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INTRODUCTION

Central paradigms of modern science are being questioned by an emerging group of scientists called chaos theorists. They argue that the reductionist approach to analysing real systems in order to predict future behaviour of the system cannot succeed. They go further arguing that unpredictable dynamic systems when observed holistically reveal patterns which have the capacity to bring order to chaos.

This paper suggests that the reductionist approach to investigation and the ideology of determinism has been absorbed by many other disciplines including education and that investigators in these disciplines need to re-assess their activities in the light of the work being done by chaos theorists.

It is beyond the scope of this paper to discuss all the work being conducted by chaos theorists.[1] The paper will therefore limit discussion to those aspects of chaos theory which strikes the author as having implications for one initiative in education - Competency Based Teacher Education.

Origins of Modern Science

Modern science based on a reductionist approach to investigation and an ideology of determinism began in seventeenth century Europe. According to Rose (Birke and Silvertown, 1984, p17) the origins of the reductionist approach to analysis can be found in the writings of Descartes

> "It is this Cartesian machine image which has come to dominate science......That the machine was taken as a model for the living organism and not the other way round is of crucial importance. Bodies are indissoluble wholes that lose their essential characteristics when they are taken to pieces. Machines on the contrary can be disarticulated to be understood and then put back together".

The ideology of universal determinism began in modern science with the work of Newton in the physical sciences. His work on gravity led to the belief that the world unfolded along a deterministic path, rule bound and therefore predictable.

Laplace the 18th century philosopher-mathematician talking of the possibilities of Newtonian determinism stated

> "Such an intelligence could embrace in the same formula the movements of the greatest bodies of the universe and those of the lightest atom; for it nothing would be uncertain and the future as the past, would be present to its eyes." (Gleick J, 1988, p14)

The history of science since Newton has shown that most scientific endeavour as been directed at breaking down particular systems into their simplest components measuring these components and then applying scientific laws and rules in order to predict the behaviour of the system. An essential

[1] A history of the development of chaos theory is provided in Gleick (1988).

assumption of modern science has been that given an approximate knowledge of a system's initial conditions, together with an understanding of physical laws and an adequate calculation capacity, one can calculate the approximate behaviour of the system.[2] There were many examples in science where this assumption did not hold true. Explanations for these exceptions were attributed to three possible inadequacies. Less than perfect measuring devices used to reveal a system's initial conditions. An incomplete knowledge of the laws which can be applied to the components making up the system or a lack of necessary calculation capacity to make sense of the numerous interactions of the components produced when the laws were applied to them.

Much of science focused on overcoming these inadequacies and the 1950's and 1960's produced a new wave of optimism. The Newtonian dream of universal determinism was resurrected at the macro level. The optimism was based on three important advances in science. Technology had developed whereby measuring instruments could gather much more information much more accurately.[3] The theories of relativity and quantum mechanics had led physicists to believe that all the physical laws had been deduced.[4] Finally computer technology enabled calculations to be made which would otherwise have been impossible.[5]

Beyond The Natural Sciences

The wave of optimism did not confine itself to the natural sciences. The Holy Grail - Prediction mesmerised psychologists, sociologists, educationalists, economists and political scientists. Complex systems in these disciplines were broken down into their components, rules establishing the relationships of the components were hypothesized and equations produced to formalise these relationships. The reductionist methodology of science was applied in other disciplines where predicting outcomes of complex systems was the sought after prize. For example Paul Lazerfield when discussing the development of the social sciences states

> "Obviously even in what Hempel calls the "pre-scientific" stage of our work, we use concepts in order to arrive at generalisations and therefore, implicitly in order to predict......Obviously no one would waste time on concepts to which he doesn't impute at least tacitly, some predictive merit." (Lazerfield, P E. 1972, p 50)

He goes on to add that as in the natural sciences "measurement" is a crucial element in sociological development.

"Occasionally, as in the case of Durkheim's suicide study, desire to interpret leads us to introduce new concepts for which we then need, if possible, more direct measurement." (Lazerfield, P.E. 1972, p59)

Similarly Wayne F Cascio writing in applied psychology confirms that classical scientific method is being used. In this particular example an equation is being used to help predict job success.

> "Note that in predicting job success the sign of the correlation coefficient is not important but the magnitude is the greater the absolute value of r the better the prediction of criterion performance. In fact the square of r indicates the percentage of criterion variance accounted for given a knowledge of the predictor." (Cascio, W.F. 1982, p381)

[2] This rule is more than an article of faith. There is a great deal of evidence which supports it. Accurate predictions of eclipses and comet sightings together with the whole of the space program relies on this assumption.

[3] Sophisticated space satellites now collect weather data (pressure, temperature, humidity etc) from a global network of grid points 60 miles apart.

[4] In 1980 Stephen Hawking Professor of Physics at Cambridge University declared "We already know the physical laws that govern everything we experience in everyday life." (Gleick, J. 1988, p79)

[5] Modern computers can undertake millions of calculations per second and can calculate mathematical systems of 500,000 equations.

The search for rules and laws which govern behaviour of systems is also a major concern within these disciplines. Victor Vroom for example when discussing leadership styles in management has formulated seven rules, which should be applied when deciding on appropriate leadership styles.

> "This occurs through a set of rules which eliminate decision processes from the feasible set under specifiable conditions....The seven rules are presented here both as verbal statements and the more formal language of set theory." (Leavitt, H. 1973, p331)

Of course most investigators in these areas were well aware that they were a long way from matching the success of the natural sciences. They still needed to produce accurate measuring instruments and discover the laws which were used in their disciplines. However with time and research these secrets would be revealed.

The work of psychologists also had a major impact in education. Learning was viewed as a system whose components could be broken down and measured. Rules concerning learning could be established and the relationship between the variables worked out. Implicit in this view of learning is that learning outcomes are predictable as long as the components can be identified and the rules governing the relationship of these components can be formulated. Nowhere in education is this view more apparent than in the Competency Based Teacher Education Movement. (Hereafter CBTE.)

COMPETENCY BASED TEACHER EDUCATION

The central view of the CBTE movement is that it is a scientific investigation of the teaching - learning system. Speaking about Competency Based Programs, Frederick McDonald writes

> "There is a more fundamental reason why it is necessary to demonstrate the effectiveness of competency based programs. Such a program will be effective - as its advocates both know well and say - to the degree that it's construction and operations are infused with the spirit of scientific inquiry." (Houston, W. 1972, p57)

Klingstedt confirms this view of the CBTE movement by stating that "Experimentalists would support this approach because of their faith in the scientific method and its role in research." (Houston, 1972, p96)

Competency Based Teacher Education is firmly on the side of scientific inquiry. Like the other disciplines its advocates are aware that they are way behind the natural sciences in the analysis of the system (teaching and learning) which interests them. However they believe that with a great deal of time and resources being spent sophisticated measurement instruments can be produced and the laws and rules which govern learning can be discovered. The behaviour of teaching learning systems can then be predicted.

The CBTE movement has already analysed the learning system in terms of the components that make it up and expressed many of them in terms of competencies, (observable activities which can be measured.)[6] However the search for measuring instruments and the laws and rules governing the system is a major focus of activity. In the U.S. for example a committee that was

[6] This reductionist approach to the teaching learning system is an integral part of CBTE. Richard Burns writing about the programs states that "Education can be viewed as a system whose parts can be defined, classified, measured and improved in other words managed systematically. Teaching skills for example are a composite of discrete but interdependent skills there is no reason to believe they are a gestalt of some type" (Houston, W. 1972, p57). Over 1000 competencies have been identified by the CBTE movement in the US.

formed to study national program priorities in teacher education recommended the development of approximately 250 school-based criterion measures of teacher performance.

"The Committee cannot emphasise too strongly the needed development of measures of teacher performance in the classroom." (Houston, 1972, p26)

Patricia Kay discussing the report notes

"The development of instruments to measure teacher performance under real classroom conditions will no doubt be extremely expensive but it is crucial to the establishment of competency based teacher education."(Houston, W. 1972, p272)

Similarly Frederick McDonald (Houston, 1972, p59) argues that measurement instruments are crucial.

"What about measurement of teaching skills? Few would disagree that the real significant aspect of teaching is the ability to behave in such a way that another person learns. Yet techniques for measurement of teaching skill are practically nonexistent."

He goes on to argue that research needs to be done on deciding what "units of teacher behaviour" should be measured.

"The problem of taxonomy development is complicated by the fact that there is no agreement on the unit to be measured.....What is the basic unit of teaching behaviour".

He adds that measurement can take place at various levels of teacher behaviour and that the units can vary.

"Personal preferences obviously will influence each investigator. Some will prefer molecular analysis others will prefer molar analysis."

The search for rules or relationships between teacher behaviour and student learning has been a major focus of educational research over the last 20 years.

However McDonald (Houston, 1972, p.20) argues that a great deal more work still needs to be done.

"The definition of teaching skills will be possible only when we have data indicating a well defined set of student responses that are elicited by each teacher behaviour."

He goes on to illustrate the way in which rules concerning learning can be formulated.

> "There is a need to identify those behavioural events that are reliably measurable and to determine the intercorrelations among these events .... I was investigating the positive reinforcement given by a teacher for student participation in the class and the adversive stimulation provided by the teacher .... Although the number of positive and negative reinforcers were negatively correlated the correlation was far more modest than I had predicted." (Houston, 1972, p72)

Competency Based Teacher Education has firmly placed itself on the side of science. It has used the reductionist methodology of science and its research activities have the flavour of scientific determinism. The natural sciences have used this methodology in order to predict future behaviour of systems and the other disciplines have adopted the methodology with prediction as the prize. There is of course at least an implicit predictive component contained in the work of the Competency Based Teacher Education movement. The major aim of any teacher training innovation must surely be to improve teacher performance and the use of these competencies to determine the certification of teachers by implication predicts the future performance of a teacher who has been certified.

In the US for example Turney reports that many States insist on their teachers

acquiring these competencies in their training it seems unlikely that this would be the case unless the states believed that the future performance of these teachers would be better.

"... the influence of competency based ideas on practising teachers has increased through the demands of teacher certification. Many States now insist that prospective teachers acquire a list of designated competencies." (Turney, C. 1985, p58)

This is confirmed by Theodore Andrews who writes that certain States in the US have adopted a competency base for teacher certification in order to

"improve teacher education by assuming the actual competence of those given certificates." (Andrews, T. 1972, p82)

Elvira Tarr commenting on the theoretical basis of the CBTE movement comes closest to stating that behind the rationale which drives the movement is the element of prediction.

"If on the other hand we employ theory in a narrower sense, ie a series of "laws" or regularities covered by a fruitful theory or a hypothesis of predictive value, we come closer to what CBTE seems to be." (Houston, W. 1974, p82)

Many of the critics of the CBTE movement also see a predictive element in the model Theodore Andrews argues that

> "Researchers have shown us that consistency of performance is exceptionally difficult to predict. Therefore, the demonstration of a discrete performance does not assure anyone that the performance can or will be duplicated when appropriate." (Houston, W. 1974, p34)

While Tarr suggests that there is no evidence to indicate that the demonstration of the ability to perform in a CBTE program can be used to predict future performance

> "The proponents of CBTE seem to share Plato's assumption that to know the good is to do the good, because nowhere are questions raised concerning the actual and continuing performance of those who have demonstrated their ability to perform." (Houston, W. 1974, p85).

It is not the intention of this paper to canvass in detail the objections of the critics of CBTE. Most of the objections do appear to be based however on the difficulties associated with identifying the components of the teaching learning system[7], or the difficulties associated with producing accurate measurement instruments[8], or the problems of deducing the rules and laws which govern the teaching learning system. The response to these criticisms by the proponents of the CBTE movement is that more research needs to be done and that the research models which need to be used are those of classical science. An increasing number of scientists are of the opinion that the classical approach of science cannot be used to predict the behaviour of most systems for example Stephen Hawking Professor of Physics at Cambridge University is quoted as saying

"It is a tribute to how far we have come in theoretical physics that it now takes enormous machines and a great deal of money to perform an experiment whose results we cannot predict." (Gleick, J. 1988, p6)

If this argument can be sustained it has of course important consequences for other disciplines which have adopted the classical scientific approach to investigation. Fundamental questions concerning the basic methodology used

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[7] H. Broudy for example argues that the search for teacher characteristics which increase learning seems to be without end. "This approach to evaluating teacher ability by looking for characteristics has soaked up so much effort and money with so little success that by now the researchers should be asking themselves whether this is the question they should be asking." (Houston W 1974 p59)

[8] For examples of some of these issues see (Quirk, T. in Houston, 1974, p251).

by science and adopted by the CBTE movement and other disciplines are now being addressed and that there is mounting evidence within the scientific community that reductionist methodology and the ideology of determinism cannot deliver the promise of predicting the behaviour of systems. The group of scientists who are questioning the central paradigms of science have been referred to as the chaos theorists, and one of the first scientists who could claim that title worked in the field of science - meteorology where the lure of prediction had always been strong.

WEATHER FORECASTING - AND THE BEGINNING OF CHAOS

In the 1950's and 60's the new optimism surrounding the possibility of resurrecting Newtonian determinism was also embraced whole heartedly by those who spent their lives divining that most unpredictable of systems - weather.

Most meteorologists believe as did most scientists that it was impossible to measure with absolute accuracy the different components of a system. However a basic assumption of all western science has been that very small inaccuracies in measurement produce only very small effects on outcomes.[9]

This assumption led meteorologists like Von Neumann, Head of the American Global Atmospheric Research Program, to believe that not only could weather be predicted but that it could also be controlled. The elements of the scientific paradigm were in place. The physical laws were understood, modern satellite technology provided approximately accurate measurements of initial conditions and computer technology could now solve the myriad calculations required. Weather was predictable.

In 1961 Edward Lorenz a meteorologist working at the Massachusett's Institute of Technology had developed a computer program which modelled the world's weather. Output from the program revealed patterns of ever changing ghost weather systems. One particular event that year not only profoundly altered his views on the possibility of long range weather forecasting but also was to make him one of the first chaos theorists.

Lorenz decided to examine a particular sequence of computer generated weather in more detail. In order to save time he decided to start the re-run half way through the sequence. To do this he typed into the computer the initial conditions applying in the print out from the earlier data. The re-run when it was completed produced a weather pattern which varied widely from the first. Here was a conundrum. Identical initial conditions run through the same computer program produced a completely different output.

The solution was soon discovered. The computer memory stored numbers to six decimal places however to save time the print out only printed to three decimal places. Lorenz had used the print out figures for his second run. The difference between the figures was minute. One part in a thousand, this magnitude of error in science would be regarded as inconsequential.[10]

Minor differences in the initial conditions had major effects on outcomes.

This led to Lorenz concluding that long range prediction of weather was an impossibility and lead him to begin a re-assessment of the central paradigms

[9] This compromise is more than an article of faith. There is a great deal of evidence to support this position. For example a tiny error in fixing the position of Comet Halley in 1910 would only cause a tiny error in predicting its arrival in 1986. However this is an example of a linear system that is a system where the components have relationships which are proportional and hence where the equations which describe the relationship are proportional.

[10] To be able to measure air pressure, temperature and humidity to an accuracy of one in a thousand would be regarded as a highly accurate measure.

of science which developed into what is now called the Theory of Chaos.

He began by examining the differences between systems such as weather which he regarded as unpredictable and systems whose behaviour could be predicted. It was well known in science that the behaviour of systems such as the solar system and the tidal system of earth were systems whose behaviour, after careful measurement and calculation, could be predicted.

The first difference he identified was that these predictable systems had a high degree of periodicity that is they displayed a regularity. Weather on the other hand displayed a low degree of periodicity that is it displayed irregularity.

The second difference was that systems such as weather were sensitive dependent on initial conditions. This point was later to be dubbed the Butterfly Effect.[11] Essentially Lorenz stated that weather conditions such as storms, showers or blizzards are impossible to predict because insignificant errors in measurement initially in the system build up and multiply their effects making prediction impossible.

The third difference which Lorenz isolated was the fact that in systems which have relationships which are not strictly proportional, that is where relationships can only be expressed using nonlinear equations then these systems will be unpredictable. Nonlinear equations generally cannot be solved and cannot be added together. The calculations cannot generally be done.[12]

The work of Lorenz indicated that the dominant scientific approach to predicting the behaviour of systems would not work with real systems [13] which were largely aperiodic, were sensitive dependent on initial conditions and whose components had mathematical relationships which could only be expressed in nonlinear equations. These conclusions have of course important implications not only for science but also for the other disciplines which have used the scientific model as a method for investigating systems and predicting their future behaviour.

The paper indicated earlier that the CBTE movement has used scientific paradigms to investigate the teaching learning system. As Lorenz has shown these paradigms only have a predictive capacity in systems which are periodic, where systems are not sensitive dependent on initial conditions, and where the relationships within the systems are linear.

This paper suggests that in terms of its system characteristics, the teaching-learning system is more like a weather system than for example the Solar System.

Like Lorenz's weather, the teaching-learning system never reaches a steady state and never quite repeats itself. The systems are aperiodic. The "Butterfly Effect" may also hold sway in the teaching/learning system. Insignificant perturbations in the system do not remain small but "cascade upward through the system" sometimes having a major impact on the behaviour of that system. Like the weather the teaching-learning system is sensitive dependent on initial conditions. A myriad of insignificant (and therefore overlooked) perturbations in the system can cascade upward producing the rich variety of behaviours that occur in the teaching-learning system.

[11] It was named this because of an analogy used to explain the point. A butterfly stirring the air today in Peking can transform systems next month in New York.

[12] There are many examples of nonlinear equations in science. In Fluid Dynamics the Navier-Stokes equation relates a liquid's velocity, pressure, density and viscosity. Gleick for example explains that "analysing the behaviour of a nonlinear equation is like walking through a maze whose walls rearrange themselves with each step you take." (Gleick, J. 1988, p24)

[13] Real systems here means everyday phenomena. In classical science experiments are conducted using simplified models of real systems. Hence particle physics can predict the result of two particles colliding in a linear accelerator. It is however unable to predict the turbulence patterns of milk when it is poured into a cup of coffee.

Finally Lorenz indicates the relationships of the components of a weather system can only be expressed in nonlineaer terms it would seem that teaching-learning relationships are also nonlinear. A constant importance cannot be assigned to one aspect of the relationship rather there is a twisted changeability between all of the elements which make up the teaching-learning system.

If this is correct of course then no amount of research designed to deduce the components of the teaching learning system and no amount of time spent in deducing the relationships or producing accurate measurements of those relationships will in the final analysis enable anyone to predict the future behaviour of the system.

This conclusion does not imply that CBTE is a poor training methodology. It may well be an excellent way of organising a teacher training program, however it cannot claim any predictive value for future success.

CONCLUSION

The work of Lorenz and other chaos theorists have had a profound influence in science, however the implications for other disciplines such as economics, social science, and psychology (which have used traditional scientific methodology) have not as yet been analysed. Essentially chaos theorists have told us that the behaviour of any system which is aperiodic and which is sensitive dependent on initial conditions cannot be predicted.

This paper suggests that the teaching/learning system is such a system and attempts to analyse this system in order to predict future performance of teachers-in-training cannot succeed. The CBTE movement uses the traditional scientific model and therefore the work of the chaos theorists must influence CBTE.

There are of course much wider implications produced by this revolution in science. All competency based training schemes may well have to be re-assessed, in terms of their capacity to predict future performance. The impact of chaos theory may well be much greater in disciplines other than education. Its importance in the disciplines mentioned earlier should not be underestimated.

The most intriguing aspect of the work of the chaos theorists is that their investigations into unpredictability have revealed patterns in apparently random systems. What this means for other disciplines remains unexplored, however the new framework provided by the chaos theorists may well be one which in future may be more appropriate for researchers in disciplines which have until now used modern science as their methodological model.

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HAS RESTRUCTURING LEFT HIGH SCHOOL TEACHERS PROFESSIONALLY STRANDED?

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In February 1987 the 'Better Schools Report' was released in Western Australia. It provided the blueprint for a radical restructuring of the state education system based on the principles of administrative decentralization, devolution of authority, and corporate management. The proposed changes were designed to make schools more self-determining. They were also intended to make the delivery of education more responsive, flexible, and accountable. To those ends, the Ministry of Education's central office was streamlined, the nine regional offices were replaced by twenty nine district offices, principals were given responsibility for recommending the permanency of all new teachers, and a process was set in motion to provide schools progressively with consolidated cash grants for purchasing goods and services at their own discretion.

One criticism levelled at the new system is that it has seriously undermined provisions for the professional development and welfare of high school teachers. Previously, these people received support and direction from subject superintendents, advisory teachers, and curriculum specialists based at Head Office.[1] Restructuring dismantled those positions, allegedly leaving many teachers "professionally stranded."

The dissatisfaction was voiced in a variety of forums. Most of it centred on the removal of the subject superintendents. For example, at the 1987 June council meeting of the State School Teachers Union, an unsuccessful motion called for the re-establishment of the position of subject superintendent. During the debate it was claimed that theabolition of this position was a terrible error, that subject teachers had no one to turn to, and that there was a "need for someone to be overviewing the implementation of the Unit Curriculum" (*The Western Teacher,* 17 July, 1987:5). Similar sentiments were expressed at some subject association meetings throughout 1987. Outside of formal settings, a common cry among many high school teachers was, "Bring back our supers." Criticism of the changes extended beyond the education system. In its response to the Better Schools Report, the W.A. Liberal Party (1987) stated:

> "The decision to down grade the role of subject superintendents in secondary schools is strongly opposed. These officers have played a significant role in assisting classroom teachers in the mastery of their subject area".

The 1988 Education Policy Statement of that party contains a promise to reinstate the position of subject superintendent.

More recently, a press article referred to teachers' "sense of isolation after the loss of subject superintendents" and "how the streamlining of the ministry

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[1] Before restructuring the Ministry of Education was called the Department of Education and Central Office was called Head Office.