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Complexity theory in education governance: initiating and sustaining systemic change

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1. Introduction

Some of the most interesting and worthwhile implications of complexity theory include the insights it offers into understanding change – and, by implication, continuity. It offers the most cogent theory of change of which I'm aware. Perhaps more realistically than a theory of change for our purposes here, it offers a metaphor, or a lens, through which we might better understand what it takes to initiate and to sustain systemic change. The conceptualization of change in complexity theory provides some insight into what manner of intervention stands the most chance of being sustained – a question of considerable importance for education governance. In this short paper, then, I consider the challenge of sustainable change in education from the perspective of complexity theory.

I want to start with two examples with which we should all be familiar: questions about the origins of life itself; and questions about how consciousness emerges from an agglomeration of biological cells. Simple questions that should get us off to an easy start. Life, and indeed consciousness, are best understood as *emergent phenomena*: while the brain is a complex arrangement of billions of neurons functioning according to the laws of cell biology, the phenomenon of mind emerges as much more than a biological agglomeration of nerve cells. The principle of emergent phenomena on account of increasingly complex networks among constituent elements has been used by the theoretical biologist, Stuart Kauffman (1992), to explain the origins of life. As the Nobel laureate physicist, Phil Anderson (1972, cited by Waldrop, 1993, p. 82), has argued, "At each level of complexity, entirely new properties appear. [And] at each stage, entirely new laws, concepts, and generalisations are necessary…. Psychology is not applied biology, nor is biology applied chemistry."

It is important to note at the outset that the notions of scale and complexity are what underlie the principle of emergent phenomena. New properties or behaviours emerge when sufficient numbers and varieties of constituent elements or agents cluster together to form a sufficiently complex arrangement of incredible scale. The concept of emergence implies that, given a significant degree of complexity in a particular environment, new properties and behaviours emerge that are not necessarily contained in the essence of the constituent elements, or easily able to be predicted from a knowledge of initial conditions. These concepts of emergent phenomena from a critical mass, associated with notions – that we will come across shortly – of lock-in, path dependence, the 'economics of increasing returns', and inertial momentum, contribute to a perspective on continuity and change that indicates what conditions might need to be in place for the emergence of sustainable, positive, system-wide change and development in education.

To reiterate, complexity theory is, first and last, about reaching critical mass among the diverse range of factors, elements and agents that constitute a particular environment. It offers, in other words, a dynamic and system-wide perspective on how sustainable change, characterized by new properties and behaviours in the education system, emerges from the interaction of a myriad factors in the economic, political, social and cultural environments in which education is situated. Other theories of change have sought 'the levers of history' – a metaphor I am going to suggest is inappropriate – in economic structures, in human agency, and in combinations of these and other factors that include or exclude either or both. Complexity theory offers a theory of change that might be said to encompass all of these and more, and that might offer the most helpful insight yet into how educational development and change might be rendered sustainable.

2. Complexity theory

Developed in the fields of physics, biology, chemistry and economics, complexity theory arises in some senses out of chaos theory in that it shares chaos theory's focus on the sensitivity of phenomena to initial conditions that may result in unexpected and apparently random subsequent properties and behaviours. Chaos theory suggests that even a very slight degree of uncertainty about initial conditions can grow inexorably and cause substantial fluctuations in the behaviour of a particular phenomenon – Edward Lorenz's 'butterfly effect'. Perhaps more importantly, complexity theory shares chaos theory's concern with wholes, with larger systems or environments and the relationships among their constituent elements or agents, as opposed to the often reductionist concerns of mainstream science with the essence of the 'ultimate particle'.[1]

Complexity theory concerns itself with environments, organizations, or systems that are complex in the sense that very large numbers of constituent elements or agents are connected to and interacting with each other in many different ways. These constituent elements or agents might be atoms, molecules, neurons, human agents, institutions, corporations, etc. Whatever the nature of these constituents, the system is characterized, as Waldrop (1993, p. 88) has described, by a continual organization and re-organization of and by these constituents

> into larger structures through the clash of mutual accommodation and mutual rivalry. Thus, molecules would form cells, neurons would form brains, species would form ecosystems, consumers and corporations would form economies, and so on. At each level, new emergent structures would form and engage in new emergent behaviours. Complexity, in other words, [is] really a science of emergence.

[1] The consideration of complexity theory offered here is based on fuller explications provided in Mason (2008)b, What is complexity theory and what are its implications for educational change? *Educational Philosophy and Theory 40 (1)*, 35-49; and in Mason (2008)a, Complexity theory and the philosophy of education, *Educational Philosophy and Theory 40 (1)*, 4-18. Interested readers who seek to engage further with the field might consider these two articles, and also the chapters in Mason (Ed.) (2008)c, *Complexity Theory and the Philosophy of Education* (Wiley-Blackwell).

One of the most important insights of complexity theory is this notion of emergence which implies that, given a sufficient degree of complexity in a particular environment, new (and to some extent unexpected) properties and behaviours emerge in that environment. The whole becomes, in a very real sense, more than the sum of its parts in that the emergent properties and behaviours are not necessarily contained in or easily able to be predicted from the essence of the constituent elements or agents. A central concern of complexity theory is thus on the relationships among the elements or agents that constitute a particular and sufficiently complex environment or system. Once a system reaches a certain critical level of complexity, otherwise known as the critical mass, a phase transition takes place which makes possible the emergence of new properties and behaviours and a new direction of self-sustaining momentum. A certain critical level of diversity and complexity must be reached for, say, an education system to achieve this sustainable autocatalytic state – that is, for it to maintain its own momentum in a particular direction. The model posits the phase transition as a fundamental law of increasing complexity, but the specific details of this phase transition – when and how it occurs, what properties and behaviours emerge – are contingent on specific contextual factors and are probably unique to that particular context.

Complexity theory makes no claim to predict what is essential and what can be marginalised in the search for 'the levers of history'. In this sense, and as will become clearer, the perspective of complexity theory on change shows how inappropriate is this analogy, with its connotations of single, powerful causes. As a research paradigm, complexity theory cautions us not to marginalise or dispense with what is apparently trivial or inexplicable. What may appear to be marginal may be part of the complexity of a system, and may be constituent of the critical level above which emergent properties and behaviours become possible.

Complexity theory suggests that it is in the dynamic interactions and adaptive orientation of a system that new phenomena, new properties and behaviours, emerge, that new patterns are developed and old ones change. It seeks the sources of and reasons for change in the dynamic complexity of interactions among elements or agents that constitute a particular environment. It is in this sense that seemingly trivial accidents of history may increase dramatically in significance when their interactions with other apparently minute events combine to produce significant redirections in the course of history, significant shifts in the prevailing balance of power. Complexity theory can accept the existence of certain essential generative elements in a particular field, but suggests that the field as a whole is much more than merely predictably determined by the primary generative element. While this may be a trigger, and indeed only one of many triggers, of subsequent phenomenal developments, complexity theory suggests that it is the manifold interactions among constitutive elements or agents that are responsible for the phenomena, patterns, properties and behaviours that characterize a particular field.

The successive addition of new elements or agents to a particular system multiplies exponentially the number of connections or potential interactions among those elements or agents, and hence the number of possible outcomes. This is an important attribute of complexity theory, in that the connections among individual agents or elements assume an importance that is critical to complexity theory's assertions about emergent properties. This emergence becomes possible by virtue of the exponential relationship between the elements or agents and the connections among them. The essence of the individual elements or agents that constitute a particular system does not alone provide the key to understanding that system. Complexity theory draws attention to the emergent properties and behaviours that result not only from the essence of constitutive elements, but more importantly, from the connections among them. The focus thus shifts from a concern with decontextualised and universalized essence to a concern with contextualised and contingent complex wholes. Complexity theory echoes Foucault's emphasis on "polymorphous correlations in place of simple or complex causality" (cited in Harvey, 1990, p. 9). Admittedly, complexity theory does suggest that new properties and behaviours will emerge out of these "polymorphous correlations", but the point is that the possibility is lessened of an accurately predicted causal relationship from known initial conditions to these emergent phenomena.

In the light of complexity theory, I would define power, or, more simply, the prevailing balance of the *status quo*, of the way things are, as the directional course of the phenomenon that enjoys the dominant inertial momentum[2] over other competing phenomena. The prevailing *status quo* will sustain, and indeed increase, its dominance by virtue of what can be simply and analogously understood as the snowball effect. Individual and apparently trivial accidents in the purview of the dominant structure's momentum will be gathered up in its path, and those outside of its purview will remain marginal and ineffective unless and until sufficient momentum in a different direction is sustained by sufficient complexity of a different, if related, concatenation, or network – to use a different metaphor – of originally trivial events. How radical the power shift is will depend on the degree of difference in strength and direction – as in velocity or in vector analysis, but rather more amorphously – between the existing and the emerging power structures. The term path-dependence, allied to the notion of lock-in, illuminates this idea by suggesting that the inertial momentum of a particular phenomenon will sustain its direction and speed along a particular path, that a phenomenon is describable in terms of the direction of its path, and that it will continue in that path to the point where sufficient inertial momentum of a competing phenomenon results in a redirection of that path. In this manner, or, analogously, good educational institutions or systems will sustain and probably increase their own momentum, and weaker educational institutions or systems will likewise compound the failure of their students, thereby further weakening themselves in an endless and vicious cycle.

The notion of inertial momentum, referring to the snowball effect, or the ever-increasing probability of the development and sustenance of correlated possibilities on account of recently developed phenomena, provides the conceptual link between the principle of emergent phenomena as developed principally in the natural sciences and the notion of socio-historical change in human society. Inertial momentum is, as I have suggested, inextricably related to the phenomenon of power. The power of an existing dispensation or social arrangement to sustain itself and to increase its purview of influence or control is

[2] The concept of inertia, most commonly used in physics, is probably familiar to social scientists less in association with the concept of momentum and more in terms of its association with resistance to movement, viz., the 'inertial mass' of a heavy object on a high-friction, level surface. The concept of inertial momentum is, however, also common in physics, denoting, in rather over-simplified terms, the resistance of an object in motion to changes in its velocity. See Mason (2008b) for an introduction of the term to the social sciences.

directly related to its inertial momentum, to the aggregate weight of the phenomena of which it is constituted. And this aggregate is the result of the number, scale and diversity of the elements and agents that constitute the social arrangement, and of the degree of complexity of the interactions among them.

This snowball effect can be understood in terms of what the economist, Brian Arthur, (1989) has called "the economics of increasing returns", allied to the idea of 'lock-in'. A striking example is the dominance of the QWERTY typewriter keyboard (at least in Anglophone countries). When mechanical typewriters were developed, touch-typists had to be slowed down by inefficient keyboard layouts because their increasing dexterity would continually jam the mechanically slow machines. One of the most inefficient designs (by Christopher Scholes in 1873) was the QWERTY layout, which was adopted and mass-produced by Remington. More typists accordingly learned on the QWERTY layout, more companies therefore adopted the same layout, and a virtually unbreakable lock-in of the QWERTY keyboard resulted. Other more efficient keyboard layouts have been designed, but the probability of their breaking the locked-in monopoly of the QWERTY keyboard, particularly now, given the contemporary proliferation of computer keyboards (and, ironically, when we no longer have to worry about the mechanical jamming of the keyboard), is almost zero.

The phenomenon of lock-in is associated with the "spontaneous self-organization" of systems identified by the Nobel laureate physicist, Ilya Prigogine (1980), in his research on the origins of order and structure at all levels of the universe. The spontaneous dynamics of living systems result from the positive feedback to or self-reinforcement of phenomena, a process which is characterized by the increased incidence and significance of initially apparently trivial events under the at first random conduciveness of circumstances. While the circumstances in which the positive feedback eventually occurs may have been initially random, the self-reinforcement leading to lock-in of a particular phenomenon reflects an autocatalytic chain of events in the field. The direct implication is of a self-sustaining phenomenon which, while the statistical chances of its appearance may have been negligible at first, emerges adaptively, locks itself in, and sustains its inertial momentum autocatalytically. To complexity theorists, "positive feedback seem[s] to be the *sine qua non* of change, … of life itself" (Waldrop, 1993, p. 34). It becomes obvious that Darwin, although I don't think he ever used the term, was a complexity theorist. The process of the emergence of new phenomena and the extinction or adaptation of existing arrangements explains the adaptive orientation and "spontaneous self-organisation" of a system, the "incessant urge of complex systems to organize themselves into patterns" (ibid., p. 118). Darwin and complexity theory are, in other words, complementary in their explanation of evolution, in their explanation of the nature of change. This autocatalytic sustenance of momentum becomes enormously powerful: any young and idealistic teachers, no matter how energetic, who have gone into weak schools with the intention of turning them around, will report that fighting their momentum is like shouting into the wind. They may touch the lives of a handful of students, but that is probably it. At the risk of stating the obvious, it takes more than the efforts of a few energetic teachers to affect the inertial momentum of a weak school that sustains its weakness autocatalytically.

A salient feature of a theory of increasing returns is that there are, initially at least, multiple possible outcomes. Which outcome is realized in the social sciences is a question of intervention at as many levels as possible: for example, at the macro-structural level and at the intentional human agency level, so that sufficient momentum is generated in a particular direction to displace the inertial momentum of the current dispensation and to create a dominant inertial momentum for the desired changes. The dominant status of a particular social policy, for example, is more a function of that policy's inertial momentum than just the legislation that supports it. Complexity theory renders largely irrelevant the agency-structure debate about which of the two is more important in effecting change. I will consider this debate, whether change can be effected through human agency or whether deeper and more powerful structural forces are at work, in a substantial example in a moment, but it is worth noting here that both structure and agency are important in introducing change that can be sustained, and much else is too.

Working in probability theory, Brian Arthur and others have constructed mathematical models by which it is possible to follow the process of the emergence of one historical outcome, to "see mathematically how different sets of historical accidents could cause radically different outcomes to emerge" (Waldrop, 1993, p. 46). What this means for successful policy implementation is that positive feedbacks shaped towards a particular outcome need to be created through conscious interventions, so that new patterns are established. Once sufficient momentum is generated in the new (and desired) direction, the positive feedback becomes incorporated into the system autocatalytically, and new phenomena predominantly typical of the desired policy's characteristics, emerge. Changing education systems to rid them of their inequities and inefficiencies will, in other words, require massive interventions at all levels.

3. Making educational development and change sustainable

In the complexity of the educational environment, the plethora of relevant constituent elements – agents and structures – includes teachers, students, parents, community leaders, the state and its education departments and policies, economic structures and business organisations, NGOs, agencies, and so on. Intervention to differing but sufficient extents in each of these areas is what would probably be necessary to shift a prevailing ethos in education. In other words, change and sustainable development in education, at whatever level, are not so much a consequence of effecting change in one particular factor or variable, no matter how powerful the influence of that factor. It is more a case of generating momentum in a new direction by attention, as I have argued, to as many factors as possible.

Such a conclusion asks a lot more of governments and their education departments, of research analysts and policy-makers, and of donors, aid agencies and development specialists, than has typically been asked in the past. Take the case of a school or an education system where the prevailing ethos is one of failure, where students are, for any number and combination of reasons, not learning. The agency-structure debate invites us to consider whether change can be effected through human agency, or whether deeper and more powerful structural forces are at work. Structuralists, who find in economic factors the primary 'levers of history', might suggest that there is little we can do about this as human agents, because the despair that pervades the school and the system is primarily a consequence of the jobless future that awaits school leavers, whether certificated or not. The ethos of the school will not change until the structure and nature of the economy change in such a way as to provide meaningful and worthwhile employment for certificated school leavers. Those on the agency side of the debate might point to the importance of an excellent school leader, or of a committed *corps* of teachers across the system. Complexity theorists would suggest that it is probably both – the structural factors and the influence of human agents – and far more. But because we can never know well enough the combination and salience of factors that are causing the school's or the system's failure, or exactly what it is that will turn things around, our best chance of success lies in addressing the problem from as many angles, levels and perspectives as possible. It's more than that we cannot quantify the salience of any individual factor: we probably cannot even isolate any individual factor's influence in order to assess its salience. This is of course because various factors compound each other's effects in ways that both increase and diminish their aggregate influence.

It is worth noting that complexity theory is in many perspectives akin to dynamical systems theory: one aspect of the shift in social theory from structuralism to complexity theory involves this focus on the dynamic, on the constantly evolving, where structuralism has been criticized for its rigid, static and ahistorical perspectives on phenomena. Another key aspect of the shift from structuralism to complexity theory involves a shift from the reductionist perspectives typical of the former – as in, say, "Danica's failure is because, as a black girl from a low socio-economic status background, she is a member of the underclass" – to the focus on dynamically emergent phenomena typical of the latter. In the perspective of complexity theory, Danica's failure is not pre-determined, and it is not reducible to what neo-Marxist structuralists might have called her class, race and gender. Rather, a myriad factors and dynamics are involved, some compounding each other, others mitigating each other, in a multi-dimensional, iterative and recursive conception of causality. Trying to isolate the influence of a particular factor either in explaining failure or in effecting change is not only impossible, but also wrongheaded. Perhaps the major practical conclusion to draw here is that changing education systems to rid them of their inequities and inefficiencies requires massive interventions at all levels of the system, to which it should be added that substantial interventions at many levels of the society in which the education system is embedded would also be a prerequisite for sustainable change.

My focus here has been on the perennial question of what is effective in the sustainable change of a failing or under-performing education system. This would require intervention, as I have argued, at every possible level, including factors associated with the state and its education and economic policies, and possibly factors beyond even the grasp of the state – those that are associated with the forces and consequences of globalisation, for example. They would include factors associated with school leaders and teachers, with the students themselves, with their parents, with the curriculum, with schools' organisation, with the local community – the list is, if not endless, long indeed. But, given that I indicated earlier that complexity theory enables little or no causal relationship to be predicted from a knowledge of initial conditions to emergent phenomena, how can we know what to do about each of these factors? If it's both impossible and wrongheaded to try to isolate and assess the importance of any one factor, how can we even know in which direction we should try to push any factor? Fortunately, what we know from research in education gives us quite a few clues. The fact that complexity theory has little predictive utility does not negate education's research findings. This is because we're talking about two different spheres with very different levels of complexity. We know, for example, that feedback provided to learners on the appropriateness of their constructions of new knowledge has an immensely powerful effect on learning. We can predict with substantial confidence that learners who receive feedback on the soundness or otherwise of the inferences they have drawn in the process of learning will learn more effectively than those who don't. Complexity theory's lack of predictive utility doesn't undermine our confidence in predicting this outcome, because this is not in itself a particularly complex phenomenon. Complexity theory does not apply here (at least not at the level at which we're discussing the phenomenon). Complexity theory has to do with complex systems, and it's at this level that it lacks predictive utility.

We know that parental involvement in their children's learning enhances learning; that good school leaders create effective learning environments through good management practices; that poor children provided with a school lunch learn more effectively than students who do not benefit from such a policy; that students who are likely to find employment learn more effectively than those who perceive little likelihood of work. If we know all this, and can predict with a reasonable degree of confidence an improvement in learning outcomes in each of these domains, then surely we can predict that change in the direction of enhanced learning outcomes in each of these domains is more likely to aggregate, in a complex adaptive system constituted by all of these factors (and more), to enhanced learning than to decreases in learning outcomes across the school?

Complexity theory thus indicates, in other words, that what it might take to change a system's inertial momentum from an ethos of failure to one of sustained development is massive and sustained intervention at every possible level, until the desired change emerges from this new set of interactions among these new factors and sustains itself autocatalytically. And despite complexity theory's relative inability to predict the direction or nature of change, we are, by implementing at each constituent level changes whose outcome we can predict with reasonable confidence, at least influencing change in the appropriate direction and thus stand a better chance of effecting the desired changes across the complex system as a whole.

Massive and sustained intervention at every possible level demands, unfortunately, very substantial resources. If there are many failing schools in a country's education system, choices might have to be made about where resources should be targeted. Trying to spread whatever resources are available across all failing schools may well result in the effects of the investment simply being dissipated. In each school, in other words, the intervention will have been too meagre to make any impact on the prevailing inertial momentum. Each school will in all likelihood revert to its ethos of failure, with the resources wasted. It may therefore be necessary to target the available resources at only a few selected schools for maximum impact – which is what it will probably take in terms of the arguments I have presented here. This will of course increase the level of inequity in the education system, a consequence that is morally questionable. But as yet I can see almost no way around this.

One might in response to this conundrum select the target schools based on a criterion that may reduce levels of inequity: for example, one might select, say, the thousand worst performing schools, or those schools that are attended predominantly by students from the poorest homes. Or one could select schools that are attended predominantly by students from minority groups (if those minority groups are indeed the least well off or in other ways excluded). The additional challenge in these cases is, of course, that these schools are going to be the hardest to turn around, and will demand substantial additional resources. The question then arises as to how policy makers might be able to predict which schools are more likely to change under the impact of massive and sustained intervention and investment of resources.

4. Complexity theory and educational research for sustainable change

Murray Gell-Mann, Nobel laureate in physics, has offered the caution that complexity focuses necessarily on “coarse-grained” (1994, pp. 29-30) descriptions and explanations of systems whose self-organizing intra- and inter-actions normally render them too complex to be encapsulated by the standard repertoire of (educational) research tools, unless the complexity of the phenomena is abstracted and reduced to a workable level of statistical generalization. Paul Cilliers (2005) has noted that the sheer scope of the variables within complex systems makes modelling them a tricky, if not impossible, task. Such models would have to be as complex as the original, since the distributed, non-linear features of complex systems do not easily allow for the compression of data. My own view, as I have indicated, is that complexity is best used as a metaphor in which to understand the nature of systemic continuity and change.

As I have argued, in this perspective there are no independent interventions: proposed changes at the classroom level, for example, have implications at school and district levels (for example, for teacher development, parental expectations, school resources, accountability, and so on) and need to be supported by related interventions across multiple levels. Most important is a change in the paradigms of our thinking about research on education: away from input-output “black-box” causal models to modelling the specific, local linkages that actually interconnect actors, practices, and events across multiple levels of organization; and away from single interventions and simplistic solutions to the recognition of the need for coordinated changes throughout the system and to its constraining and enabling contexts and resources.

To conclude by way of a restatement of what I see as the most important insight of complexity theory with regard to sustainable change and development in education: it is that new properties and behaviours emerge not only from the elements that constitute a system, but from the diversity and myriad connections among those elements. The successive linear addition of new elements multiplies exponentially the number of connections among the constituent elements. It is in this shift from linear to exponential orders of magnitude, but of course only in systems of incredible scale, that the power of complexity theory lies. The concepts of emergent phenomena from a critical mass, associated with notions of lock-in, path dependence, and inertial momentum, contribute to a perspective on continuity and change that indicates what conditions might need to be in place for the emergence of sustainable, positive, system-wide change and development in education.

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