

Complexity Theory and Education

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Abstract: This paper introduces central tenets of complexity theory and current issues that they raise, including: the consequences of unpredictability for knowing, responsibility, morality and planning; the significance of networking and connectedness; non-linear learning organizations; setting conditions for change by emergence and self-organization; fostering feedback for learning; changing external and internal environments; schools and learners as open, complex adaptive systems; cooperation and competition; pedagogy; and the significance of context. This paper acts as an introduction to the Special Interest Group and the other papers, teasing out several applications of complexity theory, including: online learning; staff development; the nature and facilitation of change; curriculum change and innovation; complexity theory and Bernstein's visible and invisible pedagogies; and the questioning of complexity theory's contribution to the moral debate over schooling. The paper introduces the context of Macau as an emergent, self-organizing territory, and locates several of the subsequent papers in this context, focusing on the fields of nursing education; premature school leaving; parental involvement in education; and curriculum change. Examples of online learning and school development from Hong Kong are also provided. The paper provides a theoretical and practical introduction to the field, with examples deliberately drawn from diverse aspects of education, diverse target groups and age groups of learning.

Keywords: complexity theory; education; schooling; Macau; Hong Kong.

Introducing complexity theory

Though complexity theory has had a short but meteoric rise in the spheres of the natural sciences, anthropology and economics, its entry into education to date has been comparatively limited, spasmodic and piecemeal (but see Morrison, 2002). Though there are some centres for the study of complexity in education (e.g. the University of Alberta's Faculty of Education (<http://www.complexityandeducation.ualberta.ca/index.htm>), the Special Interest Group of the American Educational Research Association), the penetration of complexity thinking into educational discourse is still at an early stage. This paper and the others that accompany it (Fong, K. I., 2006; Fong, P. J., 2006; Fong, P. L., 2006; Jakubowicz, 2006; Lam Norueiga, 2006; Tchiang, 2006; Tong, 2006) introduce complexity theory and provide examples of its applicability to education, thereby suggesting, and delimiting, some of its potential contribution to education.

Complexity theory is a theory of change, evolution and adaptation, often in the interests of survival, and often through a combination of cooperation and competition (Stewart, 1991; Battram, 1999; Morrison, 2002). It breaks with straightforward cause-and-effect models, linear predictability, and a reductionist, atomistic, analytically-fragmented approach to understanding phenomena, replacing them with organic, non-linear and holistic approaches, in which *relations* within interconnected networks are the order of the day (Youngblood, 1997; Cilliers, 1998; Wheatley, 1999). In one sense, many of the central tenets of complexity theory are neither new nor particularly startling; however, the bringing together of several key constructs into a more-or-less unified theory is, perhaps, what gives complexity theory its impetus and attraction.

In complexity theory an organism, however defined, senses and responds to its environment, thereby changing its environment, which changes the organism again, so that the organism reacts to, and thereby – proactively – changes, its environment; the process, in iterating itself, produces dynamic and continuous change recursively (Stewart, 1991). There is, thus, a dynamic relationship between the organism and its environment; they change each other (Battram, 1999). As Zohar (1997, p. 110) writes: ‘I am defined by my relationships . . . the boundaries of my own identity are quite ambiguous and contextual’. One is a member of a web of life, relations and networks (Capra, 1996). Further, one cannot consider the organism without considering its environment; the emphasis is on collective, relational behaviour and holism rather than on isolationism, individualism and solipsism. The whole is greater than the sum of its parts, and these parts interact in dynamical, multifarious ways, thereby producing new realities, new collectivities and new relations.

‘Complex adaptive systems’ (Waldrop, 1992, pp. 294-9) scan and sense the external environment and then make internal adjustments and developments in order to survive in those changing external environments. The processes that contribute to such changes involve *self-organization* and *autocatalysis*, wherein the catalyst of change is the organism itself. This is a theory of activity, proactivity and reactivity all together, not simply of passivity. The system – the collectivity of the organism and its environment – evolves itself, from within (e.g. Battram, 1999; Marion, 1999). When self-organization operates effectively the organism is characterised by *adaptability*, *open systems*, *learning*, *feedback*, *communication* and *emergence* (Prigogine and Stengers, 1985; Cohen and Stewart, 1995). Closed systems – those in stable equilibrium – die or move towards entropy; systems *need* disequilibrium in order to survive (Stacey, 1992). Change, disequilibrium and unpredictability are *requirements* for survival: the tadpole must become a frog if the species is to survive.

Further, in the process of self-organisation, the organism, and the system of which it is a part, demonstrate *autopoiesis*, that is, they have their own identity and nature and they self-create these (e.g. Battram, 1999; Kelly and Allison, 1999). The creation of a unique, and collective identity gives the system and its constituent elements a capability for survival, through increasing differentiation – they become unlike other systems, and, thereby, their uniqueness provides their niche in the world, and that unique situation contributes to their survival. By creating uniqueness a species/system/organism is less threatened than those species – collectivities – that may duplicate, and thereby threaten, its survival. Whilst competition and the struggle for survival create differentiation and uniqueness, that very uniqueness, though forced, provides some limited guarantee of survival; such competition, whilst also being red in tooth and claw, may also be benign.

Of course, being too different, just as being too similar, may be threatening to the system; finding one’s survival niche by being similar to, but also different from others, is tricky. This catches the partially antinomial nature of some aspects of complexity theory: cooperation together with competition, similarity together with difference, individuality with collectivity, connectedness with separation, necessary deviance with necessary conformity, diversity with uniformity, partial predictability with partial unpredictability, solipsism with the need to understand collectivities.

Through feedback, recursion, perturbation and disturbance, auto-catalysis, connectedness and self-organization, higher levels of complexity and differentiated out-of-equilibrium systems and behaviour emerge from lower levels of complexity and existing forms which, themselves, are different from, and cannot be comprehended simply in terms of, the initial forms or lower levels. *Emergence* is the partner of *self-organization*, and emergent complex systems derive autocatalytically from often comparatively simple sets of rules of interaction between the organism and the environment – local rules and behaviours generating emergent complex global order and diversity (Waldrop, 1992, pp. 16-17, 86; Lewin, 1993, p. 38; Kauffman, 1995, p. 27). An important feature of emergent systems is that they could not have been predicted in advance; they are non-linear. Further, the process of emergence is one of continuous creativity, as organisms and systems evolve through ‘self-organized criticality’ (the movement towards a level of disequilibrium such that a small change may trigger a huge change) (Bak and Chen, 1991; Bak, 1996) towards the ‘edge of chaos’ (Kauffman, 1995) – that point between linear predictability and the chaos of complete unpredictability at which a system is at its most creative, imaginative and adaptable whilst still being ordered. Creative emergence requires a process of change, determined in part by the need for survival, and is itself a process characterised by increasing connectivity, networking and feedback (e.g. Stacey *et al.*, 2000, p. 146).

Connectedness requires a *distributed knowledge* system; knowledge is not centrally located in a command and control centre (e.g. a principal’s office or a central government department). Rather it circulates throughout the system, and communication and collaboration are key elements of complexity theory (Cilliers, 1998). Self-organization emerges and is internally generated; as Kauffman (1995) avers, ‘order comes for free’ rather than being the product of external control. Order is not imposed; it emerges spontaneously, of itself, whether we like it or not; it is control that is imposed (Bak, 1996, p. 31; Battram, 1999) .

The key terms of reference for complexity theory then, and as discussed in this and the accompanying papers, are: self-organization, complex adaptive systems, non-linear change, emergence, unpredictability, diversity, differentiation and autopoiesis, networks, connectivity and relations, order without control, feedback, open systems, collectivity, distributed knowledge, autocatalysis, holism, and co-evolution.

Complexity theory and education

Educational systems, institutions and practices exhibit many features of complex adaptive systems, being dynamical and emergent, sometimes unpredictable, non-linear organizations operating in unpredictable and changing external environments. These systems, institutions and practices shape and adapt to macro- and micro-societal change, and, through self-organization, respond to, and shape the environments of which they are a part. As Stewart (1991) remarks, there is co-evolution between the organism and its environments. This process occurs through learning, adaptation and development. The papers that accompany this one attest to this, and provide illustrations of the process at work. They indicate how self-organised change and emergence of various educational ‘complex adaptive systems’ occur through autocatalysis, networking, relations, differentiation, co-evolution, connectivity, feedback, and distributed order, within unpredictable and unpredicted, non-linear environments. Further, the papers constitute case studies, and it could be argued that case study rather than, for example, randomised

controlled trials, are an appropriate research methodology for complexity theory (echoed in Lewin and Regine, 2000), as case studies catch complexity, specificity and the need to locate individual acts within multiple contexts and environments. This paper considers briefly each of the accompanying papers, and links them to complexity theory.

The paper by Peter Jakubowicz (2006) illustrates an aspect of complexity theory at work in a networked, online environment in higher education, in which interactivity and connectedness are key elements. He indicates how self-organized order emerges in a non-linear manner through the use of an information-sharing management platform at a University in Hong Kong. In suggesting that such learning can be fun, as the paper remarks, one is reminded of the playfulness advocated (or, indeed admonished) in post-modern conceptions of society (c.f. O'Neill, 1995; Cilliers, 1998). One can raise the question of how far complexity theory is a child of a post-modern age. This point also raises the issue of the connectedness between emotions and academic learning; the brain is a networked organ.

Shivonne Fong's (2006) paper takes another aspect of complexity theory – holistic and interactionist approaches to understanding change in unpredictable and non-linear circumstances – and applies these to staff development in schools in Macau, arguing that staff development is both an essential ingredient of bottom-up, self-organized change but, itself, a potentially major obstacle to change. The paper argues for connectionist approaches to staff development (staff working together and staff development connecting with real needs), openness and collegiality. Her call for 'mutual support and respect' and 'good human interrelationships' is timely in a climate in which many aspects of education are marked by bureaucratic and hierarchical control rather than self-organized, emergent order. Her paper also raises the question of what complexity theory adds to an understanding of staff development processes that is not present in many texts on the management and leadership of change; this raises the question of the utility and value-added contribution of complexity theory to education, discussed later.

The paper by Keith Tong (2006) takes a case study of an English department in a Hong Kong school that was faced with a need for high-level change, and which worked with an external change agent to facilitate that emergent change. The study is an interesting example of externally facilitated but very largely self-organized, bottom-up change and development through increased internal feedback and openness. The paper raises an important complexity-based point for school leaders: the task of the leader concerns more the creation of *conditions* for change through self-organization rather than providing the exact blueprint or specific, detailed contents of the change: the task is to be less like a Napoleon, concerned with tiny details, and more like Churchill, concerned with the bigger picture and overall direction! The paper outlines what those conditions might be. As with the paper by Shivonne Fong, Keith Tong's paper raises the question of the utility and value-added contribution of complexity theory to education, discussed later.

Bernice Lam Nogueira (2006) takes a more macroscopic view of change, in the field of nursing education at a whole-territory level in Macao. She tracks socioeconomic, technological, educational and training, and increasing supply requirements as impetuses for change in nursing education in this tiny territory which, of itself, is perhaps too small to be able to meet all of its own nurse training requirements from within the territory. The pressures for change have necessitated the move towards both networking with external nurse training providers and with

making internal – territory-wide – changes to nursing education and its providing parties (Ashby's (1964) 'law of requisite variety', which states that internal systems, flexibility, change and capability must be as powerful and diverse as those in the external environment). In Macao, nursing education – through self-organization – has to, and has had to, restructure and reorganize itself, and the paper indicates how this was approached and how it can be understood through the lens of complexity theory. As with the previous two papers, the question is raised of what added value an understanding of tenets of complexity theory can bring to the interpretation and development of the situation reported in Macau.

The paper by Isabel Tchiang (2006) examines the impact on schools of the massive changes taking place in Macao's economic sector, principally the huge expansion of the gaming, tourism and casino industries, rendering Macao the largest gaming centre in the world in terms of revenue. This has had serious effects on the employment market, with students and teachers leaving school to take up low-level employment in these sectors in response to the lure of fast and considerable money. The fallout of this on schools is significant, and one necessary response is the need for increased networking and communicating, in this instance with parents. The need for increased parental involvement presents a major challenge to Macao schools, which hitherto have been characterised by closure to outside influences and communication. The move towards greater openness and communication, advocated by complexity theory, has a high priority, though caution has to be exercised in rendering schools too responsive simply to the emergent economic imperatives of the gaming industry. Further, many schools in Macau have no tradition of, or preparedness for, openness, and a significant development exercise is required to equip them for this role, as there is no necessary redundancy (Kelly, 1994) in the system. The paper also raises the issue of how far complexity theory embraces – or can embrace – a moral dimension, or whether, as an amoral theory, it is fitting for education.

Elisa Fong's (2006) paper revisits Bernstein's (1975) constructs of 'visible' and 'invisible' pedagogies, and recasts them in terms of complexity theory, as 'control' and 'order' respectively. This is addressed in a case study of a single teacher in a large kindergarten class, in which attempts to impose control by the teacher (i.e. the organism) are frustrated by the children themselves (i.e. the environment). A collective, self-organized order emerges as a consequence of the teacher heightening the connectivity and interactivity between herself and the children, and learning is facilitated through creating the *conditions* for this, rather than naïvely trying to mandate – control – what happens in a large class and how young children can be controlled (a visible pedagogy). In revisiting Bernstein's views of visible and invisible pedagogies, the paper raises an important question concerning the extent to which complexity theory is simply a reworking of older theories in education and, if so, then what is its added value? Her paper provides an interesting example of how complexity theory's comments on order, rather than control, emerge through the interaction of the organism with the environment.

The paper by Fong Peng Long (2006) argues for the utility of analysing Macao's government-developed curriculum management system through the lens of complexity theory. It comments on the multi-level, multi-dimensional, multi-faceted, multi-agent, and multi-perspectival nature of the Macao government's curriculum reforms, and suggests that these are best met by flexible curriculum development and management strategies, together with internal changes in the schools. This echoes Ashby's 'law of requisite variety' alluded to in the

paper by Bernice Lam Norueiga, wherein the internal conditions in Macao's schools have to change in order to meet the external changes in the wider society in Macao (e.g. demographic, political, educational, technological, economic).

Complexity theory affords the opportunity for a re-awakening of several educational topics which have been relatively silent in climates of high control of education, heavy prescription and mandated contents, reinforced by high-stakes assessment systems and constant surveillance of an individual's performance against predicted targets. Complexity theory redefines 'the basics' of education, away from a controlled and controlling subject-based education and towards a discovered, inter-disciplinary, emergent and constructivist curriculum, and a reassertion of freedom as a *sine qua non* of education (Doll, 1993). Complexity theory takes us in a direction opposite to the neatly stated, over-determined, tidy, traditional, Tylerian, externally mandated and regulated prescriptions of governments for the aims, content, pedagogy and assessment of learning and education.

Additionally complexity theory suggests a movement towards bottom-up development and change, local and institutional decision-making on education, a re-assertion of child-centredness and experiential, exploratory learning, a rejection of tight prescription and linear programming of teaching and learning and a move towards non-linear learning and their curricular derivatives. Complexity theory emphasises the process rather than the content of learning, as the constituents of relevant and enduring curriculum content are uncertain (Doll, 1993). Emergence and self-organization require room for development; tightly prescribed, programmed and controlled curricula and formats for teaching and learning, and standardised rates of progression are anathema to complexity theory. It breaks a lock-step curriculum.

Some challenges for complexity theory in education

The papers here, single and severally, raise some important questions facing complexity theory. There are eight issues that can be raised here, both from complexity theory *per se* and from the papers that accompany this.

Firstly, there is the issue of how novel a theory complexity theory actually is. Many of the issues and concepts raised by complexity theory are not new. How far is complexity theory simply a modern-day reformulation of the structure/function or the agency/structure dyads of pre-structuration-theory sociology? How far is complexity theory a rehearsal of interactionist sociology, albeit on a broader canvas? How far is complexity theory simply new wine in old bottles (Morrison, 2005), for example, serving up Giddens's (1976; 1984) theory of structuration in refashioned terminology, restating the significance of Bourdieu's 'habitus' (1977; 1986), 'structuring structures' and 'structured structures' or Bernstein's (1975) 'visible and invisible pedagogies'?

Secondly and perhaps as a corollary to the first point, one has to ask whether complexity theory is not simply a statement of the obvious. As Popper remarked, albeit in a different context, is it not simply a collection of 'trivialities in high sounding language' (Popper, 1984: 161). It may be true, but trivially so. Could not the relatively arcane and abstruse terms and constructs of complexity theory not be put more simply in plain English, thereby revealing their commonsense and everyday status?

Thirdly, one has to ask how useful complexity theory actually is. For example, though it offers an explanation for change and evolution in particular situations, it can be regarded as essentially a *post hoc* explanation, with limited *prospective* or *predictive* utility. It can describe and theorise what has occurred and what is occurring, but not what will occur; it proscribes predictability because the future is necessarily unpredictable, it emerges over time. That said, as in some of the papers here, complexity theory can be, and has been, used *prospectively*, to prescribe actions and situations that promote change and development, e.g. one can promote the climate or conditions for emergence-through-self-organization by fostering creativity, openness, diversity, networking, relationships, order without control, co-evolution, feedback, bottom-up developments and distributed power.

However this raises a difficulty for complexity theory: it is essentially a descriptive or reflective theory. To move from a descriptive to a prescriptive theory is to commit a category mistake, to mix fact and value, to derive an 'ought' from an 'is', to commit the naturalistic fallacy. How easily one can slip from an 'is' to an 'ought' is evidenced in, for example Bai (2003), who uses tenets of complexity theory to prescribe how we ought to behave and what educational dispositions we ought to cultivate. However, one has to ask, for example, whether self-organization is such a good thing, or whether it will lead to diversity, inefficiency, time-wasting, mob rule, and a risk of people going off in so many different directions that the necessary connectivity between parts of an organization, its values and direction will be lost or suffocated.

Further, how desirable are highly complicated systems of inter-relationships? How much will a developed network of inter-relationships, a feature of complexity theory, promote or inhibit development – some relationships and networks promote change; others, Gulliver-like, tie down agents and inhibit change. Just because networks exist does not make them a good thing. Why should school principals support and tolerate risk-taking, when it might bring about student and school failure, particularly if the future is uncertain? How desirable is unpredictable change? The issue here is that moving from an 'is' to an 'ought' in complexity theory is not only unjustified and illogical but may be positively dangerous!

Hence, more cautiously, Davis and Sumara (2005, p. 318) state that 'complexity science will not tell educators or educational researchers what to do in any prescriptive sense . . . but it can provide direct advice on how to focus efforts when preparing for teaching'. Does this reduce the significance of complexity theory, or simply locate it more clearly? Is it acceptable for education, as a moral and humanistic activity, to call upon a morally and humanistically neutral theory? Education is caught in a problem here: to utilise a theory that is amoral might be to misrepresent the nature of education, but to invest an amoral theory with morality (to derive an 'ought' from an 'is') is to misrepresent the theory in question. It is a no-win situation.

Fourthly, complexity theory is a theory of unpredictable, non-linear change, why it is important and how it can be promoted. How comfortably does this sit within educational contexts in which responsibility exists for what happens now and in the future, and in which there is accountability for what is planned? If I cannot predict the consequences of my actions, in what sense can I be held responsible for what happens after my actions? What is the nature of

responsibility if the same behaviour does not produce the same results twice? If one cannot predict what is going to be an outcome, how far does this absolve or exonerate leaders, managers, planners and participants of responsibility for what happens or what turns out to be the situation (c.f. Stacey, 1996, pp. 266-82)? This rehearses the dilemma of a morally neutral theory. If education is, at heart, a deontological, valuative, humanistic and moral enterprise, then should one abide by a theory in which responsibility, humanitarianism and morality are so unclear, in which we play with amoral dice, or in which values seem to be so impermanent and unimportant?

One can take this further, to question not only whether self-organization is as desirable as the proponents of complexity theory might suggest, introduced earlier, but to ask whether autocatalysis really works with a stagnant staff. Further, is not complexity theory simply an excuse for inefficiency, lack of accountability and lack of 'bottom-line' thinking? Is it not, ultimately, a deterministic, covertly teleological theory (order will emerge over time)? Why should schools commit themselves to an uncertain future simply on the strength of a theory or a faith in the belief that an acceptable order will emerge and, in the process, be prepared to tolerate potential confusion, unacceptable practice and unnecessary, avoidable, difficulty? Why should complexity theory be any better, any more efficient, any more effective at improving schools than its alternative, linear theories, and where is the evidence to support its claim of advantage (Galbraith, 2004)? Should schools take a leap into the dark future of uncertainty when the theory has not been tested or where the evidence is so limited? Is that not irresponsible?

Fifthly, complexity theory has the putative disadvantages (Kelly, 1994: 23-4) of being: (a) non-optimal (because there is deliberate redundancy in the mind, there is also inefficiency); (b) non-controllable (there is an absence of authority); (c) non-understandable (as causality is multi-directional); (d) non-immediate (complex systems 'take time to boot up' (*ibid.*, p. 24)). This sits perhaps uncomfortably with that which is desired by politicians educational policy makers and practitioners who seek efficiency, control, comprehensibility and immediate solutions (Levin, 1991). Indeed, if the future is uncertain and outcomes are non-linear, then where or why should money and effort be spent on education, if they are not guaranteed to improve outcomes?

Sixthly, complexity theory embraces a deep-seated pragmatism, justified only by (perhaps selfish) survival and suggests that what is right at any moment is that which works at the time, to ensure survival. Is this satisfactory or sufficient as a theory of education; does it 'satisfice' (Simon, 1957) the requirements of an educational theory? Akin to this, does not complexity theory's pragmatism risk the insignificance or ephemerality of relativism? Indeed it was suggested earlier that it is a child of post-modernity; could complexity theory have come to the fore at an earlier historical conjuncture? If not, then what is its status? As O'Neill (1995, p. 199) remarks about postmodernism: 'having mocked tradition and intergenerationality, postmodernists can only fear their own posterity – why should they be remembered?'. Is complexity theory disguised ideology? Does this matter?

Seventhly, there are, perhaps questions to be asked against the coherence of the 'theory' in complexity theory; as was mentioned earlier, there are several antinomies and, indeed, aporias in complexity theory, even though most of its central elements are mutually reinforcing and mutually potentiating. Not only are there those that were introduced earlier, but one can also question whether there is an epistemological contradiction at the heart of complexity theory – it

purports to be against predictability and law-like behaviour in positivism, yet, in law-like fashion, it specifies its own laws – of emergence, self-organization, self-organized criticality, feedback, networking, connectivity, co-evolution, the regularity or inescapability of indeterminacy and nonlinearity, and so on. Complexity theory is caught in a double bind: if it does prescribe and predict the future then it is unconvincing *qua* theory, as it undermines its own tents of unpredictability, and yet, if it does not prescribe and predict the future then it has little use. It is caught.

Eighthly, the papers here all provide worked examples of educational activities, small-scale to large scale. Whilst an understanding of these might be illuminative or illustrative of complexity theory, what actual added value does complexity theory bring such that it moves to becoming a *sine qua non* of understanding the situations described in the papers? In short, is complexity an interesting, but ultimately trivial, dilettantist, theory in which one can indulge one's imagination appetitively but which actually has little else to offer? For example, with reference to the papers that accompany this, what does complexity theory add to our understanding of:

- (a) online networking (in the paper by Peter Jakubowicz (2006)), that simply investigating online networking *per se* would not expose?
- (b) staff development, schools and departmental improvement, and curriculum changes in the three relevant papers here (by Shivonne Fong (2006), Keith Tong (2006) and Fong Peng Long (2006)), that a study of school leadership, management and change would not yield?
- (c) the development of nursing education in Macao (in the paper by Bernice Lam Norueiga (2006)), that a simple contemporary and socio-historical analysis would not yield?
- (d) parental involvement through opening up schools (in the paper by Isabel Tchiang (2006)), that would not be yielded by a simple reading of educational management literature and an elementary understanding of the Macao situation?
- (e) kindergarten classrooms (in the paper by Elisa Fong (2006)), that would not be yielded by introductory texts on teaching in kindergartens, or a quick revisiting of Bernstein's visible and invisible pedagogies?

In short, what is the *real* and practical, rather than perhaps (pejoratively speaking for the sake of clarity) self-indulgent, added value that complexity theory brings? The point here is that many of the issues and elements of complexity are the everyday stuff of educational discourse, e.g.: distributed control; self-organization and emergence; communication and networking; creativity and openness; relationships and dynamical systems; unpredictability and non-linearity; feedback and learning for development; redundancy and diversity; collectivity and connectedness; co-evolution, continuous development and adaptation; agency and structure; the social construction of knowledge. This may be simply a serendipitous and fortunate happenstance, a coincidence that is a function of the topics presented in the papers here. On the other hand it may be to require complexity theory to justify itself in educational discourse, beyond mere conceptual convenience (drawing together several important features into a coherent framework). To what extent could the issues reported in the papers stand alone, i.e. without the addition of complexity theory? Perhaps a lot.

Given these concerns, complexity theory is in an uncertain position in education. Does it have a role to play in education, or is its domain elsewhere (e.g. in the natural and physical sciences)? Is complexity theory important for education? Is it a useful practical tool for understanding and developing education, or a neat but ultimately unnecessary metaphor for unrigorous research? Is it a theory, a metaphor, an exhortation, or something else, and if so, what?

Conclusion

Complexity theory demonstrates some elements of a 'good' theory (e.g. Lakatos, 1970; Siegel, 1987; Laudan, 1990), e.g. parsimony, operationalizability, internal coherence of its terms, outline of its conceptual framework; fertility; ability to spawn a research enterprise, suggest a research methodology. On the other hand it is difficult to see how it could be falsified, and, thereby, it is difficult to class it as a scientific theory. This is not necessarily a weakness, there being other types of theory, but it does place upon complexity theory the onus of justifying itself *qua* theory and, if it is a theory, then identifying what kind of theory it is.

This paper has deliberately endeavoured to introduce some of the central tenets of complexity theory, to lead into the accompanying papers that illustrate some elements of complexity theory at work. Given the space here, it is impossible to do justice to the realm of educational issues that have been addressed in complexity theory (but see, for example, the conference papers from the University of Alberta (<http://www.complexityandeducation.ualberta.ca/index.htm>)), not least in important fields of epistemology, learning and pedagogy, neural networks, webs of learning, but this has not been the purpose of this paper. Here the intention has been to illuminate some key elements of the theory, to introduce the accompanying papers that have deliberately cast the net of complexity widely into several very different fields of education, and, taking the role of a sympathetic skeptic, to throw down a small gauntlet to 'complexologists' in education in respect of adopting a cautious approach in considering the value, or applicability, of the theory to educational discourse. It is a fascinating and alluring theory, but is it a siren song?

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