CHAOS MINI-THEME

Organisational leadership and chaos theory

Let's be careful

Peter Galbraith

School of Education, University of Queensland, Brisbane, Australia

Received November 2002
Accepted January 2003

Keywords *Chaos theory, Metaphors, Modelling, Leadership*

Abstract *This article addresses issues associated with applications of ideas from "chaos theory" to educational administration and leadership as found in the literature. Implications are considered in relation to claims concerning the behaviour of non-linear dynamic systems, and to the nature of the interpretations and recommendations that are made. To aid the analysis a simple non-linear model is constructed and its behaviour simulated. Questions emerging from the analysis are used to focus on issues deemed significant, both for evaluating arguments presented on behalf of chaos, and for furthering insights aimed at enhancing the understanding and practice of leadership in organisations.*

> So my answer to the question "How do you know? What is the basis of your assertion? What observations led you to it?" would be: "I do not know: my assertion was merely a guess. Never mind the source . . . if you are interested in the problem which I tried to solve by my tentative assertion, you may help me by criticizing it as severely as you can" . . . (Karl Popper, 1968).

Introduction

As we are all aware, language forms and descriptors from the wider world of business and industry has increasingly become part of the discourse of management and leadership as education providers and institutions have become increasingly corporatised. In this respect no term has received greater exposure during the past decade than "learning organisation". A recent Web search located 82,803 sites for "learning organisation" (36,000 when combined with education and 458 when systems thinking was added also). As a comparison there were 66,102 sites for "performance indicator", 21,900 when combined with education. Now there is no denying that the term "learning organisation" is invoked by those who embrace a variety of system faiths, as well as faiths that do not overtly espouse a systems view. Furthermore, the search for legitimacy frequently encourages proponents to borrow or use terms such as "non-linear", "complex systems", "systems thinking", "feedback", in ways that are at times idiosyncratic, and at times seemingly unaware of essential properties implicit in these terms.

There have long been severe reservations about the "scientific approach" to leadership and management in organisations, which sought to identify

Journal of Educational Administration
Vol. 42 No. 1, 2004
pp. 9-28

0957-8234
DOI 10.1108/09578230410517440

generalised skills to provide keys to successful management practices. Such approaches adopted a positivistic stance within which the nature of an enterprise or the characteristics of individuals within it were deemed of small importance. So called "paradigm wars" which emerged as the basis of such assumptions were challenged.

The publication of *The Fifth Discipline* (Senge, 1990) provided an impetus for a reconceptualisation of organisational leadership, and the way that this has impacted on education is interesting. A passage from *Schools that Learn* describes how *The Fifth Discipline* and the subsequent field books, despite their focus on business corporations, "found a large and avid audience among teachers, school administrators, parents and community members who care about schools" (Senge *et al.*, 2000, p. 5). Now the fifth and fundamental discipline of "systems thinking" requires an understanding of the structure and behaviour of non-linear systems, and during the same decade the popularisation of chaos theory has resulted in a number of attempts to apply its principles and insights to the field of organisational management and leadership. Deterministic chaos is also associated centrally with non-linearity.

The purpose of this article is to examine claims for applications of chaos theory, in so far as they are applied to leadership and management in educational organisations, and this will involve in part a discussion of the properties of non-linear systems. To address this purpose four articles from the *Journal of Educational Administration* have been selected as representative of this field of interest. The approach involves considering selected texts from the respective articles, and analysing their claims from the perspective of complex systems. System dynamics concepts (e.g. Sterman, 2000) provide a framework within which to engage the claims and implications of the arguments presented – an approach rendered appropriate by the contemporary focus on "learning organisation", and the references in the articles to mathematical structure and behaviour, feedback loops, initial conditions, non-linearity, oscillations etc.

Literature sources

The new science of chaos: making a new science of leadership (Sungaila, 1990)
This article appears to be one of the first to seriously develop ideas from chaos theory for purposes of addressing issues in educational leadership and management.

> The first principle, which the new science of the global nature of systems recognises, is the principle of self-renewal. The second principle is the principle of self-organisation. This is simply order through fluctuation. The characteristic non-equilibrium in the system can be the source of a new order, whenever the fluctuations that constitute it, can no longer be absorbed within a particular dynamic regime (p. 8).

A system dynamics view would endorse the recognition of non-equilibrium as characteristic of system behaviour, but would hold open another possibility in which explosive fluctuations lead to disintegration or collapse rather than

self-organisation. We recall the note in *The Fifth Discipline* that one third of firms listed in the *Fortune* "500" in 1970 had vanished within 13 years (Senge, 1990, p. 17).

> The challenge is not to treat educational systems as if they were dissipative structures, but to consider what difference it would make to the study and practice of educational administration in general, and of leadership in particular, if educational systems really are dissipative structures, characteristically self-renewing and self-organising (p. 9).

This is an interesting perspective, which raises the notion of metaphor as a means of developing new frameworks for interrogating organisational life. While such thought experiments can be exciting and innovative, it will emerge that the blurring of model and metaphor is a persistent problem characterising appeals to chaos theory to provide insights for organisational change.

> Changing education by changing educational administration is like changing the course of the Mississippi by spitting into the Allegheny (James March). But the butterfly effect suggests differently. If educational systems are dissipative structures, then a little bit of "spit" in the administrative Allegheny, could just change the course of the educational Mississippi (p. 10).

> The new science of chaos has alerted us to the butterfly effect, to the very considerable impact tiny fluctuations in a non-equilibrium system can have on its output. It is already generally recognised in the literature that it is the function of leadership to bring about qualitative change in the system. The new science of chaos suggests that the creative input of a single individual who is prepared to stand his or her ground can be enormously effective (p. 12).

> The leader deals in ideology, in the formulation of a code: what needs to be done, firstly to change the status quo and, secondly, to replace it with something else. It is this something else, which the leader envisions for his or her followers (p. 15).

> If the leader is to succeed in reinforcing the fluctuations from within, to the point where the system is driven over the threshold into a qualitatively new regime, then the leader must also deal in culture; destroying old myths, stories, legends . . . and where appropriate creating new ones (p. 17).

> However there is also the danger that these self-reinforcing fluctuations will be dampened down by the dissipative structure's own self-renewing dynamic. This means that the leader must either destroy or at least modify the cultural political and material supports, which provide integral support to that dynamic. As the self-renewing dynamic is thus weakened, so is its power to absorb the ever-increasing fluctuations. Thus the system is able to organise itself at a new level of operation (p. 20).

These extracts appeal to the "butterfly effect" and then proceed to develop implications for educational leadership. The potential of these implications to legitimate unilateral action on the part of leaders seems thinly disguised. Essentially we are told, "you" (a leader) can make a difference by your own actions. It is your job to envision what is necessary, and this may involve destroying an existing culture and replacing it. While well intentioned as an antidote to moribund practice, we seem to have another manifestation of the maxim "crash through or crash" this time based on an argument from "chaos".

As such it could be argued that this encourages the "great leader" perception of management and runs counter to the valuing of aspects of learning organisation theory such as shared vision, mental models, and team learning, and the leverage potential that resides in them.

Jurassic management: chaos and management development in educational institutions (Gunter, 1995)

This is a stimulating article that explores the proposition that management of educational institutions suffer frequently from the same malaise that lead to problems at Jurassic Park. The author begins by pointing out that:

> Jurassic Park failed because the senior management thought that planning and organization combined with skilful marketing would bring success.

There is a perceptive analysis of Jurassic management and links to the way educational organisations are led. For present purposes the interest is in the latter part of the article in which implications of chaos theory are provided as principles for regenerating management approaches in schools and colleges.

> For the manager-practitioner schooled in the entrepreneurial mindset, the science of fractals, strange attractors, and the butterfly effect seems far removed from organizational behaviour. To be successful a school or college needs to give recognition to the fact that educational institutions are not linear but complex networks with equally complex feedback loops. However, current orthodoxy is that schools and colleges operate a rational cycle of review, forecast, implement and evaluate in relation to resource management. Therefore curriculum and resource needs are identified and prioritised, and forecasts made of pupil/student numbers and income linked to targets. This is informed by the development plan and the long-term vision of where the school/college wants to be at a given point in the future. During the annual cycle negative feedback (e.g. changes to the funding formula) is prevented from causing a downward spiral or vicious circle by monitoring and so adjustments are made in order to ensure stability. Similarly positive feedback, (e.g. increased demand for places in sixth form) can form a virtuous cycle of success and must be prevented from leading to disintegration or explosively unstable equilibrium (p. 14).

Following a clear exposition of the "conventional wisdom" that is being critiqued by the author, some "complex systems" language is introduced in reference to feedback. But feedback is described as relating to events, rather than to circular causality, and vicious and virtuous circles are inappropriately associated with negative and positive feedback respectively. And further:

> Chaos theory allows us to see that education managers have a third choice to either stability or disintegration and that is to operate within "bounded instability". A successful school or college would therefore operate away from equilibrium between stability and disintegration . . . The future cannot be visioned as it is unpredictable and depends on chance. Feedback can produce behaviour which is complex, and you cannot see a direct link between cause and effect. The future is created by the sensitive response to fluctuations in the environment or the "butterfly effect" – the flap of a butterfly's wings could cause a thunderstorm in another part of the world (p. 14).

The claims on behalf of an approach informed by chaos theory thus tend to the heroic, with managers granted sufficient perception to deliberately choose to operate within "bounded instability", between stability and disintegration, with uncertain future movements categorically assigned as due to the "butterfly effect". Here the use of metaphor appears to have crossed the boundary to claim a status close to established scientific fact!

Following this elevation of status the implications of chaos theory for education management are described in some detail, and the language is normative.

> Managers must be interventionist within the environment by seeing how small changes can have a considerable impact over time. The investment of time and energy in such dissipative structures is high, but turbulence does not interrupt or interfere but as Sawada and Caley argue it "embodies information". Hence the use of information and decision making must be by use of analogy and intuition rather than analysing cause and effect by modelling and statistical forecasting. Visioning is not only an illusion but also a delusion in that its only function is to provide comfort for those uneasy about living with turbulent change … The people within an organisation will not learn if they are subject to the control of a strong value system but will learn if they know how to recognise disorder … The butterfly effect allows us to recognise that one person can have an impact and therefore schools and colleges must tap into and encourage the whole skills of colleagues … When events or crises hit individuals and groups there is a spontaneous capacity to organise and respond (pp. 14-15).

We would question on what basis such categorical claims can be sustained. How for example disorder is to be distinguished from counterintuitive behaviour that is a rational if non-obvious outcome of interacting delayed feedback. What can intuition and analogy achieve, and how and at what level does one decide that an analogy is appropriate or valid? What if people rather than being subject to a strong value system co-create their own? Certainly individuals and groups when hit by crises have a capacity to organise and respond, but the response may lead to disintegration or collapse as well as to a new productive order.

> Chaos theory allows us to see the subversive or the maverick in a positive way as an enabler, and emancipator … Continuous professional development should focus on enabling teachers to understand the context which they are in and chaos theory provides opportunities to explore how learning is about changing perceptions through group interaction which discovers, questions, makes critical choices, and takes action (p. 17).

Arguments that promote the profound contributions that mavericks can provide as potential enablers are certainly welcome. Whether concepts from chaos theory are relevant to facilitating changes in perceptions through group interaction etc. is however at least open to question; others might argue that this is precisely what sharing vision and surfacing mental models informed by systems thinking sets out to do. The idea of using novel notions from chaos theory to promote learning through changing perceptions is interesting, but we should also note that other systems approaches provide alternate means to this

end. In particular accountability should accompany claimed insights attributed to the application of any given theory.

Non-linear systems and educational development in Europe (Reilly, 1999)

Reilly (1999) is straightforward in his assessment of the perceived failures of educational initiatives despite injections of large amounts of capital.

> This is a result of a linear expectation wherein the output should be proportional to the input non-linear theory ... is a more valid way of conceptualising educational development efforts and does not assume this proportional relationship (p. 424).

There are no problems so far, and the author then proceeds with his intention of using non-linear theory to examine educational initiatives in Western and Eastern European nations. But here we run into difficulty for the author equates "non-linear dynamical systems theory" with "chaos theory", and goes on to anticipate that its study will increase the understanding of why current unanticipated developments and outcomes should be expected. There follows a listing of "differences" between linear and non-linear systems deemed central in this application to educational contexts. Selected content from Table I in the paper is reproduced below.

A variety of accompanying comments include:

> In linear systems, initial differences are not important ... Sensitivity to initial conditions in non-linear systems is often referred to as the "butterfly effect" (p. 428).

> A fourth and very critical difference ... is that feedback is negative in linear systems. The purpose of negative feedback is to alert the system that something is beyond acceptable limits, and corrective action must be taken to re-establish the stability of the system. In non-linear systems feedback is positive. Positive feedback in a linear system generally indicates no significant problem in system functions and thus no corrective actions are necessary. In non-linear systems, feedback tends to be positive. Positive feedback in a non-linear system is the mechanism that serves on a continuing basis to actuate the difference between an initial condition of a system and a resulting one (p. 429).

System dynamics takes issue with much of the above. First the identification of non-linear with chaotic systems; second the alleged differences between linear and non-linear systems expressed in terms of feedback characteristics and sensitivity to initial conditions; third the behaviours attributed to feedback. There appear to be fundamental problems with respect to all these factors as will be illustrated later in this paper. Specifically linear systems do not contain feedback, non-linear systems may contain negative feedback only, positive

Table I.
Difference between linear system and non-linear system

	Linear system	Non-linear system
Initial conditions	Not important	Very important
Equilibrium	Stability	Chaos
Prediction	Deterministic	Chance
Feedback	Negative	Positive

feedback only, or both; the behaviour of non-linear systems is in most cases insensitive to initial conditions, although under certain circumstances chaotic modes may develop.

> Essentially, a non-linear system demonstrates an irregular but oscillatory pattern of behaviour … There are four stages that range on a continuum from linearity and predictability through two stages of mixed linearity and non-linearity to a final stage of chaos where the behaviour is characterized by non-repeating periodicity (p. 430)..

Here the author is perhaps referring to self-referencing properties (Stacey, 2000), which ignore that such progressions occur at most within a particular parameter range.

> A decision to move a system in one direction, e.g. implement new behaviours, can cause a future set of behavioural interactions that would not have been encountered if the decision had been to move the system in a different direction … Because the set of behavioural interactions cannot be predicted, it is not possible to accurately forecast future directions of the system, its behaviours or their outcomes. Each of these characteristics and stages is related to current conditions of educational systems in both Eastern and Western European nations (p. 431).

> These efforts (Eastern Europe) to dramatically alter the structure, philosophy and goals of the educational systems require increased diversity of behaviour that move the educational systems further from a state of equilibrium to a more chaotic one (p. 432).

A problem here is not with the expression of uncertainties, which are consistent with complex system behaviour. The difficulty is with attribution to specific real contexts (Eastern and Western Europe) and the strength with which the attributions are applied. This is in order provided the link is at the level of "possibility", but stronger claims mean that a model level correspondence really needs to be argued for. Here the strengths of claim vary from the theoretical possibility that a butterfly effect may emerge, to a rather decisive claim about needs to move Eastern European regimes towards chaotic modes. There appears to be no structural evidence in support of the validity of such an attribution, nor how the desired moves might be achieved.

> One must always be open to the continuing series of bifurcation points that will emerge throughout the development process. Each is likely to prove to be a critical decision point on which the future directions and possible success of development effort will depend. Many times such an event will not be evident as a major turning point in the development process because it does not appear to be related to the critical issue. However in retrospect it can be clearly seen that it began a chain of events. Each event caused a new bifurcation point and fed a continuing process of positive feedback that led to a final point in the development process (p. 436).

The general principle of learning from previous observation is important. However the claim of bifurcation requires again that the existence of a non-linear model with a chaotic regime be established, noting that counterintuitive behaviour is a frequent outcome in complex systems with no chaotic properties. The temptation to ascribe "after the fact" observation to a favoured explanation falls under the spell of an approach that philosophers such as Popper have been keen to dismantle.

Leading people in a chaotic world (Sullivan, 1999)

This article also draws freely on the language of complex systems, and consequently needs to be viewed in terms of the concepts it sets out to apply. Of interest is the frequent use of the term "system dynamics" although it becomes clear that this is used generically – the author appears unaware of the formal field of system dynamics and there are no references to any work in this field. For example:

> As little as a decade old and with the help of the latest developments in computer technology, chaos theory is transforming the scientific interpretation of system dynamics (p. 409).
>
> A study of system dynamics is a study of the shifts in structure, function, relationship, process and direction. It is an account of observations on the motion of change (p. 410).

In discussing the "butterfly effect" the author noted that Nadebaum (1990, p. 13) had argued that the butterfly effect process "offers the opportunity to consider systemic change in a way consistent with the present government administrative strategy of devolution (of decision making authority) and within the context of accepting the disequilibrium and unpredictability that will characterise our school systems through the 1990s". He refers to comments (Sungaila, 1990) that imply that successful and enduring initiatives often spread through an entire school organisation, with networks of communication lines made up from people from every facet of the school organisation and its much larger environment. In this way if opportunities are seized and communicated along the naturally occurring networks, initiatives can spread even to a whole system of education. This is interesting in that what here is suggested as an application of the "butterfly effect" sounds very like what Fritz (1999) would call finding and using the path of least resistance, a far from chaotic approach.

This article includes discussion of a school-based project that considered what statement of principles would be valued in a school system. The author's related observations and experiences of the project are drawn upon to argue for and illustrate, quite specifically, features deemed to be indicative of the presence of chaos in the system.

> However the ordered phase of policy implementation did not continue indefinitely. When some organisational groups accepted new influences, they also took on new expectations and acted different. In so doing they changed the expectations that other groups had of them. This process was repeated many times along the communication and action networks until radical deviations to the evolutionary paths of some groups soon emerged as a chaotic threshold. At some point near this chaotic threshold the open dynamic system was dominated by a chaotic attractor, which literally attracted additional self-referential communicative influences around it. … The chaotic attractor, on which so much self-referential communication was focused was the system of policy … The policy acted as a chaotic attractor by becoming the focus of attention for people in the organisation … The accompanying organisational action stimulated the self-organising dynamics of self-renewal and self-transcendence. These dynamics fluctuated and became unstable as some people attempted to align their expectations and actions with the policy, while others ignored the policy. Soon the various groups were unaligned and in a state of chaotic order. The system remained in this state until

> the dynamics finally stabilised into a new transformed order. The chaotic attractor (in this case the system of policy) was the power drive of change in the school organisation (p. 415).

Here the language of chaos is being used retrospectively to provide an interpretation of organisational behaviour. At most this would seem to be legitimately constrained to metaphor in the absence of a model, but the language is assertive, and purports to explain characteristics in terms of specifically identified chaotic elements. The reader is entitled to ask for substantiation in terms of precisely defined structure, if elements as specific as chaotic attractors are to be identified. Some apparent anomalies appear to invite further explanation. For example a system of policy (an input) is said to emerge as a chaotic attractor (a behaviour) rather than being responsible for its generation?

> These evolutionary dynamics were detailed and explained over the period of the case study from a phase of regular order, through the dynamics of chaos and to a new regular order ... The report and analysis intuitively portrayed a map of the system dynamics present in the school by giving meaning to the data collected and storing it as a database for strategic management ... In the research mentioned above, the reader must reflect not only on the events, but also on the processes that drive the organisation. In this sense, it is not a chronological or linear study of change, but an analysis of its dynamics (p. 416).

But if there are dynamics, there are equations, and if equations then a model. What principles gave "meaning to the data collected" beyond the preferred choice of those involved in the program?

> The science of chaos tells us that signs of disorder might well be signs that the system of education is healthy and on its way to a much improved new order (p. 421).

This seems a high-risk strategy, as signs of disorder may equally indicate a permanent or fatal disability. The viewpoint does not appear to provide any basis for action, or indeed whether action is desirable or necessary.

Summarising central issues featured in these literature selections we note:

- Various statements concerning the mathematical structure and behaviour of non-linear systems.
- Invoking of the "butterfly effect" with suggested implications for educational leadership.
- Claims that chaotic modes both describe and offer opportunities relating to the general operation of educational systems – as for example in Eastern, and Western, Europe.
- Identification of specific structures (e.g. chaotic attractors), and behaviours alleged to represent manifestations of deterministic chaos within a particular organisation.

Testing the water

In order to address issues such as the above, we note that the claims are essentially at the level of analogy and metaphor. That is, they are based on generic properties of complex systems rather than on models designed to

investigate particular cases. At the next level the discussions encompass both general aspects of structure and behaviour such as the "butterfly effect", and specific elements such as precisely identified chaotic attractors. So in order to address such claims it is appropriate to build a non-linear systems model, whose structure and behaviour can be used to examine the arguments presented. That is, the model should be of a non-linear complex system capable of testing specific dynamic assertions, but also able to generate behaviours useful to inform debates in which chaos and non-linear behaviours are invoked in a generic sense. It is useful out of interest, although not essential, for such a system model to address an educational context. A simple model to serve these purposes is described below. It has been designed to incorporate aspects of the problem of matching teacher supply and demand.

Model structure

Figure 1 contains a representation of a simple model whose principal components are described below. The behaviour of a non-linear model such as this is ultimately determined by the cumulative effect of interacting feedback loops. This simple model contains three negative (balancing) loops and a positive (reinforcing loop). The signs on the arcs indicate the nature of causal relationships. A+(−) sign indicates that the change or tendency to change in the variable at the head of an arrow is in the same (opposite) direction as the change in the variable at the foot of the arrow that is impacting upon it. In a balancing loop (B) an initial change in a variable works its way around the closed circuit to eventually cause a change in the same variable in the opposite direction. In a reinforcing loop (R) the final impact is in the same direction as the initial change.

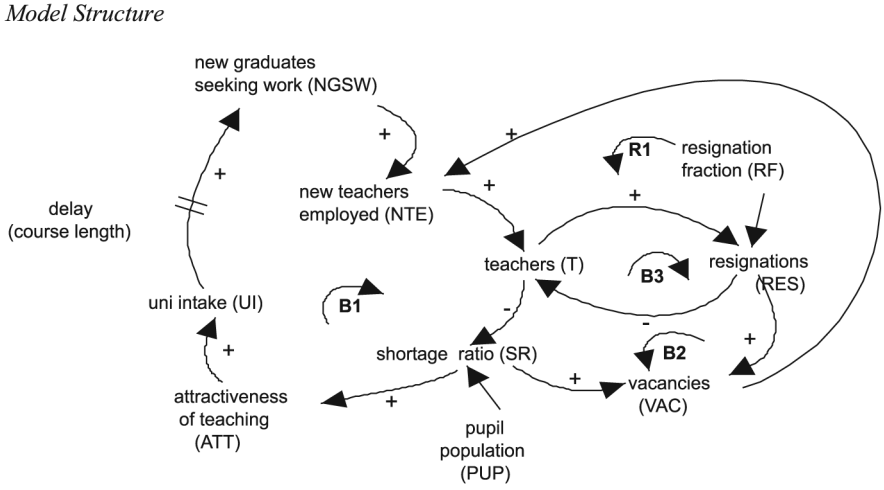

Figure 1.
Feedback loop structure

$$\text{LoopB1} : (\text{increase})\text{T} \rightarrow^{-} \text{SR} \rightarrow^{+} \text{ATT} \rightarrow^{+} \text{UI} \rightarrow^{+} \text{NGSW} \rightarrow^{+} (\text{decrease})\text{T}$$

This representation is read as follows, noting the interpretation of the arc signs given above and the diagram structure in Figure 1. An increase in teacher numbers reduces the shortage ratio, resulting in less attractive job prospects, leading to a reduction in university intake to teacher education courses, leading (after a delay) to fewer graduates seeking employment as teachers, and hence eventually to a decrease in teacher numbers.

$$\text{LoopB2} : (\text{increase})\text{T} \rightarrow^{-} \text{SR} \rightarrow^{+} \text{VAC} \rightarrow^{+} \text{NTE} \rightarrow^{+} (\text{decrease})\text{T}$$

An increase in teacher numbers reduces the shortage ratio, resulting in fewer vacancies, hence leading to fewer new graduates being employed, and thence to a decrease in teacher numbers.

$$\text{LoopB3} : (\text{increase})\text{T} \rightarrow^{+} \text{RES} \rightarrow^{-} (\text{decrease})\text{T}$$

An increase in the teacher population leads to an increase in resignations, which leads in turn to a decrease in the teacher population.

$$\text{LoopR1} : (\text{increase})\text{T} \rightarrow^{+} \text{RES} \rightarrow^{+} \text{VAC} \rightarrow^{+} \text{NTE} \rightarrow^{+} (\text{increase})\text{T}$$

An increase in the teacher population leads to an increase in resignations, hence to an increase in vacancies, thence to an increase in new teachers employed, and thus to an increase in the teacher population.

The positive (reinforcing) loop acts as a virtuous circle when operating in a growth phase, but as a vicious circle if running in reverse. It is not the case that a virtuous cycle is associated with negative feedback and a vicious cycle with positive feedback as suggested in the literature. The structure summarised in the loops is written precisely as sets of non-linear integral equations using specialised software such as Powersim, iThink, or Vensim. The equations (in Powersim) are not provided here, as they are not central to the argument. They are solved iteratively to simulate behaviour over time. For present purposes our interest is in using the model to test claims made about the structure and behaviour of non-linear systems, and the resulting inferences concerning organisational leadership.

To achieve this it is necessary to examine the model output in relation to the conditions under which it is simulated and for this purpose the time-histories of selected variables are plotted as shown in Figure 2. The plotted variables have been selected on two grounds. First to enable a "sense" of the model to be appreciated, and second to enable claims made in the literature to be precisely addressed. It is important to recognise what the model does not claim to do. It does not set out to predict precise quantities in a supply-demand situation. Rather it enables (at the level of behaviour mode) some understanding of the behavioural consequences of changes in the operating environment.

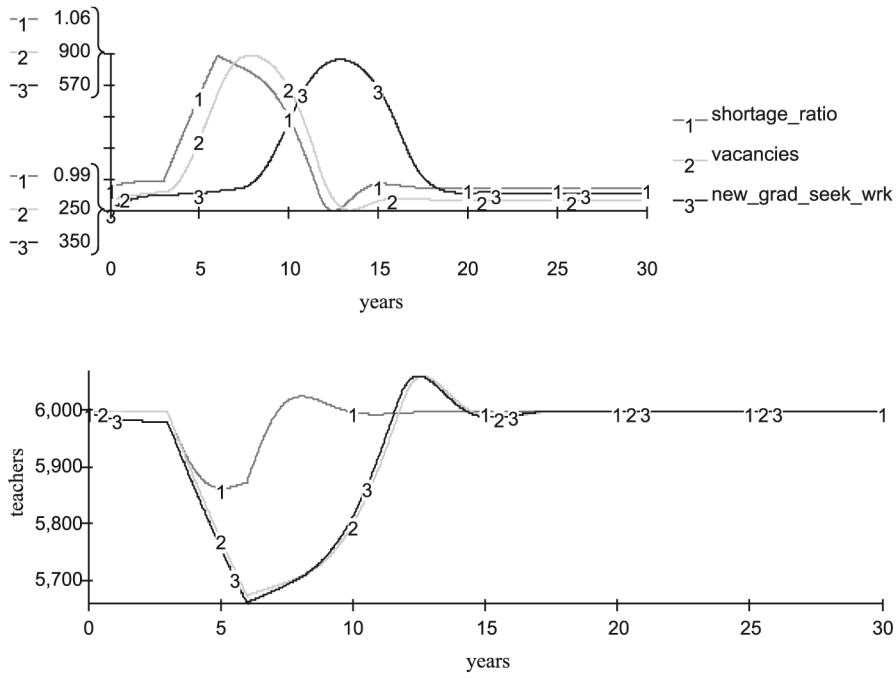

Figure 2 (a) (b).
Model output

The model is started in steady state with a constant resignation rate of 5 percent of the teaching workforce, and a graduate supply tuned to replace them. The dynamics are activated by an increase in this resignation rate of 2 percent for a period of three years from time=3, after which it returns to the former value. Initial values of the variables are chosen arbitrarily, as this is a policy analysis model, not for purposes of point prediction. The graphs in Figure 2(a) then provide insight into the way the real world of supply and demand is reflected in the model. The change in the resignation rate triggers a shortage followed closely by an increase in advertised vacancies as shown in graphs 1 and 2. The enhanced teaching opportunities signalled, result in an increased enrolment in teacher education programs with the subsequent response in new graduates seeking work (graph 3) delayed by the length of the training program, as indicated by similar behaviours displaced in time. As the resignation "shock" passes the system returns again to steady state. As a matter of interest the historical appearance of cyclic behaviour in surpluses and shortages has been noted.

Examining the claims

We may further divide the literature comment into two categories:

(1) making general statements about the structure and behaviour of non-linear systems, and

(2) making specific reference to chaos and inferences for leadership.

Noting the summary in Table I (Reilly, 1999), we observe that linear systems in fact contain no feedback and hereafter confine our interest to non-linear systems. The system model in Figure 1 is strongly non-linear and contains both negative and positive feedback as illustrated in the description above – a single loop of either persuasion is enough to provide non-linearity. We examine next the behaviour modes represented by the three graphs in Figure 2(a) together with graph 2 in Figure 2(b). These were activated by the increase in the resignation rate described above, with an initial teacher population of 375. These behaviour modes return to a state of stable dynamic equilibrium after the initial resignation shock has been dissipated.

The graphs in Figure 2(b) represent teacher numbers for three different simulations. Graph 2 is an output of the "standard run" described above and belongs with the graphs in Figure 2(a). Graph 3 was produced with the initial value of teachers set at 350 rather than 375. As can be seen the graph is virtually identical to graph 2, and this is a consequence of the policy that adjusts vacancies so as to eliminate a shortage or surplus in terms of the ratio of pupils to teachers (shortage ratio). Subsequent university enrolments responding to demand eliminate the discrepancy between the initial conditions in the two runs. These behaviours illustrate that sensitivity to initial conditions is *not* necessarily (indeed not often) a property of non-linear system behaviour, and the behaviour is not necessarily chaotic. Run 1 in Figure 2(b) has been generated by stepping up the average yearly progression rate of university students through their degree, from 75 to 85 percent. The effect is to increase the responsiveness of the system by providing more graduates more quickly, as is evident in the graph, and this illustrates that sometimes a significant change in behaviour can be activated by a parameter change.

Looking for chaos

The general robustness of behaviour modes in non-linear complex systems has been illustrated above. However chaotic modes sometimes do emerge, as shown in Figure 3. To generate this behaviour a particular "policy" was enacted in the system represented by the model – this involved changing the time-scale for action depending on whether a teacher shortage or surplus was current. Under conditions of surplus the vacancy level was adjusted over a two-year period and new teachers employed over the same time frame. Under conditions of shortage the period for action was set at three months. Thus the supply and demand system was subjected to a series of sudden jerks that caused teacher numbers to fluctuate in a chaotic mode. (In order for the graphs to show adequate resolution only a five-year period has been selected for plotting.) Here we do note the sensitivity to initial conditions, as graph 1 (in Figure 3) was

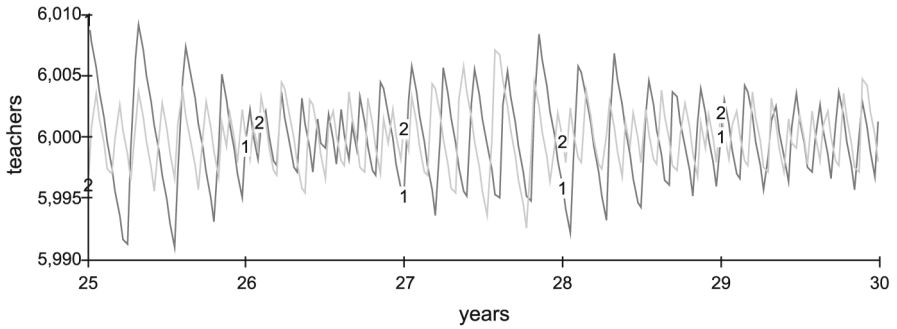

Figure 3.
Chaotic modes

generated with the teacher population set initially at 375, and the second graph with the corresponding initial value at 374. Notice the subsequent variations are random and unrelated, in contrast with the behaviour observed in Figure 2(b).

What then can we reasonably infer from the behaviours noted? In fact we have an illustration of a general property of non-linear systems, namely, that chaotic modes emerge only within a restricted range of parameter space. As (Andersen, 1988) reminds us following extensive experimentation, "even in those systems that do contain chaotic modes the chaotic mode appears only elusively". Furthermore here the chaotic mode was generated by parameter values with numerical rather than practical relevance, the policy producing chaos is unrealistic in terms of its applicability. Nothing approaching chaos emerged when policy actions remained in a normal operating range.

Reflections and implications

It is now the intention to reflect on the issues raised in the preceding sections and to address some themes that are central to matters associated with leadership and management of organisations as raised in the literature cited.

Non-linear systems

It seems that there is a degree of misunderstanding concerning the characteristics of non-linear systems, not least that they are equated with chaotic regimes. Some feedback discussions are confused, with positive feedback seemingly associated with necessary, indeed even sufficient conditions for the emergence of chaos. It seems possible that positive feedback is being equated with self-referential behaviour in which the value of a variable today is used in an iterative process to determine its value tomorrow (the variable value is "fed back" into the equation). A further assumption is that the behaviour of non-linear systems is sensitive to initial conditions when in the

majority of cases this is anything but the case. Given misunderstandings about the fundamental nature of non-linear systems it is not surprising that some very heroic claims are made with respect to the emergence of chaos.

Emergence of chaos

A number of aspects arise in discussions on this theme, which is a central feature of all the authors. These deserve careful attention as other inferences are made in consequence of the assertions. The aspects have both a theoretical and an empirical component. First we note the frequent comment that complex systems behave in various unexpected and unpredictable ways. System dynamics practitioners will be the first to concur with such an observation, but will be reticent in necessarily ascribing this property to chaos, as the counterintuitive behaviour of complex systems has been in the lexicon of system dynamics for decades – before the advent of chaos theory was generally known. The following quotation from Jay Forrester 30 years ago expresses it succinctly:

> Complex systems differ from simple ones in being "counter intuitive", i.e. not behaving as one might expect them to. They are remarkably insensitive to changes in many system parameters i.e. ultra stable. They stubbornly resist policy changes. They contain influential pressure points, often in unexpected places, which can alter system-steady states dramatically. They are able to compensate for externally applied efforts to correct them by reducing internal activity that corresponds to those efforts. They often react to a policy change in the long run, in a way opposite to their reaction in the short run. Intuition and judgement generated by a lifetime of experience with the simple systems that surround one's every action create a network of expectations and perceptions that could hardly be better designed to mislead the unwary when he moves into the realm of complex systems (Forrester quoted in Miller, 1972).

Attention to a global phenomenon (emergence of chaos) may also be at the expense of a discussion of the circumstances under which chaotic modes of behaviour emerge. As noted above, in systems where chaotic modes are among the output behaviours they typically arise infrequently (Andersen, 1988), a feature illustrated within an educational setting by subsequent experimentation with the model described in Galbraith (1998).

So with respect to organisational management the following summary points seem appropriate. First, chaotic modes of behaviour may be generated from appropriately constructed models. Second, the volume of parameter space that gives rise to this behaviour in complex systems is relatively small, and on the basis of some empirical studies at least, outside the range of practical working values. Most behaviours generated in non-linear systems containing feedback are non-chaotic. It is very possible, although not provable, that the more complex a real world system the less likely for chaos to emerge. This is because the number of checks and balances in the system constrain the operating conditions so that they do not approach the restricted range for which chaos is an outcome. Finally we reinforce that untoward,

counterintuitive, and unpredictable behaviour in complex systems is commonplace, but that this need have no association with the phenomenon of deterministic chaos. This is not to deny the existence of chaotic regimes, or their importance in understanding the range of behaviours that complex systems can theoretically exhibit.

Metaphor, archetype, model

The distinction between metaphor, archetype, and model at one level provides a set of lenses through which to consider attributes of complexity at different degrees of resolution. At another level the distinction strikes at the heart of confusion associated with claims concerning the role of chaos as a major player in the behaviour of complex systems. There is a world of difference between arguing from the precision of a model, arguing on the basis of an identified generic structure, and arguing by analogy at a system level. As pointed out by Ruelle (1994), if arguments are to be sustained at a level that supports application "a necessary condition for progress is that the relation between models and the real world be properly assessed".

It is not necessary to say that one level of representation is better than the other, for it depends on the purpose, but it is important to recognise that the nature of respective claims and associated evaluation criteria differ fundamentally. Model building proceeds at a micro level in that the model equations capture flows and decision making as they are carried out and described by those conducting the real life activities – every parameter and variable in a simulation model is matched to a real world counterpart. The order is important, first the actual activity, then its mathematical representation, for the approach to model building is essentially Popperian, with each relationship made public, explained, and justified in terms of the situation being modelled. The structure is defended or amended on the basis of critique, and the model output is then a consequence of the agreed structure. This is the approach required if, for example, it is intended to identify and defend the choice of elements as specific as "chaotic attractors".

An archetype (e.g. Senge, 1990) is a generic structure that has been identified as occurring in a range of different situations. The structure represents a small model whose behaviour is documented, and the behaviour is subsequently imported to situations in which the archetype is judged to exist in a new embodiment. In this way systemic insights can be obtained, although concerns have been expressed that archetype hunting can be a dangerous game, when those using them are not also familiar with the modelling that undergirds their integrity.

Argument at the level of metaphor or analogy is at a level well removed from that of model or archetype. The latter have accountability criteria associated with them – tests of model validity, or reasons why a particular archetype is relevant to understanding a given set of behaviours. Building models that can

withstand scrutiny is not easy and some doubtful efforts have emerged in the attempts to apply chaos theory to human systems.

> Some purported "applications" of chaos theory – for example to business management or literary analysis – are patently absurd (Sokal and Bricmont, 1998, p. 135).

The problem is not with the existence of chaos in complex systems, but with claims that unusual and unpredictable behaviour is representative of chaos with no tests of accountability applied to the conjectures. Argument at the level of metaphor is not equipped to meet such criteria.

Madam butterfly

Perhaps it is not surprising that the "butterfly effect" has been invoked consistently, given its public profile in popular discussions of chaos. Following from the previous section, it is not its occurrence, but the authority with which it is invoked that invites comment. Some of the suggestion by advocates is normative, promising wondrous change at the snap of an administrator's fingers, at times suggesting the necessity to ride roughshod over alternative viewpoints and beliefs in order to achieve a goal. This confrontationist stance, admittedly not promoted by all supporters, stands in contrast to the kind of leadership model arising from learning organisation theory in the tradition of *The Fifth Discipline*.

> Our traditional views of leaders – as special people who set the direction, make the key decisions, and energize the troops – are deeply rooted in an individualistic and non-systemic worldview. Especially in the West, leaders are heroes – great men (and occasionally women) who "rise to the fore" in times of crises. Our prevailing leadership myths are still captured by the image of the captain of the cavalry leading the charge to rescue the settlers from the attacking Indians. So long as such myths prevail, they reinforce a focus on short-term events and charismatic heroes rather than on systemic forces and collective learning . . . In a learning organization, leaders are designers, stewards, and teachers. They are responsible for building organizations where people continually expand their capabilities to understand complexity, clarify vision, and improve shared mental models – that is, they are responsible for learning (Senge, 1990, p. 340).

And finally we wonder whether another concept may be useful in the debate about strange and idiosyncratic behaviour of individuals and groups in organisations. The concept of "viewing distance" is fundamental in identifying patterns of behaviour and organisational activity. No one knows where the electrons are in the subatomic world of random activity, but aggregated matter tends to behave predictably according to the macro laws of physics. So perhaps the random and left field acts of individuals are mostly of limited consequence in the overall scheme of organisational activity? Indeed individual differences within a wider purpose are recognised in learning organisation theory, and provided for in the distinctions made between agreement and alignment. But my argument here of course carries no weight other than that of metaphor, it is at the same level as arguments claiming the "butterfly effect" will enhance the effect of small disturbances in organisational life.

Concluding comment

First it should be emphasized that there is strong sympathy with the intention, and indeed much of the content, of the papers addressing applications of "chaos theory" within educational administration. The artificial world of strategic plans, performance indicators, and management styles is a bleak repository for stimulating ideas. It has been argued however that problems exist in the attempts to apply "chaos theory" to educational administration and leadership. These include misunderstandings about the nature of non-linear systems and the kinds of dynamics they generate, misunderstandings concerning the nature of feedback, and about conditions for the emergence of chaos, which in some cases is treated as a fact of life rather than a mode appearing under certain, usually rare, circumstances. There are related problems concerning implications for practice that do not recognise essential differences that need to be respected when arguing respectively at levels of model and metaphor. While it has been known for many years by systems thinkers that complex systems differ from simple ones in being "counterintuitive", it seems likely that this property is mistakenly linked to the existence of "chaos", which is then evoked almost at the drop of a hat to support a wide range of interpretations and claims at the level of metaphor for management and leadership in organisations. There is no basis at this level of justification for ascribing properties of education systems and school operations to manifestation of "chaos" in action, or to suggest that, "a successful school or college would therefore operate away from equilibrium between stability and disintegration". Nor to ascribe disagreements within a school to the operation of a "chaotic attractor" or to suggest that the science of chaos indicates "that signs of disorder might well be signs that the system of education is healthy and on its way to a much improved new order". One might rather prefer to look for inept management! More dangerously arguments based on the "butterfly effect" stand to encourage megalomaniacs to introduce bizarre policies on the grounds that a flap of their wings will create an organisational thunderstorm to change the face of the future. This stands in direct conflict with a "learning organisation" concept that seeks alignment informed by systemic understanding, together with collegiality in leadership and management, in the search for profound and sustainable change. The last intent here is to stifle thinking "outside the square". What is asked for is the application of more careful criteria when appealing to mathematical theories to legitimate theory or to propose action. This is particularly so in areas such as leadership and management, where the community at large may not be accustomed to mathematical argument of this nature, and where human and organisational costs of misplaced policies and actions are so severe.

References

Andersen, D. (1988), "Chaos in system dynamic models", *System Dynamics Review*, Vol. 4, pp. 3-13.

Fritz, R. (1999), *The Path of Least Resistance for Managers*, Berrett-Koehler, San Francisco, CA.

Galbraith, P. (1998), "When strategic plans are not enough: challenges in university management", *System Dynamics: An International Journal of Policy Modelling*, Vol. X No. 1/2, pp. 55-84.

Gunter, H. (1995), "Jurassic management: chaos and management development in educational institutions", *Journal of Educational Administration*, Vol. 33 No. 4, pp. 5-30.

Miller, J.G. (1972), "Living systems: the organization", *Behavioral Science*, Vol. 17, p. 50.

Nadebaum, M. (1990), "Noah or butterfly? The changing role for school principals in the 1990s", paper presented at the Australian Council for Educational Administration National Conference, Hobart.

Popper, K. (1968), *Conjectures and Refutations*, Harper & Row, New York, NY.

Reilly, D.H. (1999), "Non-linear systems and educational development in Europe", *Journal of Educational Administration*, Vol. 37 No. 5, pp. 424-40.

Ruelle, D. (1994), "Where can one hope to profitably apply the ideas of chaos?", *Physics Today*, July, pp. 24-30.

Senge, P.M. (1990), *The Fifth Discipline: The Art and Practice of the Learning Organization*, Doubleday, New York, NY.

Senge, P., Cambron-McCabe, N., Lucas, T., Smith, B., Dutton, J. and Kleiner, A. (2000), *Schools That Learn: A Fifth Discipline Fieldbook for Educators, Parents, and Everyone Who Cares About Education*, Doubleday, New York, NY.

Sokal, A. and Bricmont, J. (1998), *Intellectual Impostures*, Profile Books Ltd, London.

Stacey, R.D. (2000), *Strategic Management and Organisational Dynamics: The Challenge of Complexity*, 3rd ed., Prentice-Hall, Harlow.

Sterman, J.D. (2000), *Business Dynamics: Systems Thinking for a Complex World*, McGraw-Hill, Boston, IL.

Sullivan, T.J. (1999), "Leading people in a chaotic world", *Journal of Educational Administration*, Vol. 37 No. 5, pp. 408-23.

Sungaila, H. (1990), "The new science of chaos: making a new science of leadership", *Journal of Educational Administration*, Vol. 28 No. 2, pp. 4-23.

Further reading

Galbraith, P. (1998), "Leadership for schools as learning organisations", in Ehrichand, L.C. and Knight, J. (Eds), *Leadership in Crisis? Restructuring Principled Practice: Essays on Contemporary Educational Leadership*, Post Pressed, Flaxton, pp. 43-51.

Galbraith, P. (1998), "Modelling issues in teacher supply and demand", in Mahanty, B. and Mohapatra, P.K.J. (Eds), *Proceedings of International Conference on System Dynamics ICSD-98*, System Dynamics Society of India, Kharagpur, pp. 296-304.

Galbraith, P.L. (1998), "System dynamics and university management", *System Dynamics Review*, Vol. 14 No. 1, pp. 69-84.

Galbraith, P. (1998), "When strategic plans are not enough: challenges in university management", *System Dynamics: An International Journal of Policy Modelling*, Vol. X No. 1/2, pp. 55-84.

Galbraith, P. (1998), "Systems thinking in management", pre-conference workshop notes: *International Conference on System Dynamics ICSD-98*, System Dynamics Society of India, Kharagpur.

Galbraith, P.L. (1999), "Systems thinking: a missing component in higher educational planning?", *Higher Education Policy*, Vol. 12, pp. 141-57.

Galbraith, P.L. (1999), "Universities as learning organisations – or not?", *Proceedings of 17th International Conference of the System Dynamics Society and 5th Australian and New Zealand Systems Conference* (compact disc), Wellington, July.

Galbraith, P. (2000), "Learning organisations – sifting the wheat from the chaff", *Perspectives on Educational Leadership*, Vol. 10 No. 5, pp. 1-2.

Galbraith, P.L. (2000), "Swings and roundabouts: riding the punches of university management dilemmas", in Altmann, G., Lamp, J., Love, P., Mandal, P., Smithand, R. and Warren, M. (Eds), *Proceedings: International Conference on Systems Thinking in Management*, Deakin University, Geelong, pp. 192-7.

Galbraith, P. (2001), *Systems Thinking: A Lens and Scalpel for Organizational Learning*, ERIC ED 453186: American Educational Research Association Annual Meeting, Seattle, 2001.