# NEW RESEARCH ON CHAOS AND COMPLEXITY pdf

## 1: Research Methods in Education

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Cascading failures Due to the strong coupling between components in complex systems, a failure in one or more components can lead to cascading failures which may have catastrophic consequences on the functioning of the system. In other words, complex systems are frequently far from energetic equilibrium: Complex systems may have a memory The history of a complex system may be important. Because complex systems are dynamical systems they change over time, and prior states may have an influence on present states. More formally, complex systems often exhibit spontaneous failures and recovery as well as hysteresis. For example, an economy is made up of organisations , which are made up of people , which are made up of cells - all of which are complex systems. Dynamic network of multiplicity As well as coupling rules, the dynamic network of a complex system is important. Small-world or scale-free networks [9] [10] [11] which have many local interactions and a smaller number of inter-area connections are often employed. Natural complex systems often exhibit such topologies. In the human cortex for example, we see dense local connectivity and a few very long axon projections between regions inside the cortex and to other brain regions. For example, the termites in a mound have physiology, biochemistry and biological development that are at one level of analysis, but their social behavior and mound building is a property that emerges from the collection of termites and needs to be analysed at a different level. Relationships are non-linear In practical terms, this means a small perturbation may cause a large effect see butterfly effect , a proportional effect, or even no effect at all. In linear systems, effect is always directly proportional to cause. Relationships contain feedback loops Both negative damping and positive amplifying feedback are always found in complex systems. History[ edit ] A perspective on the development of complexity science: The history of the scientific study of these systems follows several different research trends. In the area of mathematics , arguably the largest contribution to the study of complex systems was the discovery of chaos in deterministic systems, a feature of certain dynamical systems that is strongly related to nonlinearity. The notion of self-organizing systems is tied with work in nonequilibrium thermodynamics , including that pioneered by chemist and Nobel laureate Ilya Prigogine in his study of dissipative structures. Even older is the work by Hartree-Fock c. One complex system containing humans is the classical political economy of the Scottish Enlightenment , later developed by the Austrian school of economics , which argues that order in market systems is spontaneous or emergent in that it is the result of human action, but not the execution of any human design. This debate would notably lead economists, politicians and other parties to explore the question of computational complexity. Gregory Bateson played a key role in establishing the connection between anthropology and systems theory; he recognized that the interactive parts of cultures function much like ecosystems. While the explicit study of complex systems dates at least to the s, [17] the first research institute focused on complex systems, the Santa Fe Institute , was founded in  A scientific society called Complex Systems Society organizes every year a general conference on these topics. Applications[ edit ] Complexity in practice[ edit ] The traditional approach to dealing with complexity is to reduce or constrain it. Typically, this involves compartmentalisation: Organizations, for instance, divide their work into departments that each deal with separate issues. Engineering systems are often designed using modular components. However, modular designs become susceptible to failure when issues arise that bridge the divisions. Complexity management[ edit ] As projects and acquisitions become increasingly complex, companies and governments are challenged to find effective ways to manage mega-acquisitions such as the Army Future Combat Systems. Acquisitions such as the FCS rely on a web of interrelated parts which interact unpredictably. As acquisitions become more network-centric and complex, businesses will be forced to find ways to manage complexity while governments will be challenged to provide effective governance to ensure flexibility and resiliency. Hidalgo and the Harvard economist Ricardo Hausmann. He believed that economics and the sciences of complex phenomena in general, which in his view included biology, psychology, and so on, could not be modeled after the sciences that deal with essentially simple phenomena like physics. Chaos is sometimes viewed as extremely complicated information, rather than as an absence of order. Ilya Prigogine argued [26] that complexity is non-deterministic, and gives no way whatsoever to precisely predict the future. When one analyzes complex systems, sensitivity to initial conditions, for example, is not an issue as important as it is within chaos theory, in which it prevails. As stated by Colander, [30] the study of complexity is the opposite of the study of chaos. Complexity is about how a huge number of extremely complicated and dynamic sets of relationships can generate some simple behavioral patterns, whereas chaotic behavior, in the sense of deterministic chaos, is the result of a relatively small number of non-linear interactions. They evolve at a critical state built up by a history of irreversible and unexpected events, which physicist Murray Gell-Mann called "an accumulation of frozen accidents". Many real complex systems are, in practice and over long but finite time periods, robust. However, they do possess the potential for radical qualitative change of kind whilst retaining systemic integrity. Metamorphosis serves as perhaps more than a metaphor for such transformations. Complexity and network science[ edit ] A complex system is usually composed of many components and their interactions. Such a system can be represented by a network where nodes represent the components and links represent their interactions. Its resilience to failures was studied using percolation theory. For modeling this phenomenon see Majdandzik et al. For their breakdown and recovery properties see Gao et al. The weighted links represent the velocity between two junctions nodes. This approach was found useful to characterize the global traffic efficiency in a city. The computational law of reachable optimality has four key components as described below. Any intended optimality shall be reachable. Unreachable optimality has no meaning for a member in the ordered system and even for the ordered system itself. Maximizing reachability to explore best available optimality is the prevailing computation logic for all members in the ordered system and is accommodated by the ordered system. Realizable tradeoff between reachability and optimality depends primarily upon the initial bet capacity and how the bet capacity evolves along with the payoff table update path triggered by bet behavior and empowered by the underlying law of reward and punishment. Precisely, it is a sequence of conditional events where the next event happens upon reached status quo from experience path. The more challenge a reachable optimality can accommodate, the more robust it is in term of path integrity. There are also four computation features in the law of reachable optimality. Computation in realizing Optimal Choice can be very simple or very complex. The Optimal Choice computation can be more complex when multiple NE strategies present in a reached game. Computation is assumed to start at an interested beginning even the absolute beginning of an ordered system in nature may not and need not present. An assumed neutral Initial Status facilitates an artificial or a simulating computation and is not expected to change the prevalence of any findings. An ordered system shall have a territory where the universal computation sponsored by the system will produce an optimal solution still within the territory. The forms of Reaching Pattern in the computation space, or the Optimality Driven Reaching Pattern in the computation space, primarily depend upon the nature and dimensions of measure space underlying a computation space and the law of punishment and reward underlying the realized experience path of reaching. There are five basic forms of experience path we are interested in, persistently positive reinforcement experience path, persistently negative reinforcement experience path, mixed persistent pattern experience path, decaying scale experience path and selection experience path. In addition, the computation law of reachable optimality gives out the boundary between complexity model, chaotic model and determination model. When RAYG is the Optimal Choice computation, and the reaching pattern is a persistently positive experience path, persistently negative experience path, or mixed persistent pattern experience path, the underlying computation shall be a simple system computation adopting determination rules. If the reaching pattern has no persistent pattern experienced in RAYG regime, the underlying computation hints there is a chaotic system.

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## 2: Chaos and Complexity Theory in Health Care - Superb Essay Writers

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The exact movement, reconfiguration and subsequent catastrophic destruction of the sand pile mentioned above are largely unpredictable. In the sand pile, Michaels and Bak suggest that it would not exist were it not for the grains of sand relating to each other and holding each other together. A significant factor here is that the closer one moves towards the edge of chaos, the more creative, open-ended, imaginative, diverse, and rich are the behaviours, ideas and practices of individuals and organizations, and the greater is the connectivity, networking and information sharing content and rate of flow between participants Stacey et al. The above considerations suggest that linear, mechanistic models of research may no longer apply, and networks and dynamical, ever-changing systems and turbulent environments are the order of the day. In the setting of education, in making internal changes in order to fit the law of requisite variety, school-based, collaborative research is required Morrison,  Out go the simplistic views of linear causality, the ability to predict, control and manipulate, and in come uncertainty, networks and connection, self-organization, emergence over time through feedback and the relationships of the internal and external environments, and survival and development through adaptation and change. Society and societal systems are open; closed systems, as Prigogine and Stengers remind us, run down and decay into entropy unless they import energy from outside. They either adapt or die. The implications of complexity theory for educational research Chaos and complexity theories argue against the linear, deterministic, patterned, universalizable, stable, atomized, modernistic, objective, mechanist, controlled, closed systems of law-like behaviour which may be operating in the laboratory but which do not operate in the social world of education. These features of chaos and complexity theories seriously undermine the value of experiments and positivist research in education e. Gleick, ; Waldrop, ; Lewin,  Complexity theory argues to replace an emphasis on simple causality with an affirmation of networks, linkages, feedback, impact, relationships and interactivity in context Cohen and Stewart, , emergence, dynamical systems, self-organization and distributed control rather than the controlling mechanism of an experiment , and open system rather than the closed system of the experimental laboratory Morrison,  What is being argued here is that, even if one could conduct an experiment, the applicability of that laboratory procedure to ongoing, emerging, interactive, relational, changing, open situations, in practice, would be limited, even though some gross similarities might be computed through meta-analysis. The world of classrooms is not the world of computed statistics. Schools exhibit many features of complex adaptive systems, being dynamical and unpredictable, non-linear organizations operating in unpredictable and changing external environments. Indeed schools both shape and adapt to macro- and micro-societal changes, organising themselves maybe in response to external constraints and pressures , responding to, and shaping their communities and society i. Linear systems demonstrate Newtonian mechanistic predictability and controllability. Small causes bring small effects and large causes bring large effects. Chaos occurs when small causes can bring huge effects and huge causes may have little or no effect, i. Complexity breaks the mechanistic determinism of linear systems but not in the unpredictable, uncontrolled way of chaos; as systems move away from linear predictability, the emphasis on creativity, divergence and fecundity are maximised but are still ordered, before they spill over into the breakdown of order that is chaos. Complexity theory suggests that the tenets of positivism are highly questionable. Control, predictability, manipulation and straightforward relationships between cause and effect no longer hold true in the complex world. Circular causality and feedback are central elements in complexity theory. The creativity and knowledgeability of actors is at the core of this process and secures the re-creation of social systems within and through self-conscious, creative activities of human actors. The term self-organization refers to the role of the self-conscious, creative, reflective and knowledgeable human beings in the reproduction of social systems. Complexity theory provides a robust critique of positivist approaches to educational research, for example in experiments. The purposes of experiments are clear â€” to establish causality and predictability through control and manipulation. The impact of complexity theory and chaos theory Gleick, ; Waldrop, ; Lewin, ; Kaufmann, suggests that predictability is a chimera. In educational settings, Tymms Hence, if utilization is an important focus then experiments may have limited utility. With respect to research methodology, complexity theory suggests that educational research should concern itself with: Complexity theory suggests that phenomena must be looked at holistically; to atomise phenomena into a restricted number of variables and then to focus only on certain factors is to miss the necessary dynamic interaction of several parts. More fundamentally, complexity theory suggests that the conventional units of analysis in educational research as in other fields should move away from, for example, individuals, institutions, communities and systems c. These should merge, so that the unit of analysis becomes a web or ecosystem Capra, Individuals, families, students, classes, schools, communities and societies exist in symbiosis; complexity theory tells us that their relationships are necessary, not contingent, and analytic, not synthetic. This is a challenging prospect for educational research, and complexity theory, a comparatively new perspective in educational research, offers considerable leverage into understanding societal, community, individual, and institutional change; it provides the nexus between macro and micro-research in understanding and promoting change. In addressing holism, complexity theory suggests the need for case study methodology, action research, and participatory forms of research, premised in many ways on interactionist, qualitative accounts, i. This enables multiple causality, multiple perspectives and multiple effects to be charted. Self-organization, a key feature of complexity theory, argues for participatory, collaborative and multi-perspectival approaches to educational research. In educational research terms, complexity theory stands against simple linear methodologies based on linear views of causality, arguing for multiple causality and multi-directional causes and effects, as organisms however defined: No longer can one be certain that a simple cause brings a simple or single effect, or that a single effect is the result of a single cause, or that the location of causes will be in single fields only, or that the location of effects will be in a limited number of fields. It is untenable to hold variables constant in a dynamical, evolving, fluid, idiographic, unique situation. It is a commonplace truism to say that naturalistic settings such as schools and classrooms are not the antiseptic, reductionist, analyzed-out or analyzable-out world of the laboratory, and that the degree of control required for experimental conditions to be met renders classrooms unnatural settings. Even if one wanted to undertake an experiment, to what extent is it actually possible to identify, isolate, control and manipulate the key variables in an experiment, and, thence, to attribute causality? For example, let us say that an experiment is conducted to increase security and reduce theft in two schools through the installation of a closed circuit television CCTV. The effect is a reduction in theft in the experimental school. Exactly what is the cause here? It may be that potential offenders are deterred from theft, or it might be that offenders are caught more frequently, or it might be that the presence of the CCTV renders teachers and students more vigilant, and, indeed, such vigilance might make the teachers and students more security-conscious so that they either do not bring valuables to the school or they store them more securely. The experiment might succeed in reducing theft, but what exactly is happening in the experimental school? Are the changes occurring in the teachers, the students, or the thieves, or some combination of these? We simply cannot infer causes from effects, and it is a pretence to believe that we can isolate, control and predict social behaviour from, and in, naturalistic settings. Yet it is precisely this explanatory understanding that should be informing practice. The experiment is still a comparatively opaque black box, disabling the identification of detailed causal mechanisms that produce treatment effects Clarke and Dawson, An experiment, as Pawson and Tilley This is a crucial matter, for experiments require exactly the same intervention or programme across the control and experimental groups, i. Yet this is impossible. Because sentient people tailor their behaviour to each other, their behaviour will differ, and, therefore, the planned intervention or program will alter. Social processes at work in the experiment may well be determining factors, and experiments may be quite unable to control for these. This is the well-rehearsed problem of causality â€” behind or alongside an apparent cause A causes B lurk other causes C causes A which causes B, and D causes A and B respectively. It is akin to a person taking ten medicines for a stomach pain: Small events cause major upsets and render long term prediction or generalizability futile. How do we know what the effects of small changes will be in an experiment? In the short term school inspections might improve academic results, but, in the longer term, they could lead to such demoralization of teachers that recruitment and retention rates suffer, leading to falling academic results. The thirst for improved grades in schools might lead to an initial improvement in performance but contributes to a testing and cramming culture of nightmare proportions Noah and Eckstein, ; Sacks, One might find, for example, that constant negative harassment of teachers by a school principal might increase the amount of time they spend on lesson preparation, which might or, indeed might not improve lesson quality. Increasing homework may be effective according to a school principal, but may demotivate students from lifelong learning â€" clearly a failure in the eyes of students. There is a problem in experiments, in that a single intervention does not produce only a single outcome; it produces several. A treatment for cancer can cure the disease but it might also bring several side-effects, for example hair loss, amputation, sickness and gross lethargy. Experiments are inherently reductionist and atomizing in their focus and methodology; they are incapable of taking in the whole picture Cohen and Stewart, Complexity theory not only questions the values of positivist research and experimentation, but it also underlines the importance of educational research to catch the deliberate, intentional, agentic actions of participants and to adopt interactionist and constructivist perspectives. Just as complexity theory suggests that there are multiple views of reality, so this accords not only with the need for several perspectives on a situation using multi-methods , but resonates with those tenets of feminist research that argue for different voices and views to be heard. Heterogeneity is the watchword. A quantitative research methodology that respects this has to break with simple linear models e. Complexity theory provides not only a powerful challenge to conventional approaches to educational research, but it suggests both a substantive agenda and also a set of methodologies. It provides an emerging new paradigm for research. Introduction to Systems Theory and Complexity. University of Capetown Press. Scientific American, January, pp, 46â€" John Wiley and Sons. Systematic Practice and Action Research, 16 2 , pp. Emergence, 2 4 , pp, John Wiley and Sons Inc.. Questions from a Complex Systems Perspective. New England Complex Systems Institute. Life on the Edge. An Exploration of Discovery. The Chaos Network, http: Pedagogy, Culture and Society, 22 2 , Fad or Radical Challenge to Systems Thinking? Discovering Order in a Chaotic World second edition.

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