IMPLICATIONS FOR EDUCATION (AND OTHER)
RESEARCH FROM THE CHAOS THEORY STORY

Paper for presentation at AARE Annual Conference, 1991, Gold Coast, Queensland

by

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...the only truth lies in learning to free ourselves from insane passion for the truth....The order that our mind imagines is like a net, or like a ladder, built to attain something. But afterwards you must throw the ladder away, because you discover that, even if it was useful, it was meaningless.

William speaking in The Name of the Rose, Umberto Eco, 1984, 491 and 492.

Introduction

When I read the book Chaos: Making a New Science (Gleick, 1988) a forceful message emanated from the story told therein. This message concerns
research and researchers whether involved in the physical sciences or areas like education.

Many messages flow from this book and implications in other areas can be drawn from this amazing story. At the 1989 AARE Conference, for instance, in The Presidential Address, Helen Hocking drew from Chaos Theory pointers for a new way of viewing change and its achievements (see Hocking, 1990). The Chaos story is a cautionary tale for every researcher in that it highlights old issues and warnings which we tend to forget or repress when researching. The story, however, does more than this in that it provides a graphic example of how important is a certain attitude to research. This attitude is the one noted in the quote at the beginning of this paper, and is vital if significant advances are to be made in our understanding, and for productive paradigm shifts (see Kuhn, 1970) to occur, as was the case with Chaos Theory. This attitude is currently poorly exemplified, even in our universities, where there is much obsession with productive research (for which read “publishable and safely acceptable”) and useful research (for which read “non-speculative, non-exploratory and non-incongruous”).

In exploring the messages from the Chaos story as told by Gleick (1988) I am not going to consider the implications of Chaos Theory per se, although they are perhaps even more important and fascinating. I have organised the key implications drawn under five headings: Perspectives; Irregularities; Systems; Boundaries; and Products.

(In referring to “the Chaos story” I mean Gleick, 1988. Numbers in brackets provide relevant page(s) from Gleick, 1988.)

Perspectives

In the Chaos story the importance of perspective in research, especially in how we ask and answer a problem or question, is well illustrated by the case of Mandelbrot. Initially he asked “How long is the coast of Britain?” (94) and found this not easy to answer. The surveyor who uses a one yard (metre ?) set of dividers will get a smaller measure than will the one who uses a smaller set of dividers. Mandelbrot found also that this measure increases infinitely as the scale of measurement gets smaller. An acceptable answer to the question depends on your point of view (e.g. what you mean by “length”; what are your purposes in asking the question) and on how you go about answering it. Again, if you observe a coastline from a satellite your perception of its length (and other features) will differ from the one you would have if you walked over the bumps and around the wiggles of the coastline. (96-97)

It is easy to forget that everything is infinitely complex and that our simplifications of phenomena (like a map in the atlas of Britain), although powerful explanatory tools for many purposes are from some perspectives inadequate in that they mask detail and complexity.

Another point which relates to perspective and which is important for
researchers to remember is the fact that when we sample and collect data it is inevitable that “one kind of information is lost; another is brought into high relief”. (143). In the Chaos story this point is made when explaining how sampling of data about a rotor’s movement, concentrating on different data from the usual, revealed pattern within the rotor’s behaviour which from another perspective and from other data appears chaotic. This data collection also revealed the presence of an “attractor”, the holding- together mechanism which became a fundamental aspect of understanding Chaos Theory. To continue with Mandelbrot. Rather than despairing about the inability to get an “accurate” answer to the coastline question, he pursued an entirely different notion of measurement, namely of fractional dimension (in the case of a coastline its bumpiness). He took seriously the problem of complexity, in his case the complexity of shape dimension. But he found wanting the perspectives offered by the geometries and mathematics of the time and so developed a new geometrical measure which he termed the measurement of fractals, or of irregularity in shapes. (More about irregularity next section.) He opened the window onto complexity in a research world still fearful of it. Further explorations into complexity by Mandelbrot and others eventually led to a basic finding in Chaos Theory, namely that chaos and order can exist within the one system (and more about systems later).

Irregularities

Mandelbrot, with his investigation of complexity in irregular shapes was one person within a steady if small stream of researchers fascinated with irregularity and aberrations in phenomena. (By the way, Mandelbrot investigated complexities in other phenomena, see later.) Such fascination was antithetical to orthodox scientific procedures where imperfections were seen as a nuisance or as showing faulty measurement or poor observation. Aberrant data were thus hidden in bottom drawers or discarded in the round file. Where aberrant data were admitted in publications it was cause for apology.

Without researchers fascinated with irregularity Chaos Theory would not have eventuated. These people found that such phenomena and events did not fit the accepted conceptions or models (as had Mandelbrot). This incongruity was not resisted or ignored by them, but, as with Mandelbrot, was occasion for them to look for new conceptions. Thus they contributed to the eventual paradigm shift that Chaos Theory represents. I will provide three examples mentioned in the Chaos story of orthodox models or conceptions that were found wanting.

(i) The bell-shaped or Normal Curve

Data on fluctuations in cotton prices over a period of years collected by an economist Houthakker could not be made to fit this standard model for plotting variation (84). He discarded the bell shaped curve and applied a scaling model only to discover that seemingly random cotton prices had a symmetry of change. Daily price fluctuations produce the same scaled curve
as monthly price changes for data over a period of about 40 years (86). At each point was randomness, but taken all together the price changes had an otherwise hidden orderliness.

(ii) The ecological notion of equilibrium

Population biologists kept finding (and at first ignoring or explaining them as caused by faulty calculations) data which, although they showed that populations did not grow without limit showed also that they did not reach a steady state (65).

Robert May, one such biologist with a mathematical bent, began in 1971 to investigate the question of how a single population grows over time. He found that when certain parameters change a population grows in cycles of period-doubling bifurcations e.g. 4, 8, 16 etc. years, but then suddenly an odd period like 3 or 7 years, a chaotic period, will appear, only to return to another period of doubling bifurcations (69). A type of patterned irregularity was revealed and the notion of steady state was superseded by a Chaos Theory type conception.

(iii) that more information means better prediction

The Chaos story illustrates the dangers of accepting this claim. It is shown that no matter how much information meteorologists gain about the weather (helped in particular by improved instrumentation) small differences in input can result in huge differences in output (8). Although repetitions were found in the behaviour of weather phenomena the repetitions were never quite exact; there was irregularity and the possibility of instability at every point. This means that long range forecasting is doomed. However Lorenz, a meteorologist at MIT, turned his attention to trying to examine closely the irregularities of aperiodic systems of which weather is an example (as opposed to tidal systems which are periodic). He mapped the phenomena of weather geometrically and found they illustrated disorder, infinite irregularity with no exact recurrences, yet the mapping formed a distinctive shape with a finite perimeter; the data showed there was order with chaos within the system (llff). This brings us to the next section which is on Systems.

Systems

Gleick (1988) notes in the Chaos story “Scientists break things apart and look at them one at a time” (115). This approach achieves simplicity in the same way as ignoring irregularities enables the application of certain simple explanatory models (see earlier). Such an approach, however, means that characteristics of dynamical processes can’t be examined. (Also, this procedure, often called “reductionism”, breeds a particular way of looking at things which is linear and piecemeal, and tends to explanations in terms of specific variables.)

In the Chaos story it was willingness to examine dynamical processes and
the behaviour of systems that led to the unveiling of the intricacy yet self similarities within systems, of order within disorder (15). Chaos and order were found within the one system (8) with an attractor which holds and pulls it towards order when the system becomes chaotic (Ch. 5).

Boundaries

The Chaos story tells us that in the preliminary work into chaos scientists in different disciplines were working independently and often unknown to each other: meteorology, biology, economics, physics, mathematics, geometry, chemistry. As Gleick (1988) says: “Chaos breaks across the lines that separate scientific disciplines” (5). These days Chaos Theory has application also in medicine, astronomy, psychiatry and social theory.

For the development of Chaos Theory it was fortunate that some researchers were in fact cross-disciplinarians. An example is Lorenz, mentioned earlier as concerned with weather. He was a mathematician cum meteorologist (22). His work was some years later handed by a fluid dynamist to Yorke, a mathematician cum philosopher who worked at a multidiscipline institute at the University of Maryland. Yorke was free to work at problems outside the traditional disciplines and did so. Yorke talked with his friend May a biologist who began work on ecology irregularity mentioned earlier (65-69). Mandelbrot, aforesaid and a famous name in the Chaos story, was a mathematician who became enthralled with economics as well as fractals. Within the irregularities that plague economists order within disorder was identified, a feature Mandelbrot had discovered in mathematics.

Research that cannot be exactly classified into an orthodox compartment can produce scorn and even hostility (as happened at times in the Chaos story) (37), yet it can also be significant in furthering our understanding.

Being cross-disciplinary in one's research also poses the problem of where does one publish (given that one can avoid a hostile editor!). Publications are largely specialist in nature and even if one finds a publisher the readership tends to be limited to a specialist audience.

Eventually, however, Chaos Theory began to unite the specialisations because of its study of systems (see earlier). The big names in its development, however, had to break from the perceived straight and narrow pathways and be willing to put up with their work being seen as weird and unproductive. This takes us onto the next section: Products.

Products

It was fortunate for the development of Chaos Theory that most of the contributing researchers, for example Mitchell Freigenbaum (2; 158ff) had no concern for products in the traditional sense of publications, neat results, ‘useful’ findings. His concerns were with solving the “unsolvable” non-linear problems: turbulence; colour; parabola motion etc. (163-6). In so doing he made important contributions to Chaos Theory.
Another message from the Chaos story concerns the occurrence of serendipity. A concern for product usually shuts out serendipity like that which Lorenz experienced (21) when he realised weather was irregularly regular (see earlier).

Products of research are usually judged in terms of current acceptability. In the Chaos story this had problems for some of the researchers. For example, the “products” Swinney and Gollub mentioned when applying for a grant were disbelieved by those fluid dynamasists on the funding panel and they were refused a research grant (131).

However, most of the chaos researchers consciously turned from the 'acceptable' in their research. Some gave up doctoral research in orthodox problems, for example Shaw (246) who became the central figure in the Dynamical Systems Collective or Chaos Cabal within the University of Santa Cruz (248). This collective never received research funding and its members were seen as off beam by their Faculty, and as time wasters by some.

The persistence of these researchers, despite their difficulties with their contemporaries’ attitudes to products, has resulted in the greatest paradigm shift since Einstein.

Summary & Conclusion

Any impact on research in education from the paradigm shift that accompanied the development of Chaos Theory will have to overcome obstacles. Not the least of these is the emphasis on “productivity”. When applied to research this tends to encourage research which is in well established areas, uses well accepted research procedures and reveals unsurprising findings. (How otherwise will a university department achieve a competitive quantity of publications, or individuals establish an impressive enough record of productivity to be considered for promotion or funding?)

There is some evidence that research into irregularities and aberrations has support in education as a procedural goal and as offering potential for new ways of looking at the phenomena in which education researchers are interested. I recently had a doctoral student who did exactly this (Paoletti, 1990). Her work was and is acclaimed. One of the thesis examiners wrote: “New light is shown on the use of power in class-rooms through concentration on contradiction”. Another examiner said: “The descriptions of multiple perspectives on the same event...provides [sic] solid evidence that there is no single view of an event [whereas] past research in education has generally accepted a single perspective or point of view from which to view an event ... The contrasts that are identified make visible what is occurring as perceived and experienced by members of the class....The existence of these contrasts suggests that simple
reductionist perspectives...are naive and inappropriate to the study of teaching-learning processes in educational settings”. (Examiners names not provided on ethical grounds.)

We cannot know how many data have been and are still being discarded as aberrant and/or as not fitting currently accepted conceptions and models, or because of our preference for the power of simple explanations. If education researchers can adopt an attitude towards this type of data similar to that exemplified by the Chaos Theory researchers a number of positive outcomes is likely:

- new conceptions and new models will be created to assist our understanding of the complexity of the phenomena we study;

- investigation and pursuit of the irregular could tell us more than a lot of current research which serves only to support what we already know;

- special pleading and the temptation to “fudge” results (remember Burt?) will lessen as the attitude towards variations becomes: “what does this tell us?” instead of: “it’s worthless for my purposes”;

- unwarranted over confidence with regard to generalisation, prediction and explanation of infinitely complex phenomena could dissipate (and thus avoid many disappointments of application). An increase in cross-disciplinary approaches to research in education is also likely to have positive outcomes. As with Chaos Theory, understanding of the “deep” problems of education research will have to break across disciplines. (I use “deep” in the same sense as it is used in the Chaos Story : “For the hardest problems, the problems that would not give way without long looks into the universe’s bowels physicists reserve words like ‘deep’.” (3)

Perhaps most important will be willingness on the part of employers, senior staff, colleagues and funding committees and agencies, to support ideas and procedures, and “low productivity” at times, of researchers who place their efforts into looking into the “deep” problems in education.

References

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