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Beyond 'mutual constitution': looking at learning and context from the perspective of complexity theory

Tamsin Haggis, University of Stirling

> The field of education is greatly dispersed. It must be simultaneously attentive to issues and phenomena across many levels of organisation.
>
> Davis & Sumara, 2006: 130

The question of 'mobilising learning across domains' seems to directly contradict the notion of learning as situated, and tied up with the particularities of context. The requirement to consider such different ideas together, however, signifies something of the range of competing agendas, theoretical concepts and divergent histories which characterise the state of contemporary learning theory. This chapter will argue that some of the conceptual difficulties involved in theorising learning are the result of a clash between, on the one hand, a range of perspectives which have come to the conclusion that 'knowledge must be contextual' (Byrne, 2005a), and, on the other, a prevailing ontology which declares that contextual knowledge can only ever be 'idiosyncratic' (Bassey, 1984, in Marsden, 2007). Evolving interpretations of situated learning, activity theory and actor network theory all attempt to deal with the difficulties that this creates. This chapter will explore how complexity theory, as a perspective which 'arises among' other discourses, rather than 'over them' (Davis & Sumara, 2006:8), offers a means of exploring some of the issues involved in contemporary articulations of knowledge, learning, cognition, and context in more detail.

Limitations and problems within sociocultural approaches

> A clearer understanding of human cognition would be achieved if studies were based on the concept that cognition is distributed among individuals, that knowledge is socially constructed through collaborative efforts to achieve shared objectives in cultural surroundings, and that information is processed between individuals and tools and artefacts provided by the culture.
>
> Salomon, 1993a:3 in Daniels, 2001:70

Sociocultural approaches to the study of learning represent a move away from the decontextualised, individualistic approach of certain types of cognitive psychology towards more collective, social, and participatory types of framing. Whereas in the early days of psychology learning used to refer to the behavioural and cognitive processes of

individuals, it is now more likely to be thought of as a characteristic of social practices and activities (Lave & Wenger, 1991; Engeström, 1987). Interestingly, however, despite the move towards participation and distributed notions of knowledge, the ideas of 'cognition' and 'learning' have not disappeared. Daniels, for example, suggests that sociocultural approaches investigate 'the *development of cognition* using non-deterministic, non-reductionist theories' (2001:70; my italics), and describes the focus of these theories as being 'the processes of the social formation of *mind*'. An extension of this approach is the idea that cognition itself is 'distributed' (eg. Nespor, 1994). What does it mean to talk of 'mind' and 'cognition', distributed or otherwise, within an overall framing of practice and participation?

Deep structure, underlying principles, categories
Despite the intentions of many theorists to develop non-deterministic, non-reductionist types of theory, the concepts and approaches used in current discussions about learning are usually strongly constrained by particular types of Anglophone/ Euroamerican predisposition. These include certain epistemological and ontological assumptions, many of which reflect the early intentions of science 'to reveal the simple behind the complex' (Gare, 2000). In education this often translates into a desire to identify general principles[1] which can in some way meaningfully be said to 'underlie' (Briggs, 2007) manifestations of difference and apparent unpredictability (see Haggis, 2007; 2008). For example, whilst a theory such as situated learning might be expected to imply the impossibility of any general statements about learning (as learning is so specific to context), Lave & Wenger nonetheless formulate two general principles which apparently apply to *all* types of situated learning: 'community of practice' and 'legitimate peripheral participation'. Here, the epistemological imperative to create a general principle arguably merges with a perceived need to demonstrate progress in the 'cumulation of knowledge', resulting in an implicit striving to created the *best* and most *complete* approach or theory. In the case of situated learning, this results in general principles such as 'community of practice' being taken up across a range of different fields as if 'the' mechanism of learning has finally been identified.

Similarly, in the move away from trying to articulate underpinning structures[2] in relation to individuals, many forms of sociological/sociocultural research attempt instead to identify underpinning, explanatory structures of the social, which are then used to explain difference (eg. division of labour, class, gender, social capital). These types of formulation can be immensely useful, particularly in trying to understand the ways in which people may be constrained and produced by larger social forces. But there are also limitations to investigating and explaining difference in terms of categories of the social. Methodologically, the 'underlying principle' imperative (which also appears as the requirement for qualitative studies to outline 'implications for other contexts') creates serious problems for the theorisation and investigation of learning, in the sense that learning is arguably always local and particular. The assumption underlying this imperative (ie. that everything in the world is amenable to description in terms of underlying principles) creates a conceptual impasse when it is applied to phenomena that might also be validly characterised in terms of their particularity. This, in turn, arguably results in an endless circularity of argument about the supposed impossibility of understanding dynamic, multi-factorial specificities.

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[1] Suggested by categories, types, classes, and 'key' features
[2] The notion of 'underlying structure' here is not necessarily literal, in a realist, explanatory sense. It can be simply instrumental, in terms of providing an interpretive framing.

Backwards and forwards across the binary: the social 'wins'
Whilst most perspectives will certainly discuss the idea that individual practices contribute to the emergence of the social, in many sociocultural framings there has been a demonstrable shift from a focus on 'the manner in which the individual constructs the world to the manner in which the world constructs the individual' (Davis & Sumara, 2006:117). In these types of framing, there is a sense that 'the social' is *the* ultimate deep structure:

> Briefly, a theory of social practice …claims that learning, thinking, and knowing are relations among people in activity, in, with, and arising from the socially and culturally structured world. This world is socially constituted: objective forms and systems of activity, on the one hand, and agents' subjective and intersubjective understandings of them, on the other, mutually constitute both the world and its experienced forms.
>
> <div align="right">Lave & Wenger, 1991:50/51</div>

Many examples of educational theorising seem only able to seesaw backwards and forwards across the individual/social binary, and in contemporary discourses this movement almost always ends up privileging the structuring forces of society. Historically, this stress on the social has been important in understanding the role of discourse and language forms, recognising the effects of power, and surfacing the oppressive nature of many forms of social practice[3]. The focus on collectives in relation to learning has developed understandings of activity and practice which have radically changed the way that learning is understood. The privileging of the structuring forces of the social, however, has also made it increasingly difficult to talk about individual human agents. Although 'agency' and 'identity' acknowledge some aspects of human particularity in general terms, too much focus on this tends to be seen as a reactionary return to previous, de-contextualised and 'individualistic' positions.

Social and collective orientations potentially provide new contexts within which to re-examine previous concerns differently. Instead, however, the 'deep structure'/ generalisation imperative, combined with the shift to the social end of the individual/ social binary, often come together to produce particular kinds of theoretical limitation. Discussing how individual affects social, how social affect individual, or which of the two is the most influential, is relevant to some questions, but not others. For example, it seems relevant for anthropologists to talk about the need for human societies to *distribute* the 'tasks of learning, remembering, and transmitting cultural knowledge' (Hutchins, 1995:262 in Daniels, 70), when the focus is on the maintenance and development of cultural knowledge, in the context of societies. But can this idea be transferred to all discussions about learning as this might be understood by educators?

Some of the problems discussed so far in relation to educational theorising arguably arise because of a lack of clarity about the meaning of the term 'learning'. Far from being self-evident, as is often assumed, 'learning' covers a wide range of possible meanings. The idea of distributed knowledge or cognition has been generative in relation to understanding the largely 'unintentional' (Lave & Wenger, 1991) learning involved in different forms of vocational and professional learning, as these forms of learning are

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[3] The 'emancipatory' and social justice imperative which permeates a great deal of contemporary theorising has, however, also arguably coalesced with other reasons to focus on collectives, resulting in the creation of strong, value-driven biases which are often taken for granted and not examined

focussed on the development of collective and culturally-based knowledge practices. But a perspective which is useful for understanding collective, unintentional forms of learning does not necessarily work particularly well for understanding how and why individuals within collectives *experience participatory practices differentially*. It also provides only one type of answer to the question of how and why people involved in intentional forms of collective learning activity (eg. assessed learning in institutions) are *differentially engaged*, and produce *differential results* in terms of assessment outcomes.

Generalised notions of interdependence

Another challenge to current sociocultural framings is the difficulty of articulating the way that the complexities of the social work together. Many attempts to do this suggest that different elements are 'mutually constitutive', but the desire to express mutual co-specification can result in an extremely generalised articulation of 'things working together':

> …context is not simply where action and learning are located, it is constructed in the course of social interaction as part of the meaning-making processes, or learning, which inform action. The meanings are an integral part of the context. Thus, action and learning exist in a mutually constitutive relationship with context or situation.

> Bloomer & Hodkinson, 2000:589/590

> The weaving together of layers of context, histories and intentions, the dialectical construction of self and the shifting locations of individuals within different configurations does relate agency to context in a way that accounts for both individual agency and the take up of affordances. It is the embedding of agency in current interwoven and shifting contexts which distinguishes the sociocultural view of agency

> Edwards, 2001:173

Both of these discussions try hard to articulate the immanence of 'context' in ideas of action, meaning, learning, and agency. But the attempt to create a sense of interrelatedness, dynamic construction, and change through time arguably works to fragment each unit of analysis at the same time as it tries to create it, leaving only a vague sense of mutual co-specification. In one sense, context becomes expanded to incorporate everything, and could thus be said to refer to nothing. Valsiner (1998) has suggested that conceiving of person and context as 'being in a "mutually constituted" or "seamless" relation' (1998:15) results in the researcher being 'left without the phenomena that had interested them' (ibid). Gee (2000) discusses the same idea in relation to discourse perspectives:

> What is often left out in discussions of the mutually constitutive nature of words and contexts is the person who utters (writes) the words with (conscious and unconscious) personal, social, cultural and political goals and purposes. …the person as an actor engaged in an effort to achieve purposes and goals is left out as an embarrassing residue of our pre-social days.

> Gee, 2000:190

There still seem to be problems with finding 'non-deterministic, non-reductionist' (Daniels, 2001) ways to acknowledge and explore aspects of concrete particularity without resorting to the centring, essentialising tendencies of previous cognitive approaches.

Implicating, and avoiding, difference and particularity
It has been argued that the current focus on 'the social' has led to context largely being interpreted in terms of social and collective categories and structures, and also that the 'mutual constitution' framings employed by many sociocultural approaches can render both people and collectivities problematically vague. It has also been suggested that these problems are at least partly the result of prevailing epistemological and ontological imperatives, which make it difficult to think about differentiated human beings in non-deterministic, non-reductionist ways. And yet at the same time, a recognition of 'difference', which extends quite clearly to the level of human actors, is continually arising as a key issue in many different theoretical areas (eg. Law, 2004). Difference, in this sense, is radical, irreducible and inescapable; it cannot be captured by categories or laws. The reality of difference is recognised even in traditionally 'scientific' disciplinary areas such as medicine:

> …the 'truths' established by empirical observation of populations in randomised trials and cohort studies cannot be mechanistically applied to individual patients or episodes of illness, whose behaviour is irremediably contextual and (seemingly) idiosyncratic.
>
> Greenhalgh & Hurwitz, 1998:251

> Our exploration hints at the importance of understanding how individuals are functioning in terms of their dynamics, i.e. how people interact with their context, their social networks and their own bodies, and how this changes over time.
> Griffiths et. al, 2007: 43

These interests create a need for ways to conceptualise and articulate the local, the concrete and the particular, whether at the level of person, group, culture, or society. Dominant epistemologies, however, demand that particularity be deliberately transcended, prescribing methodologies that work upwards and out of specifics towards the identification of more abstract and general principles. The conclusions of a great deal of research in the social sciences and humanities (that 'knowledge must be contextual') thus stand in direct contradiction to the assumptions and mechanisms of many current epistemological/methodological practices (Thomas, 2002), particularly in the field of Education. One way to address this problem is to tackle it at the level of underlying ontology; to develop a wider range of ways of understanding both 'things in the world', and the ways that such things come into being. This will be returned to below in relation to possible ontologies implied by complexity theory.

Learning: collectivist confusions and exclusions
Lemke (1997:38 in Daniels, 2001:71) suggests that situated learning portrays people as:

> …functioning in micro-ecologies, material environments endowed
> with cultural meanings; acting and being acted on directly or with the
> mediation of physical-cultural tools and cultural-material systems of
> words, signs, and other symbolic values.

Though this kind of articulation has been very important for drawing attention to the importance of collective processes (or for conceptualising processes collectively…), the problem with the dominance of these types of frameworks is that they are often interpreted as implying that *the only things which are relevant to learning are collective.* Examination of the following example shows how this kind of understanding can arise:

> Analyses of distributed cognition focus on how humans working with instruments such as computers and how humans working in groups form integrated cognitive systems that cannot be understood by examining the elements of such systems taken separately (eg Hutchins, 1995). Analysis of mediated action pursue this line of reasoning by assuming that virtually any human mental process is distributed. Even an individual thinking in seeming isolation typically employs one or another set of linguistic or other semiotic tools, the result being that the mediational means shape the performance at hand.
>
> <div align="right">Daniels, 2001:83</div>

Here, it is suggested that the idea of distributed cognition is useful for thinking about situations involving 'humans working with instruments' and 'humans working in groups'. This is a focus on a specific type of collective, which uses an analysis of mediated action as a means of examining the functioning of such collectives. However, drawing attention to the use of semiotic tools in relation to the shaping of individual action *within* the collective broadens the discussion in somewhat ambiguous ways.

In the first case, the 'cognition' is collective, even if such collective cognition partly arises within human brains. 'An individual thinking in seeming isolation' could thus refer to the individual as a site of collective cognitive activity. But 'an individual thinking in seeming isolation' might at the same time be 'thinking' in directions that are produced by their own history, conditions and current circumstances (Davis & Sumara, 2006)[4]. This second aspect is often eclipsed by the prominence of discussions of the collective aspect of cognition. In addition, individuals are *biological* beings, and both individuals and collectives are physically located in material *space* as well as *time*. An individual is not only not 'in isolation', it is also not only 'thinking'; at any moment in time a person is also responding to emotional pressures and disturbances, and manifesting behaviours and actions of which they may have little or even no awareness. Furthermore, the linguistic and semiotic tools which shape individual performance are not limited to the collectivity which is the focus of the analysis, but arise out of much bigger types of collectivity in which the community of practice or activity set is embedded.

The way that all of these things are interacting from moment to moment in relation to individual human beings far exceeds a person's 'perspectives' or interpretations, not least because the interactions of the many different, embedded systems involved constantly produce emergent effects which arise spontaneously (beyond the control of the individual), rather than being individually 'constructed'. These various issues can all usefully be investigated further with the help of complexity theory.

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[4] A further way in which cognition may be said to be distributed is 'across levels and areas' in the brain, which is different from the distribution of cognition seen in networks of humans working on a shared activity, or within a shared disciplinary area…

Complexity theory
The theoretical interest in the local and the concrete which is now evident in many areas of the social sciences draws attention to difficult issues not only of difference, but also of process, multifactoriality, and dynamic flow through time. Though these issues are implied, and sometimes integral to, many social constructivist, sociocultural and postmodern/poststructuralist approaches, each of these groups of perspectives offers a unit of analysis or framing which focuses on only some of these aspects, from their particular position. Davis & Sumara suggest that 'complexity thinking takes the discussion to realms that these discourses often ignore or evade' (2006:30), arguing that such thinking moves beyond the oppositional extremes of individual concerns and society's needs, introducing 'the biological across all phenomena'[5] (ibid), and providing a way of articulating multiple levels of scale simultaneously. For Davis & Sumara 'the vital question…is neither, 'how are these discourses different?', nor 'how are they alike?' but 'at what level of complex organisation is this theory a description?' (2006:120).

Ecologies of the social: the implicit connectedness of 'nested systems'
'Complexity theory' is not a unified theory, and though some writers suggest that it is 'relatively new in science' (Byrne, 1998), others would argue that the perspective it represents is not new (Gare, 2000). Though the emergence of complexity theory into public awareness is often seen to be connected to the establishment of the Santa Fe Institute in 1984, Gare lists von Bertalanffy's general systems theory, Whitehead's philosophy of organism, MucCulloch and Pitts on neural networks, von Neumann on cellular autonomata, Wiener on cybernetics, and Prigogine on dissipative structures, as being precursors to the work of the Santa Fe Institute. He also discusses Waddington's work on epigenisis, Jansch's work on self-organisation, Maturana and Varela's work on autopoeisis, and Pattee's work on hierarchy theory. In his view, complexity has long been of interest to those philosophers and scientists who are part of what he calls 'a counter tradition within science', which has attempted to challenge 'a mechanistic, reductionist view of the world' with 'an organic view of the world' (Gare, 2000:335).

Complexity offers a view of the world as composed of multiple, nested, and open dynamic systems (Byrne, 2005a). In contrast to 'the disorganised situations with which statisticians can cope' (Weaver, 1948 in Johnson, 2001:47) dynamic systems 'show the essential feature of organisation' (ibid); they have a coherence, an identity. Such systems, however, are neither static nor closed, and continually 'self-organise' in response to their environments. They can be very small (eg. cells, amoebas), or very large (eg. ecological or weather systems); they can be biological and physical, social and cultural, linguistic and political. One of the most important aspects of this perspective is that complex systems are embedded within each other, and therefore *cannot be considered in isolation from each other*.

Not all systems, however, are complex. Closed systems in which all the parts can be specified, which can be taken apart and then put back together again, and the workings of which can be clearly described on the basis of precise rules (Davis & Sumara, 2006; Cilliers 1998), are not complex. By contrast, complex systems are open, characterised by dynamic interactions between multiple elements, and the rules which govern them 'can vary dramatically from one system to the next' (Davis & Sumara, 2006; 11; this is a very

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[5] Though Davis & Sumara stress the biological, my argument is for ways of conceptualising *interconnection* between aspects of phenomena that are usually considered separately. Complexity insists that the physical and the biological be brought into discussions of 'the social', which otherwise often tend to ignore the urges and emotions of bodies, physical elements in space etc

important point in relation to systems that appear to be similar). The list below summarises some of the features of this type of system.

Complex adaptive systems :

- are *open,* materially and energetically, and exist in a state which is *'far from equilibrium'.* There is a constant flow of energy and matter between the system and other systems in which it is embedded.
- have a *large number of components,* which are multiply connected, in *non-linear* ways. Information can feed back on itself, and systems affect themselves as well as other systems which they are connected to and embedded within.
- are characterised by interactions which take place at the *local level* only, as the system responds and adapts to changes in its inner and outer environments.
- *evolve through time* from specific *initial conditions.* Such systems thus have specific and unique trajectories through time.
- manifest '*sensitivity to initial conditions'.* Small changes in initial conditions can become amplified through time to result in very different results, even if the initial conditions of two systems appear to be the same. At the same time, two systems which appear to be very similar may be the product of very different initial conditions and histories of interaction.
- continually adapt, change and survive through processes of *emergence.* Emergent features and conditions arise as a result of the multiple interactions between elements, but transcend such elements. Emergence is difficult to explain and to understand, and is conceptualised differently by different researchers. 'Radical' versions of emergence state that there is no trackable pathway back to antecedents, even retrospectively (Goldstein, 2005). Emergence arises out of a *diversity* of interacting elements, (it is this diversity, which includes elements which are apparently redundant, which make it possible for the system to continually change and adapt), and the interaction of such diverse elements *through time.*
- have structures, but these structures are not 'directed' or caused by any central organising mechanism. Self-organisation is *dynamic, responsive,* and *distributed* (there are rules, but no 'underlying' or centralised generative forces).
- emerge not only 'initially' in relation to specific initial conditions, but also *continually,* in relation to a specific constellation of 'multiple presents' at any one moment in time.
- emerge within the *constraints* provided by other, larger and smaller systems which they embed, and are embedded within.
- exhibit *dynamic coherence.* A dynamic system has an identity, despite not having a centre or even, in many senses, a surround[6].
- *evolve* and *learn.* 'A complex system learns, that is it is constantly altering its own structure in response to emergent experiences…its response to a virtually identical stimulus may change dramatically in a very brief span of time' (Davis & Sumara, 2006:100)
- are *mutually implicated.* Whatever complex system(s) may be the focus of analysis, it is always 'embedded in larger ecologies of relationships' (Davis, Sumara & Luce-Kapler, 2000). This means that researchers have to define the nature of the

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[6] 'The structures that define complex social systems…maintain a delicate balance between sufficient coherence to orient agent's actions and sufficient randomness to allow for flexible and varied response' (Davis & Sumara, 2006:148).

complex system in which they are interested (Byrne, 2005a; Haggis, 2006 [7]), and also that researchers are always implicated in their subject of study (Haggis, 2006; Davis & Sumara, 2006)

- embody *unpredictability:* 'systems that are virtually identical will respond differently to the same perturbation. Hence, one cannot generalise the results from one system to another' (Davis & Sumara, 2006:100)

Any dynamic system which is a unit of analysis is both itself, and at the same time, because of its openness, simultaneously part of the interactions of a number of other dynamic systems. Dynamic systems of a similar type (eg. schools, departments), therefore, will share in the interactions of the larger systems in which they are embedded (eg. physical, ecological, cultural, and social systems). The shapes and patterns of these larger system interactions, in combination with each system's own historically-created patternings[8], provide the *constraints which are necessary for emergence to occur* (at the level of the smaller system). Though the patterns of the larger systems may be shared, however, the patterning of the smaller systems, whilst remaining open to perturbations caused by other dynamics, is also always specific to that system's history and conditions. The result of this is that what emerges from the combined interactions (at the level of the specific system) will be specific *to* that system. It would make no sense for it to be otherwise, as the stimulus to emergence is the continuing survival of each particular system. Each system thus evolves in its own particular way, within shared sets of larger system constraints.

A system is particular in three senses. Firstly, it has its own set of initial conditions. Secondly, these conditions have given rise to a specific history of emergent effects and ongoing conditions, in relation to that system's evolution through time. Thirdly, the system is connected to, and partly constituted by, a particular configuration of other, different systems, some of which exist at the same 'level' as itself (in the sense that they are all contained within the larger system interactions as listed above) and some of which exist beyond this. This combination of initial conditions, history through time, and particular configuration of present systems make up the 'context' of each dynamic system, though it is questionable as to whether context is a meaningful notion in this situation. If it is, it would be tempting to say that context is both 'internal' to the system (in terms of initial conditions, and specific interaction history), and 'external' in the sense of connection to other multiple systems. This is only partly helpful, however, because the interactions of other, changing systems have been part of the 'internal' structure of the system which is the unit of analysis from the moment it emerged; indeed it is the interactions of other multiple systems which produced the system in the first place, and which enabled it to become established and viable.

Emergence is the feature which might be said to most distinguish this perspective from others; or which perhaps develops vaguer notions of context and society most specifically. The individual system is not 'constituted by' the larger systems in which it is embedded. It continually emerges from within the constraints of these systems, transcending them at the same time as being constantly adjusted and constrained by the multiple, non-linear nature of the various interactions involved.

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[7] 'What is a system of interest at any point in time is defined by observation and action. Boundaries depend on what we are looking for and at. This is not to say that boundaries are arbitrary relative or unreal…' (Byrne, 2005:105).
[8] A system is 'a pattern of causal organisation' Rosen, 2000:23

Conditions and time: 'structure determinism'
One of the most important implications of the idea of 'sensitive dependence on initial conditions' is that any complex adaptive system is 'structure-determined' (Davis & Sumara, 2006). Davis & Sumara define structure-determinism as follows:

> It is one thing to try to make sense of where a complex unity begins and ends. But even if that issue could somehow be unambiguously settled, another at-least-as-difficult issue is the fact that *it is the system – and not the system's context* - that determines how it will respond to emergent conditions

> Davis & Sumara, 2006:99 (my italics)

In other words, not only are systems always specific and particular, but it is the specificity of a system's own dynamic structure which will determine its responses. From this point of view, comparing systems with each other may be of limited usefulness, in terms of understanding the kinds of dynamic systems which are of interest to educators. As discussed above, even two apparently similar systems will be emerging out of quite different initial conditions, past histories, and presently-connected other systems; likewise, apparently similar sets of initial conditions, histories and present constellations may give rise to two very different systems. This is why, as discussed above, the rules which govern such systems 'can vary dramatically from one system to the next' (Davis & Sumara, 2006; 11).

The idea of 'structure determinism' provides an explanation of the genesis and evolution of difference; a difference which, from a complexity perspective at least, cannot meaningfully be aggregated into larger, 'overarching' categories or types. The assumption that general principles can be identified which will meaningfully pertain to groups of diverse phenomena is replaced by the idea that phenomena are fractal (ie. they do not get any simpler at greater degrees of magnification [Davis &Sumara, 2006]), and therefore that they cannot be meaningfully simplified[9]. From this perspective, people, groups, institutions, cultures, societies, whilst continually emerging as a result of openness, connection and interaction, are nonetheless also specific to themselves. Many important aspects of such systems can therefore can only be understood in relation to the particular histories and conditions (past and present) of each system. This is not an argument for an isolating, individualistic approach, however, as 'present conditions' refers to the need to study systems-in-themselves in relation to at least some aspects of the many other systems in which they are currently embedded. It also, crucially, implies a need to attend to relationship and patterns/characteristics of interaction, as the system is itself constantly emerging out of multiple dynamic processes.

In relation to learning, and research into learning, 'structure determinism' provides one possible rationale for the investigation of specific systems through time (whether these systems are people, groups, vocational areas, institutional cultures, or discourse systems). This approach implies a shift from seeking to identify general principles of correlation, cause and effect, to an analysis of *conditions* and *effects* in specific situations (Goldstein, 2005; Byrne, 2005b).

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[9] Cross-sectional patterns, from this perspective, might be seem as representing aspects of the interaction patterns of the *larger* systems in which the systems which are being analysed are embedded, rather than indicating 'underlying' structures-in-common in relation to these smaller systems (see Haggis, 2006, 2007, 2008).

Learning and complexity
In relation to the discussion in the first part of this chapter, complexity theory provides a 'non-deterministic, non-reductionist' (Daniels, 2001) way of acknowledging and exploring aspects of concrete particularity which is not based upon the centring, essentialising tendencies of previous cognitive approaches. It offers a way of both understanding and exploring why individuals within collectives might experience participatory practices differentially, or why apparently similar collectives may respond very differently to aspects of context which are assumed to be the same. Using this approach, it would be possible to investigate any kind of 'learning', including the questions discussed above about the differential engagement of people involved in intentional forms of collective learning activity (eg. assessed learning in institutions), and the differential results (ie. assessment outcomes) which emerge from the interactions of person-as-system and discipline-/tutorial group-/or institution-as-system.

Complexity theory is not a totalising description which attempts to accommodate or explain all things. Instead, thinking of things in complexity terms arguably develops and opens out the potential for new kinds of creative thought, rather than closing such thought down. Describing things in terms of interaction and emergence, for example, does not attempt to describe *what* will emerge in any given situation; the framing of dynamic systems, the choosing of units of analysis, and decisions about what types of emergent feature may be meaningful all rest with the researcher[10].

Learners and learning

- *evolve* and *learn*. 'A complex system learns, that is it is constantly altering its own structure in response to emergent experiences…its response to a virtually identical stimulus may change dramatically in a very brief span of time' (Davis & Sumara, 2006:100)

As well as implying a different ontological basis for epistemology and methodology in more general terms, complexity theory also incorporates a very specific definition of learning, which may at first seem tangential in the context of education. The overall argument of this paper, however, is that complexity offers radical challenges not only to many aspects of educational theorising and research practice, but also to the often taken-for-granted nature of 'learning' itself.

Classes, teams, institutions, departments, students, and/or disciplines can all be defined as interpenetrative complex adaptive systems. As complex adaptive systems, each of these units of analysis has to be considered not only as dynamic and continually emergent, but also in relation to the wider ecologies and sets of relationships in which they are embedded (thus allowing for progression beyond the conceptual fuzziness of 'mutual constitution'). Considered in this way, it can then be asked what the effect would be of defining 'learning' as the process by which a class, institution, or student might be 'constantly altering its own structure in response to emergent experiences…' (ibid).

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[10] This is not to suggest that dynamic systems are simply the conceptual projections of the researcher. However, even if a realist position is adopted in relation to a 'real world' conceived of as being composed of dynamic systems, the researcher still has to make decisions about which of these multiply embedded systems to focus on, and which aspects of the interacting features within such systems are of interest.

> Overwhelmingly, the word learner is used to refer to the assumed-to-be-isolated and insulated individual. By contrast, in complexity terms, learners can include social and classroom groupings, schools, communities, bodies of knowledge, languages, cultures, species…also organs and bodily sub-systems, cells, neurons. ..It is not at all inappropriate to say that a discipline 'argues' or a cell 'knows' or a culture 'thinks'..
>
> Davis & Sumara, 2006: 14

From this perspective, the changing dynamics and emergent effects which are produced by multiple and embedded complex systems are not merely implicated in a person's learning (whatever the focus of that learning may be), they *are* learning itself; if a learner is understood to be 'a complex unity that is capable of adapting itself to the sorts of new and diverse circumstances that an active agent is likely to encounter in a dynamic world' (Davis & Sumara, 2006:14). If a person is conceptualised as an embedded dynamic system, then the question is no longer how people create understanding/meaning (cognitive constructivism) or how social reality creates people (radical constructivism, critical theory). Rather, the question is how understanding and meaning may arise in particular ways from specific kinds of dynamic constraint. A complexity framing forces engagement with particularity, but not in an individualistic way, as the particularity cannot be separated out from the interactions of the many different dynamic systems within which it emerges. A complexity framing is also not simply 'social', in the sense that interpenetrating systems are both entities and environments (for other dynamic entities) as the same time.

Because of sensitive dependence on initial conditions, people, groups and institutions continually emerge uniquely, though within the constraints of the interaction characteristics of larger social, linguistic and cultural systems. As constraints which contribute to emergence, the patterns of 'the social' do not, as some social framings might suggest, mould and form people in predictable ways (though obviously there are limits to unpredictability; a person cannot emerge as a butterfly…). Though it is possible to make general statements about the interaction characteristics of larger systems such as culture or society (e.g. gender, class), thinking of people as dynamic systems creates a way of understanding how larger system interaction characteristics *become transformed* when they become part of the specific dynamic system which is the person. The dynamics of larger social systems create constraints, but within those constraints, each person emerges slightly differently.

Learning and context
The idea of nested, dynamic, open systems, all implicated in each other, and yet all with their own identities and impetus to survive, changes many contemporary questions about learning. From a complexity perspective, learning is perceived not as 'being embedded in social and cultural contexts' (Boreham & Morgan, 2004: 308), but *as a characteristic of embedded, dynamic systems*. It is also not 'best understood as a form of participation in those contexts' (ibid) but as *a survival mechanism for such systems*. Complexity suggests radical (though embedded and dynamic) specificity, a response to which is that, as dynamic systems, people, groups/collectives, institutions, societies, cultures, all arguably have to be studied on their own terms, looking at conditions and effects in relation to initial and present conditions (ie. the multiple systems in which they are embedded), and histories through time.

This understanding of learning develops the idea of a 'more fluid and relational set of practices' (Edwards & Miller, 2007: 265) in very specific ways. It provides a unit of analysis, the dynamic system, which is itself profoundly fluid and relational, but which also has a form. Such a system is embedded in multiple other systems of interactions, and continually emerging. A complexity approach also goes beyond the current preoccupation with activity and practice. It suggests a need to understand how physical location, biology, activity, discourse, awareness, and intentionality work together to produce emergent effects across a range of embedded and mutually implicated systems; but with effects in each case being specific to *the survival of a particular system* . From this perspective, learning is far more situated than theories of situated learning imply.

Thinking of domains as complex adaptive systems raises questions about the idea of 'mobilising learning' across them. Domains are specific, and also implicated in each other, producing emergent effects in relation to the changing diversity of elements which compose them, and the changing conditions within which they seek to survive through time. A domain such as 'family' seeks to survive *as* a family; a domain such as 'school' seeks to survive in the same way. A person carrying out an activity in either of these domains is, first and foremost, also seeking to survive; physically, emotionally, psychologically, communally, and in relation to their own 'sense of themselves'. When they are part of the interactions that produce the family domain, a person will emerge in ways that attempt to further their survival as a part of that particular system; when they are part of the interactions that characterise and produce 'school', they will emerge differently. From this perspective, when a person moves from domain to another, it does not really make sense to talk of learning that they can 'take with them'. In each situation, different types of interaction come together, producing different types of effects. As conditions and agents are continually changing, even something that appears to be organisationally stable, such as 'class 3a, taught by Maria', is nonetheless subtly different every time it comes together (e.g. John is off sick today, Maria is stressed because she had a fight, this is a particularly hard chapter, the radiators aren't working properly).

Arguably nothing that has been discussed here is news to teachers, or, for that matter, to doctors, or to ethnographers. Complexity is useful, however, because it outlines an ontology (and thus also epistemologies and related methodologies) of the 'irremediably contextual' (Greenhalgh, 1998). This provides both a theoretical and a practical starting point (Davis & Sumara, 1996) from which to begin multi-system analyses of conditions and effects in relation to specific learners, classes, schools, cultures and societies; not in order to replace forms of research which aim to identify correlation and generalisation, but to make exploration of aspects of learning and education which these forms of research cannot accommodate become possible . Complexity opens the way for an exploration of 'difference' in its most radical sense.

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