural dispositions: concerned with habits, motives, opportunities and responses

Scientific thinking: concerned with conceptions of the discoverable in nature and of scientific enquiry and explanation in relation to intellectual commitments, scientific context and experience, and available technical possibilities, with their historical sources.

For Crombie an historical narrative requires an examination of where people lived, how they lived and how they thought. I shall refer to these aspects respectively as *physical, social* and *intellectual* ecology. The term "physical" is preferred to "historical" because it emphasises that the forces are natural; the term "social" is preferred to "cultural" because it is more likely to be seen as encompassing a wider range of non-physical forces existing within a society. The three approaches taken together will be called the Broad-Spectrum Ecological (BSE) model. Together they provide a wide-ranging metaphor for developing historical interpretation. The Colonial Echo model is set mainly within social ecology, the Muddling Through model within physical ecology.

Ecology has developed within biology, being concerned with organisms' relations with each other and with their physical environment. It is particularly concerned with the way in which individuals respond to *forces* operating within their environment. The BSE model looks at humans in their social and intellectual environment as well. There are important ecological principles which are well understood within biology, but which seem not to be well understood by some who apply the term to education. In particular, they fail to consider the forces which are operating. For example, Reed (1993, p. 46) sees individuals as acting autonomously *within* the environment rather than as *under* its influence, and Jardine (1994, p. 111) treats human ecology as a description of interpsychic and dialectical processes mediated by joint intentions. Some of these principles need to be considered here.

Ultimate and Proximate Factors

Ecologists distinguish "ultimate" and "proximate" factors causing biological behaviour (Baker, 1938; Immelmann, 1972). For example, breeding behaviour may be seen as being brought on by a proximate factor such as increasing hours of daylight or by an ultimate factor such as the desirability for the species to produce young when food and shelter are most likely to be abundant. Proximate factors may be linked with their response across a brief time span. Ultimate factors have a much larger time span. They are the environmental and evolutionary factors which have led to the mechanism which selects those proximate factors which are advantageous to the individual.

This approach may be applied to education. Our current rapid changes result in part from the development of the computer and its related technology over the last 50 years. The development has not been an overnight phenomenon; there have been quantum leaps, like the design of the Macintosh, but they have taken time to consolidate. It is very hard for individuals or small groups like schools to place themselves accurately within such a rapidly changing world. Their decisions are subject to much more proximate forces like the funds available to purchase technological equipment and expertise. Everyone is moving in the same direction, but the rate of progression is subject in a significant way to proximate factors.

Optimisation criteria

A second concept of importance is the criteria used for establishing optimal behaviour. In zoological terms the term "best" is often applied to behaviour which requires the least effort to obtain adequate food or shelter, and this approach seems to be a helpful one for education where resources are always scarce. So in this thesis, society is seen as an organism whose individual members respond to a variety of pressures in ways which are practicable, in the best interests of those individuals, and in many cases in the best interests of society as perceived by those individuals. The BSE approach extends the meaning of "ecology" from one concerned only with the physical environment to one which examines how natural forces (often the results of limited resources) operate within a social *milieu* (such as respect for education) and an intellectual *milieu* (where content and pedagogical knowledge of teachers and administrators are important) in such a way that individuals and society are sustained and improved. This will often not be easy to assess, because what may be best for the group may not be best for the individual and because the range of forces operating will not always be clear.

The Principle of Convergence

In zoology, it is quite common to find unrelated families of animals which are very similar in appearance. Evolutionary theory argues that similar environments have led to a convergence of appearance quite independent of the families' different genetic background. In education genetic transmission does not occur, so the parallels with zoology are not straight-forward. But it is reasonable to assert that if similar educational practices are observed in different countries, then the possibility that they arise from convergence, rather than cultural transmission, should, at the least, be examined.

An Example from the Introduction of Probability into Australian Schools

General Principles

So, when discussing the teaching of probability it is necessary to examine the physical environment within which schools are set, the social culture operating within them, and what was known about probability at the time under discussion. Issues such as time allocation, class size and available equipment represent the physical forces. Issues about the nature and purpose of teaching and assessment, which will reflect the differing perceptions of politicians, teachers, administrators, children and parents, represent the social forces. And understandings of probability and its pedagogy held within different sections of the academic community constitute the intellectual forces.

There are, of course, strong links between the three sets of forces. Teachers can only teach what they know. For probability, most teachers initially knew little, so the links between classroom practice and the academic community were especially important for the ways in which the topic was treated. Physically, the large classes and very limited resources in schools in the 1960s also influenced what could be satisfactorily done in a classroom. The argument that understanding probability would be a social asset to children was a new social force, one not often well understood. To understand change it is necessary to examine more than ability and organisation: "wider factors such as resources, status and legitimacy" are also important (Openshaw, Lee & Lee, 1993, p. 145).

A Specific Example

The General Environment: As an example, let us consider the period in the late 1960s when probability was first taught as a major topic in Australian schools. For some years there had been very strong advocates for the teaching of probability, because stochastic thinking was becoming increasingly important in science and industry, and because a clear understanding of chance was seen as an important part of a general education. These views were strongly presented at the 1959 Royaumont Seminar (OEEC, 1961) and at the Cambridge Conference on School Mathematics (1963). Intellectually, probability had become so well understood that it was able to be used constructively in many fields. Its consequent advocacy as a subject suitable for schools marked a significant change in the social forces operating on the mathematics curriculum.

Applicable knowledge spreads rapidly across the world within the academic community, so the intellectual changes were well understood by Australian academics, but they bypassed the majority of Australian secondary teachers, who were working under many difficulties and interested primarily in what went down well in the classroom (UNESCO, 1965). From their point of view, responding to physical forces was their most urgent task. Few had studied probability, so their knowledge was limited. Nor were there strong social forces operating within teaching which saw probabilistic understanding as a social asset. Such forces were present for statistics, which was seen both as an applied tool and as easy to teach in a classroom, but the intellectual links between probability and statistics were poorly understood.

Furthermore, there was no established pedagogy for teaching the topic. The most significant work had been done by the American College Entrance Examination Board (1959), but there had not been time for this work to be refined in practice and modified for wider use. So when the intellectual forces were successful in arguing that probability should be part of the Australian secondary mathematics curriculum, the topic was placed into a physically difficult school environment and an impoverished social one.

Solving a Specific Problem: Did Australians solve this problem by meekly copying overseas practice? The answer must be "No". A wide variety of approaches specifically designed for Australian schools was developed, some of which are discussed here.

The Canberra Mathematical Association released a small work on probability for teachers (Neumann, 1966) which was seen as the best available at the time (Newman & Wall, 1974), even though its approach was far too academic for ordinary students and teachers. In Western

Australia Hume (1966) developed a course for Year 12 based on CEEB (1959). The book was practical, and attractively presented, but the modifications required were found to be far more than anticipated (Hume, 1970). Hume later felt that the level she wanted to reach could not be achieved until here was a higher level of teacher knowledge (Hume, 1970). South Australia had started to change its academic syllabus by including statistics as early as 1964, well before the main movement for change in Australia (University of Adelaide. Public Examinations Board (1966). Soon after, a committee of teachers, administrators and academics decided to use the SMP textbooks, which included probability, as a basis for classroom work because these were believed to be the best available (Baxter, 1972). The books were found to be too hard for the students, and were soon replaced by locally produced material. At least two quite different approaches to teaching probability were taken in Victoria, accompanied by considerable debate, and some acrimony. The official approach was to emphasise formal structures, and Preston & Watterson (1972), two academics, took this to extremes. Lucas & James, two independent school classroom teachers, started to produce more straight-forward texts from 1967.

Discussion

There were several reasons why Australian mathematics education had to change in the 1960s. These included changing school clientele (physical forces arising from social changes) and changing views about mathematics (intellectual forces). The introduction of decimal currency in 1967 freed up the mathematics curriculum, and meant that change of some sort had to occur, and provided an opportunity for major restructuring.

When we examine the wide variety of responses to these changes with respect to probability across Australia it is hard to see how a Colonial Echo theory is tenable. The sheer diversity of responses alone means that it cannot be argued that any copying which did take place was automatic. At the least, each State had to choose from many competing messages. And we must presume that the administrators who made these choices were responsible people trying to do a good job. While there is some evidence that they had limited perspectives, and perhaps an eye to profits from textbooks, there is no evidence that they deliberately tried to foist poor material onto the schools.

It is true that some of the states made a conscious decision to use overseas materials, particularly South Australia. This State had been cautious about change, but when decimalisation demanded change a decision was made which was informed by years of deliberation, which could be defended as an efficient use of scarce resources and which involved the use of what was probably the best and most attractive course available. It was not "Muddling Through". Judged on the physical and intellectual forces operating at the time the decision was essentially a good one though it paid inadequate attention to the very academic emphasis of the project. Neither the teachers nor the students were able to adjust to the academic open-ended style. Social forces saw it replaced by an approach which conflicted less with the existing classroom environment.

The same may be said of many of the other innovative approaches described above. Hume's project and Neumann's text were too hard for teachers. Preston & Watterson's text was too formal for the classroom environment of the time. The environment could have been changed: after all, European classrooms are much more formal than ours, but this would have required far more energy than was available.

In the long term, the approach to probability in most parts of Australia ended up being remarkably uniform. A definitional, pure mathematics approach. After a short practical introduction, the main emphasis of the courses centred on simple calculus of probabilities in a concrete setting. This uniformity is a classic case of educational convergence. A deterministic approach to probability fitted best with the social and physical forces in classrooms at the time without breaching intellectual rigour.

May I be forgiven for quoting an example from personal experience of how the optimisation principle operates in practice. In 1969 I was teaching at an Australian school which used its own internally written textbook. The approach to probability was formal and

abstract, and was not popular with staff or students. I had had experience with using a more concrete approach to the same material as a result of my time with SMP and it was easy to persuade the department to revise this aspect of the course. This was not echoing, it was making use of pedagogical knowledge (within intellectual ecology) to propose a more efficient way of communicating an idea. Given approaches all of which are academically acceptable, it is natural to choose the one which goes down best in the classroom.
This discussion has concentrated on proximate forces. The ultimate force operating is the increasingly data-driven nature of our society (Hacking, 1990). In spite of this the long-term position of probability in schools is not yet secure. So a study of probability in schools is especially able to illuminate the uneasy relationship between proximate and ultimate forces on the mathematics curriculum. This work remains to be done.

Conclusion

Crombie (1994, v. 1, p. 69) calls the process he uses "historiography"—"an art resembling natural science both in its commitment to searching for a particular and general truth through the control of evidence by critical scholarship, and in the design and presentation of its arguments in order to convince and persuade". I would argue that, for the issue discussed here, the Broad-Spectrum Ecological framework is more able to convince and persuade than the other frameworks discussed here, and so deserves more detailed examination.

Ackowledgements

I wish to thank Mr Ian Brice and Dr Paul Scott, University of Adelaide, and Mrs Kath Truran, University of South Australia, for their helpful comments on earlier drafts of this paper.

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