The Dynamics of Emergent Self-Organisation: Reconceptualising Child Development in Teacher Education

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Abstract: For more than half a century, child development has endured as one of the main components of teacher education. But if children do develop, as developmentalists claim, what precisely is it that develops and how? Traditionally, within education, answers to these questions have drawn heavily on the theories of Jean Piaget and Lev Vygotsky. Piaget advocated the progressive development of reasoning through identifiable linear phases or stages. Vygotsky emphasised the role of cultural mediation, whereby the child internalises the habits of mind of his/her social group. More generally within cognitive psychology, development has been attributed to the interaction of two distinct causes - nature and nurture - and the developmental process has been viewed as being linear, progressive, and incremental, guided by some inner mechanism of design; by schemas or genetic blueprints acting as programs in the mind. According to the Dynamic Systems Approach (DSA), however, there are no programs or blueprints and no teleological design. Instead, human development is the results of non-linear emergent self-organisation; a holistic process that rejects the dualisms of nature/nurture, perception/cognition and mind/brain associated with traditional theory. This very different account of development calls for a reconceptualisation of child development theory in teacher education. Our paper attempts to move some way in that direction.

Introduction

Of the many components that have contributed to teacher education courses over the past half century, child development has been one of the most enduring. In the 1960's, it was taught as part of Psychology of Education; one of the so-called 'foundation subjects'. James Comer (2005, iv) notes that since then, in the US, the number of teachers he encountered who had 'taken child and adolescent development courses in their pre-service training increased to almost all'. Currently in the UK, despite the obsession with trying to reduce teacher competence to a set of prescribed *can-do* 'competencies', the Training and Development Agency (TDA)[1] requires that teacher

education programmes include 'understanding child development'. Development is widely taught in teacher education courses throughout the Asia Pacific region and in Australia, in New South Wales for example, graduate teachers are required to: 'Demonstrate knowledge of the typical stages of students' physical, social and intellectual development'. [2] Indeed, Australia and New Zealand are currently celebrating the publication of the first Australasian edition of the textbook *Lifespan Development*, (Hoffnung et al., 2010), aimed at local psychological, allied health and educational settings.

Teachers need to understand children, and if children develop in the ways that development theory claims this can be applied in the classroom as 'developmentally-appropriate practice' (McDevitt & Ormrod, 2007, .23), when planning curriculum and dealing with student behaviour. So if, according to Piaget, children develop along a fairly predictable linear trajectory, teachers need to be aware of these 'continuities' or 'typical stages' in their classroom practice. Or, as Vygotsky claimed, if development is a matter of 'cultural mediation' and 'internalisation' of pre-existing knowledge, norms and habits of mind; teachers can incorporate this insight into their lesson. But, is the notion of progressive and orderly linear development correct? Would it not be more accurate to say that human cognition and action become more complex in ways that are often non-linear and emergent from circumstance? And although cultural mediation plays its part - for development is always highly context-sensitive - isn't the process much more dynamic than Vygotsky's notion of 'internalisation' suggests?

The idea that development is inherently dynamic and is frequently non-linear, the result of emergent self-organisation as each child engages with the multiplicities of its experience of being in the world, is central to the Dynamic Systems Approach (DSA). The dynamics approach, also known as complexity theory or Non-linear Dynamic Systems (NDS) theory (Guastello, et al. 2008), was introduced into mainstream psychology by pioneers such as Esther Thelen and Linda B. Smith (1994) as an *alternative developmental paradigm* to much cognitive theory. It can therefore be somewhat unsettling for those of a more traditional cognitive persuasion. Though dynamic systems theory is currently being applied in biology, psychology, anthropology and sociology (Fogel, et al. 2008), it is hardly mentioned in child development textbooks in education. Even in mainstream psychology, there is concern about an 'escalating gap between the state of the science of NDS and the average level of awareness of its accomplishments by professionals in psychology' (Guastello, et.al. 2008 xiii).

So, what *are* teachers being taught about development? What theories are they being encouraged to apply in their practice; how accurate are those theories and the assumptions they entail? And is there some overarching metatheory that draws the many theories one finds in the textbooks into some coherent whole? In short, what is the nature of this discipline called human or child development? Paul Van Geert (2008) suggests that a good method for getting an idea of what an academic discipline entails is to browse through introductory student textbooks. In the case of developmental psychology, he notes that the majority of textbooks:

…either focus on childhood to adolescence or on the human life span. The first chapters typically provide an overview of the "perspectives" on development and comprise a selection of theories ranging from psychodynamically (Freudian) inspired via learning theory to theories of Piaget and Vygotsky. Most handbooks address the nature-nurture problem, discussing the effect of genes and environment on development and present some sort of interactionist or transactionist approach. The main chapters are divided according to two dimensions. One is a content or domain dimension and comprises physical, cognitive, and social aspects of development. The other dimension refers to age and amounts to a distinction in phases or "ages." (Van Geert, 2008, 242)

A browse through the development textbooks used in education (e.g. Shaffer & Kipp, 2007; McDevitt & Ormrod, 2007, p.23; Woolfolk, 2007; Hoffnung et al., 2010) reveals a similar picture, with much space being given to the theories of Piaget and Vygotsky and an emphasis on stages, phases or ages, the nature-nurture problem, and the effects of genes and environment. In this paper we will be taking a critical look at these ideas when we consider the inherent dualism of much development theory, but underlying the discussion we will also be attempting to address a more worrying problem. As Van Geert notes:

The main picture revealed through such textbooks is that development 'is basically a collection of perspectives and approaches (theories), of influences on development (e.g., genes, environment), of aspects or dimensions (e.g., physical, cognitive), of phenomena' (e.g., attachment, conservation), spread out across the life span or part of it, in phases or ages…. Developmental psychology is apparently not a first-principles-based science. There seems to be no fundamental developmental mechanism, the understanding of which forms the key to a thorough understanding of the emergence of developmental phenomena. (Van Geert, 2008, 242-243 (emphasis added))

The main purpose of this paper is to argue for dynamic systems theory and its core concept of emergent self-organisation as the fundamental developmental mechanism that should guide human and child development studies in teacher education. The adoption of the DSA makes the study of development into more than a descriptive science; a collection of perspectives, approaches and dimensions. The DSA is a comprehensive theory and, as such, it is able to accommodate much previous theory (for example, Piaget's notion of *Cognitive Dissonance* or Vygotsky's *Zones of Proximal Development*), while also setting it in a more comprehensive conceptual framework. Similarly, it can to some degree accommodate the rather predictable, orderly and linear processes advocated in much traditional theory as providing broad approximations to the complexities of human growth; in the same way that Newtonian theory may approximate to relativity theory within certain parameters. Though replaced by relativity theory, Newtonian mechanics was nevertheless used to successfully navigate the stricken Apollo 13 back to Earth (Chalmers, 1999, 174).

If human beings do indeed develop, as we believe [3], *what precisely is it that develops and how?* In pursuing that question, which we take to be the core question for human development, we begin by raising some concerns about the notion of 'development' and how it has often been portrayed in teacher education. We then consider the assumed divides that have traditionally been drawn:

between internal and external causes; between perception, cognition and action, and; between mind and brain. This discussion will enable us to frame an answer to our question of what precisely it is that develops and how? We then turn specifically to dynamics systems theory to consider what is meant by non-linear emergent self-organisation, and to argue for the central role of perception in learning, which is denied in traditional cognitive theory. Finally, in contrast to the notion of incremental phases or stages of development, we describe briefly how development can be conceived in terms of the shifting stabilities and instabilities of attractor basins.

The notion of development

We cannot escape the assumptions we live by, for they influence our personal and professional lives greatly. One very pervasive assumption, seemingly underscored by everyday observation, is that all animal species 'develop' throughout the course of their lives. Babies grow to be adults and in the process many things change, both bodily and mentally. Though not in themselves problematic, these assumptions can provide a slippery slope for the unwary. As soon as we use the word 'develop', we seem to be buying into notions of 'going forward, of 'orderly progression' and, in the case of babies, of their being 'on a pathway leading upward and onward' towards adulthood. Thus, it is hard to conceive the course of development as being regressive. Indeed, to be told that a child's development was regressive is surely to be told that she did *not* develop at all. This matters, because, as teachers often discover, each child's trajectory in every aspect of their maturation is *both* progressive and regressive. Employing the terms 'develop' and 'development' can mask the variability and sometimes even regression in the 'developmental' story.

Everyday assumptions of 'continuity' and 'orderly' progression are frequently found in child development theory. Thus, in one popular textbook on *Developmental Psychology* we read: *Development refers to the systematic continuities and changes in the individual that occurs between conception…and death. By describing changes as 'systematic' we imply that they are orderly, patterned and relatively enduring, so that temporary mood swings and other transitory changes in our appearances, thoughts and behaviours are therefore excluded.* (Shaffer & Kipp, 2007, 2)

What is particularly revealing in this definition is not only the claim that development refers to 'systematic continuities' - the 'orderly, patterned and relatively enduring change' one finds in everyday assumptions about development – but also a systematic bracketing out of all that is contrary to that notion. Thus, from the perspective of traditional developmental theory, all that is messy and highly variable, including 'mood swings' and 'transitory changes' of thought and behaviour, indeed much of what makes us the persons we are, is 'excluded'. But why? And is the exclusion of discontinuity and the messy, variable side of child development helpful for teachers facing the demands and challenges presented by students in their classrooms? Surely, the

'evidence suggests both continuities and discontinuities, and we must explain them both' (Thelen & Smith, 1994, p.31).

A large part of the reason for bracketing out discontinuity and variability derives from the conduct of research. It has been common practice in developmental studies to conduct cross-sectional sampling that compares groups of subjects at a number of different ages. Development is said to have occurred if statistically-reliable differences are found in the mean levels of performance at the different age levels. This approach carries the added implication that if variability among individuals is high, it is difficult to detect group differences. Thus, as a result, variability and diversity are viewed only 'as "noise" in the system' (Thelen & Smith, 1992, 145), and in 'experimental psychology "noisy" data are bad data' and 'have to be discarded as they do not produce statistically reliable effects' (Thelen & Smith,1994, 67). The instabilities that are of particular interest for teachers are perceived as a problem to be 'excluded' when conducting research.

But, this is a case of the tail wagging the dog. The methodological decision to bracket out variability, in order to reduce noise in the system when conducting research, becomes an ontological decision to exclude variability from the notion of development. And, here we see an important contrast with the dynamic systems view of development, which 'considers the origins and functions of variability as absolutely central for understanding change' (Thelen & Smith, 1994, 67). Indeed, from the perspective of the DSA, behavioural instability is 'particularly important for understanding development, because it is frequently associated with transitional events' (Howe & Lewis, 2005, 249). Though sometimes linear and quantitative (increased functioning and ability), child development is often non-linear and qualitative. For teachers in real classrooms with real students, what needs to be emphasised, we suggest, is the messy, unpredictable, individually-variable nature of development. It is this notion of development that needs to be taught in teacher education courses.

Moreover, teachers should be cautioned that group average studies, that are pervasive throughout social science, provide 'a highly limited and in some cases even a misleading story' (Fogel et al., 2008, 241). In particular, the notion of *on the average* improvement or development is problematic when viewed at the level of individuals, for, by definition, an average increase means that some increased more than others, and some may even have decreased. This is doubly problematic when it is realised that 'policy makers in government and private settings may only have this *on the average* information at their disposal' (Fogel et.al., 2008, 243). While this information may help set the broad parameters of the research problem, it does not address the fine detail. The dynamics approach provides a more focused lens, by frequently sampling individual variability over a longitudinal time-span, thereby focusing on the relationships between the individual parts that comprise the whole group or population.

To return to our main theme, if, within education, the results of group average studies suggest a linear trajectory of progression, individual data will almost certainly show a different non-linear

reality. As teachers, we need to be constantly aware of the danger of adopting a group average mentality when describing the behaviour or ability of the group of children we teach – every class of children is comprised of individuals – and we need to appreciate that each individual will exhibit variability (stabilities and instabilities) in development at all ages. We will return to the stabilities and instabilities of development later in the paper, when we discuss the notion of attractor states.

Dichotomies of nature and nurture, perception and conception, mind and brai

Nature, nurture and genetic determinism

Another area of concern regarding traditional developmental theory is its dualistic language. Central to the traditional model is the assumption that all human thought and action result from two very different causes: *internal causes* that are innate, biological and genetic and *external causes* that result from the influences of the natural and social environments - two causes, nature and nurture. Moreover, the structure determining developmental change is said to be 'fully formed, either in the blueprint in the genes which gets "read out" in development or in the existing structure of the environment which becomes internalised through learning' (Richardson, 2000, 2). Of course, in true Cartesian fashion, having made this absolute separation between these two utterly different causes the theorists needed a way of bringing them back together. The result is the doctrine of *interactionism* between the innate biological and the learned, although, if these really are two completely distinct causes, as we are meant to believe, 'we are never told even in the most general terms how molecular biological mechanisms involving genes can "mix" with learning mechanisms' (Richardson, 2000, 3). One wonders why it was felt necessary to set it up in this dualistic way in the first place. Why separate the internal from the external and, as a frequent corollary, why give priority to processes that reside *within* the organism as somehow more foundational than those that reside outside the organism in the environment?

Part of the reason must surely be what Mary Midgley, in a different context, calls 'the 'misleading sense of genes as all-powerful' which has 'been much encouraged by the information metaphor which depicts them as constantly giving orders to the entities around them' (Midgley, 2006, p.6). Genes, however, are not all powerful; they operate relationally within the context of the *whole* organism. As the neurobiologist Steven Rose has emphasised: 'You may leave DNA or RNA for as long as you like in a test-tube and they will remain inert…. The functioning cell, as a unit, constrains the properties of its individual components. The whole has primacy over its parts' (Rose, 1997, 169). Or, as biologist Brian Goodwin (1994, 3) has noted, genes certainly play their part, but 'organisms cannot be reduced to the properties of their genes and must be understood as dynamical systems with distinctive properties that characterise the living state'. Moreover, genes 'create organisms in a non-additive and non-linear fashion' (Rothschild, 2006, 166), and organisms are situated in multiple environments. In short, what is required is a *holistic concept of*

development as advocated in the dynamics approach, which stresses the continual interplay between the child as organism and the multifaceted natural and social environments she encounters *as part and parcel of the one same process*.

A fundamental premise of the traditional view is that 'information can pre-exist in the processes that give rise to it' (Oyama, 1985, 13). The logical problem here is one of infinite regress, for if the genes carry the instructions, who or what instructs the genes? A second problem with this view is that it implies that novelty does not really 'develop' as it is there from the start, transcribed in the genes. So the notion of development becomes one of predetermination. 'Postulating an interaction of genes and environment does not remove this logical impasse. It merely assigns it to two causes instead of one' (Thelen & Smith, 2005, 259). Instead of espousing genetic determinism, these authors note that within embryology it is widely recognised that genes do not, in and of themselves, determine developmental outcome. Rather: 'Genes are essential elements in a dynamic cascade of processes' (Thelen & Smith, 2005, 263). Indeed, many dynamics theorists turn to the new field of epigenetics, which claims that the environment and individual choices can actually influence the genetic code (Eva & Gal Raz, 2009) In clarifying what they mean by a 'dynamic cascade', Thelen and Smith offer the metaphor of a mountain stream.

At some places, the water flows smoothly in small ripples. Nearby may be a small whirlpool or a large turbulent eddy. Still other places may show waves or spray. These patterns persist hour after hour and even day after day, but after a storm or a long dry spell, new patterns may appear. Where do they come from? Why do they persist and why do they change? No one would assign any geological plan or grand hydraulic design to the patterns in a mountain stream. Rather, the regularities patently emerge from multiple factors: The rate of flow of the water downstream, the configurations of the stream bed, the current weather conditions that determine evaporation rate and rainfall, and the important quality of water molecules under particular constraints to self-organize into different patterns of flow (Thelen & Smith, 2005, 263).

They go on to point out that what they describe above is only part of the picture, for the stream has a history that includes the geological formation of the mountain, a history of climatic conditions and so forth, all of which impact to a greater or lesser extent on the nature of the stream here and now. Similarly, human development may be viewed as an epigenetic process that is a product of its own history and system-wide activity. In that case, when each cell or small group of cells is influenced by its position among other cells in the overall cascade, as, for example, when cells migrate and constantly signal to each other in the early formation of the brain, 'it is simply not feasible to ask whether this structure or this behaviour is "caused" by genes or by environment' (Thelen & Smith, 2005, 263). The whole cascade is the product of all of the parts, and it is more than the sum of the parts.

Perhaps part of the problem is that the notion of 'interaction' carries, at least implicitly, rather separatist, mechanistic and linear connotations as, for example, when two billiards balls collide and

'interact' with each other, producing two new linear trajectories. A dynamics approach, by contrast, avoids mechanistic models and stresses instead the holistic, organic, non-linear aspects of development. The metaphor of a 'cascade' is helpful in this regard, although, like every metaphor, it has its limitation. Another metaphor might be the *patterns* that constantly form and reform when turning a kaleidoscope[4]. As with the mountain stream, the metaphor of the kaleidoscope helps to capture the constrained unpredictability of development: one does not know exactly what patterns will form. But, though unpredictable they are nevertheless constrained by and within the totality of the whole. Similarly, the actual development of any individual child, though unpredictable, is nevertheless constrained by the nature of cells, tissue, blood, hormones and so forth and within the totality of the organism.

It would, however, be wrong to imply that the difficulty of separating these two putative causes goes unrecognised in the child development literature. It is recognised, but what one then finds is often confusion. For example, when considering the issue of 'sensitive periods' in development, McDevitt & Ormrod (2007, 72) say that: 'the timing of sensitive periods is dictated by heredity, which determines *when* particular kinds of environmental stimulation can come into play'. Thus, we have the image of two separable causes, heredity and environment, with the genes in charge *determining* (dictating) the timing of events. From the perspective of Thelen & Smith's notion of a 'cascade', however, separating heredity and environment in this way is 'simply not feasible'. Later in the textbook, McDevitt & Ormrod appear to admit this when discussing intelligence and the measurement of IQ. They say:

…most psychologists now believe that it may ultimately be impossible to separate the relative effects of heredity and environment. They suggest that the two combine to influence children's cognitive development and measured IQ in ways that we can probably never disentangle (McDevitt & Ormrod, 2007, 295).

To come straight to the point, the adoption of the DSA in teacher education would not only challenge the persistent and confusing references one finds in the literature to the dichotomy of nature, nurture and their interaction, it would also help teachers to escape the trap of genetic determinism – the idea that we are somehow pre-programmed in our behaviour and in our abilities and intelligence and that these determine the outcome of our education. That, in turn, would open up for all children the prospect, held out by the new science of epigenetics, that their genes need not be their destiny [5].

Perception, cognition and action

A second dichotomy (or trichotomy) is the traditional distinction made between perception, cognition and action. This is similar to the philosophical distinction often made between perception and conception which, as Lakoff & Johnson have noted, is based on the mistaken view

that conception, the formation and use of concepts, is:
…purely mental and wholly separate from and independent of our abilities to perceive and move…. Concepts and the forms of reason based on them are assumed to be purely part of the faculty of reason. Perception may inform reason, but in the tradition no aspect of perception or movement is part of reason. (Lakoff & Johnson, 1999, 37)

Whether in psychology or philosophy, primacy is given to the cognitive/conceptual over perception and action, all three being distinguished clearly from each other. We share the view of Lakoff & Johnson that the 'properties of concepts are created as a result of the way the brain and body are structured and the way they function in interpersonal relations and in the physical world' (Lakoff & Johnson, 1999, 37). Moreover, perception, action and cognition are rooted in the same dynamic processes that are laid down in the neuronal mapping of the brain as a result of perceiving and acting in the world. By contrast, traditional theory claims that learning and development rely primarily on the ability of the mind to make internal representations of the external reality. The mind is thus conceived as in some way mirroring nature, although this Kantian notion has been soundly discredited by Richard Rorty (Rorty, 1979).

Furthermore, these internal representations or conceptualisations are said to analyse and validate the deceptive world of appearances, thus enabling us to make complex decisions that are then operationalised by our bodies in the performance of actions and behaviour. Hence, Piaget's claim that knowledge has to be constructed through the action of the mind, and cannot be simply a result of perception. In the most recent edition of a popular textbook on *Educational Psychology*, the question is asked: 'Why is Piaget's theory of cognitive development consistent with active learning?' The reader (presumably a beginning teacher) is then provided with the model answer: 'Piaget's fundamental insight was that individuals construct their own understanding; learning is a constructive process' (Woolfolk, 2007, p.60). But is learning primarily a constructive process, or is learning driven by perceptual categorisation? We will return to this question again shortly.

Mind and brain

Implicit in all of this is a form of mind/body dualism. Given the belief that the function of the mind, the seat of concepts, is to represent the external world internally, the role of the body is said to be to act as the vehicle of the mind and to respond to the decisions of the mind. Whether intentionally or not, mind and body are thus being held apart; to repeat what Lakoff & Johnson said, the cognitive, conceptual actions of mind are considered as 'separate from and independent of' (and one should add 'superior to') the bodily functions of perception and action. But then what is this notion of mind if it is not conceived as essentially embodied in and thus inter-dependent with bodily perception and action? And if mind is not the product of the embodied brain, what is its source?

It is not our purpose here to engage with the many complexities (if not tangles) of philosophy

of mind. We tend to agree with John Searle when he said that 'the philosophy of mind is unique among contemporary philosophical subjects, in that all of the most famous and influential theories are false' (Searle, 2004, 2). We do wish to affirm, however, that when brains, which are open, non-linear, dissipative systems (existing far from thermal equilibrium), reach a certain level of complexity (as in the case of human beings and some other 'higher' species) they simply *do* produce the conscious experience that we refer to as 'mind' or the self. In that sense, at least, there is no problem of mind and consciousness to be resolved, much less a problem beyond resolution (McGinn, 1991); minds and consciousness *do* result from, *emerge* from, the immense complexity of human brains; that is what highly complex brains do. Thus, it is no more of a mystery [6] how sentience or awareness come into being than it is a mystery why thunder heads come into being or why intricate patterns are produced in the Belousov-Zhabotinski [7] reaction by inert chemicals; it is what happens to these dynamic systems at the required level of complexity when given a continual input of energy (Prigogine, 1997, 66). Certainly it is unexpected and it is marvellous to behold, but then so is the fact that the salt used to flavour your chips comprises one atom of sodium and one atom of chlorine. Sodium may spontaneously ignite on water and chlorine is so toxic that it is a favoured substance in chemical warfare. Put these two together, however, and you have the totally unpredictable result of producing table salt. It is the way the world works, and it is what is meant by the notion of (weak) emergence [8] (Clayton, 2006,7). What we experience as our mind, our self, emerges from our highly complex brain.

We hasten to add that we are not saying that all that constitutes the experience of sentient mind is 'nothing but; or 'can be reduced to' the electro-chemical processes of the brain. The dynamic systems approach is strongly opposed to reductionism of this kind. Indeed, by invoking the notion of emergence, which affirms that the whole is greater than the sum of the parts, a dynamics approach is the very opposite of reductionist; it turns the reductionist thesis on its head by asking how developmental change arises from the biological, chemical and physical parts. Thus, the DSA aims to provide 'a biologically valid, but nonreductionist, account' (Thelen & Smith, 1994, xviii) of the development of cognition and action, in which no one element in the process has causal primacy over any other. Notice, however, that development *is* being identified as in part a biological phenomenon. In other words, the developmental story has a strong biological substrate and although philosophy and psychology are not reducible to biology, they do need to be *consistent* with biology and neurobiology. We should also emphasise that we believe it important that the study of human development is not taken to belong to psychology alone. Rather it involves philosophy, psychology and neuro-biology and in such a way that the insights of all three disciplines operate in mutual modification and none is considered, *a priori*, to be in the lead.

Emergent self-organisation

We can now begin to address what we earlier identified as the core question of child development: what is it that develops and how? The short answer is that *the whole psycho-somatic human organism develops*, and the way it develops is *through a process of emergent self-organisation*. More specifically we can say that what develops is the perceiving, thinking, acting organism, which can be conceived as the human brain, situated in the human body, perceiving, thinking and acting in response to, and in inter-relationship with, the multiple complexities of the natural and social environments.

Though it is the whole organism that develops not everything develops at the same time and, as we have been stressing, development is inherently variable, comprising both stabilities and instabilities. When viewed in this holistic way, there is no nature and nurture divide, and therefore no need for the doctrine of interactionism. Nor is there an absolute divide between perception and conception, or between perception, cognition and action. Instead, there is a 'multiple, parallel and continuously dynamic interplay of perception and action' (Thelen & Smith, 1994, xiv) and cognition.

Let us look a little more closely at the notion of emergent self-organisation. Thelen & Smith use the metaphor of viewing from above and below when comparing the perspective of much previous developmental theory with that of the DSA. When seen from above, at one level of magnification, human development has appeared to many theorists as 'orderly, progressive, incremental', and 'teleological' (1994, xv), guided by some inner mechanism of design. By contrast, they describe how their research into motor and cognitive development forced them to see a very different picture, the view from below. From that perspective, development appeared 'messy', 'exploratory, opportunistic, syncretic', and 'context sensitive' (1994, xvi). If that is the reality of development, then what is happening; what processes are occurring that allow for development of this kind?

In seeking an answer they turned to dynamic systems theory.

The science of dynamic systems has its roots in mathematics, physics and chemistry, but it has also been applied widely to a host of phenomena that are complex and exist far from thermal equilibrium as non-linear, self-organising, 'dissipative structures' (Prigogine, 1997, 66). These are systems that draw on a high energy source to do work before giving some of the energy back to the environment. They are 'open systems' in which, with a sufficient injection of energy, new and ordered structures and patterns of behaviour may spontaneously emerge. All living structures are emergent, dissipative, self-organising systems; from the behaviour of ant colonies to the functioning of human brains (Solé & Goodwin, 2000). The human organism therefore shares a similarity with all living systems in that it is maintained and may develop as a result of emergent self-organisation, and this applies to the development of cognition and action, and even in regard to moral development (Kim & Sankey, 2009). The 'cornerstone of a dynamic theory of development is this

emergent nature of behaviour assembled in real time'
…even behaviours that look wired in or program-driven can be seen as dynamically emergent: behaviour is assembled by the nature of the task, and opportunistically recruits the necessary and available organic components (which themselves have dynamic histories) and environmental support (Thelen & Smith, 1994, 73).

The notion of 'opportunistic recruitment' employed in this citation is quite deliberately invoking evolutionary theory, where development is not 'program-driven', or 'wired in', or teleologically designed but results from selective processes. These processes do not produce optimal fits between organism and environment (Gould & Lewontin, 1979), but rather make-do solutions that opportunistically recruit available resources. Interestingly, complexity theorists are now arguing that species development not only results from natural selection, but is aided by processes of self-organisation; 'we must encompass the roles of both self-organisation *and* Darwinian selection in evolution' (Kaufman, 1995, 26). As Kaufman further explains:
…the emerging sciences of complexity begin to suggest that the order is not all accidental, that vast veins of spontaneous order lie at hand. Laws of complexity spontaneously generate much of the order of the natural world…. Profound order is being discovered in large, complex and apparently random systems. I believe that this emergent order underlies not only the origins of life itself, but much of the order seen in organisms today. (Kaufman, 1995, 8)

Nowhere is this 'profound order' more apparent than in the human brain, the most complex organism on Earth. It is time to consider - if only briefly - the dynamic organisation of the brain and particularly the role of perceptual categorisation in the process of self-organisation whereby the child, as an organism in the world, develops.

Perception, categorisation, learning and development

We noted earlier the tendency in cognitivism to attenuate the role of perception in learning and development. Even though Piaget recognised the importance of active, repetitive perception and movement and the ability of the system to self-equilibrate, he nevertheless advocated the primacy of construction over perception. Moreover, there has been a strong tendency in cognitivism to postulate entities (things) in the mind. Thus we have accounts of structures and hierarchies of structures, processing devices, programs, schemata, modules, universal grammas, all of which are said to account for how children learn and develop. But is any of this necessary? Is it not possible to explain all that they are said to explain by invoking principles of emergent self-organisation; the interrelationship between the whole organism and its embodied, holistic, plastic, self-organising brain, operating in response to multiple, variable natural and social contexts? If so, then presumably perception and categorisation must play a pivotal role in the process. From the perspective of the DSA, perceptual 'category formation is the primitive of mental life; the

ontogeny of category formation is the basis for behavioural development' (Thelen & Smith, 1994, 162).

However, a core assumption of traditional theory is that 'when perceptual data enters the mind it has no meaning and involves no categories' (Richardson, 2000, 184). But then what is meant by perception? For if perception involves no categories and has no meaning, it is hard to consider it perception at all: it is simply undifferentiated sense data. And, for an animal in the wild, suddenly confronted by a potential predator, undifferentiated sense data is no good and it has no time for cognitive construction. What it needs are salient perceptual categories to trigger action. Even so, though it would be reassuring to think that this issue of whether perception has meaning and contains categories could be decided by experimental evidence, evidence can cut both ways (Richardson, 2000, 184-197), as often it does when two competing paradigms are involved. So, instead, let us look again at a key assumption and work up from there.

As already noted, from the perspective of the DSA the mind is not the mirror of nature. Moreover, the world does not present itself as ready-labelled; we have to do the labelling. The central question then becomes, how is it possible for the organism to learn and develop when operating in such an open-ended world? How, that is, on the basis of what is given to us as unlabeled in perception are we able to categorise our present and past experiences into a collective whole? The standard answer has been a 'representational epistemology… which holds that our knowledge "stands for" or represents a world that is separate from the knowledge itself' (Osberg, et al., 2008, 214); a view that these authors challenge in terms of complexity and emergence, drawing on Dewey's transactional realism and deconstruction theory.

Though also invoking complexity and emergence in opposing a representational epistemology, we turn instead to Gerald Edelman's theory of neuronal group selection (Edelman, 1987, 1989, 2004, 2006) and the studies of perception conducted by Walter Freeman (1987, 1991, 2000). Common to both authors is recognition of the immense complexity of the human brain and the central role of perceptual categorisation in learning. In recognising complexity, both authors focus not so much on the role of individual neurons but more on what Edelman called *neuronal maps* and Freeman calls *nerve cell assemblies*. Edelman draws our attention to the immense population and variability of neurons and neuronal maps; one hundred thousand million neurons, each with up to a thousand connections, producing an almost innumerable number of potential firing patterns. As the brain develops it lays down a huge diversity of firing patterns, providing an enormous range of possible thoughts and actions.

Neuronal maps connect with sensory receptor cells and also between themselves: a process Edelman calls *global mapping*. Signals between maps interrelate in immensely large numbers, in response to internal and external experience; a process he calls *reentry*. In this dynamic process some of the many connective patterns formed become strengthened because they possess salience or meaning for the individual, whereas those connective patterns that are not valued are weakened or die - there are neurobiological reasons why teaching and learning should be meaningful for each

individual student in the group; teachers are brain-makers, for better or worse. It is this dynamic, selective process, whereby the vast array of maps constantly self-organise in response to the ongoing 'cascade' of internal and external experience that accounts for perceptual categorisation. The implication of this is that categories so formed are not static and fixed in the mind, but are dynamic entities, dependent on and changing in response to cues, contexts and salience, including the organism's past history of cues, contexts and salient experience.

Neuronal maps are said to be 'degenerate', meaning that they allow for considerable flexibility and plasticity, but not such that they exclude specification. In *How brains make up their minds*, Freeman (2000) describes his life-long study of olfaction in rabbits that had been trained to recognise a number of different odorants (sawdust, banana etc.). His research has provided strong evidence of the brain acting as a self-organising dynamic system, where groups of mutually excited neurons participate in global over-lapping and inter-relational modification. Electroencephalogram (EEG) recording produced a characteristic contour (similar to contours on a geographical map) when the rabbit sniffed a familiar sawdust odour. However, when it was then introduced to the odour of banana it not only produced a characteristic banana contour, a somewhat changed sawdust contour emerged as well, which 'can only happen if sawdust is represented in the [olfactory] bulb not as a fixed structure or schema but as a dynamic assembly that is always a function of global activity' (Thelen & Smith, 1994, 132).

Attractor states: stability and instability

Thus, from the perspective of the DSA, perceptual categorisation and brain plasticity provide an alternative to schema theory. Indeed, in place of fixed structures in the mind (schemas, modules, genetic blueprints, universal grammas and so forth) a dynamics approach sees only dynamic emergent self-organisation.

There are, however, broad parameters within which development occurs, just as there are physical constraints on the multiple dynamic processes of a mountain stream, and these constraints can sometimes give the impression of there being a fixed structure or internal design guiding development. Employing the metaphor of the mountain stream helps us see that the impression is not the reality. Though, in principle, a self organising system could display an enormous range of patterns, it will normally settle into or 'prefer' a very limited range of manifestations or modes of behaviour. In dynamic systems terminology this 'preferred' mode is an *attractor* state. When disturbed from that state it will tend to return there, like the steady and regular swing of a pendulum. If initially pushed too far or not far enough, it will nevertheless find its own preferred attractor state.

Piaget recognised the importance of constraints when he postulated the existence of discrete phases or stages as major parameters of development. Thus, according to Piaget, whatever individual differences occur they are nevertheless constrained within a predictable pattern (phases

or stages) of onward and upward growth. This appears to be valid at one level of magnification, but a dynamics approach requires that we look with greater magnification at an individual's trajectory of development, and then we will find 'considerable fluctuations from the mean' (Kim & Sankey, 2009, p.288). This brings us back to a point made early in this paper; we need to account for both the stabilities and instabilities of development.

One way of dealing with this in the context of the DSA is to replace Piagetian phases or stages with the notion of attractor basins and attractor landscapes. Picture an artificial landscape with hills and valleys. A small ball like a glass marble is perched on top of a hill. This is an unstable repellor, for the ball will be easily dislodged. On the other hand, a ball lodged in a deep valley will require considerable energy to dislodge it into another valley. If disturbed only gently, it will return to its stable attractor. A ball in a shallow valley, by contrast, will be more easily moved to another valley, although given time it will probably end up in a more stable attractor. On this model, development is the individual's trajectory, not through predetermined stages, but rather through a shifting landscape of repellors and attractors.

Perhaps teachers can be pictured as guides, accompanying children through many hills and valleys of learning opportunity, presenting them with alternative routes and resting places, nudging them from one attractor to another. But, the landscape is always moving, nothing is entirely stable, all is in a process of dynamic and emergent flux as each child self-organises, changing and developing in response to the multiple complexities they encounter on the way.

Conclusion

In this paper we have tried to argue that instead of the dualisms of conventional theory and instead of postulating stages, schemas, or genetic blueprints acting as programs in the mind, human development is better represented as a process of holistic non-linear, emergent self-organisation. The issues at stake are not trivial, for, as McDevitt & Ormrod point out:

Children are nurtured most effectively when adults understand how children generally progress but also show sensitivity to children's individual needs. In other words, when teachers engage in developmentally appropriate practice, instruction and caregiving adapted to the age, characteristics, and developmental progress of individual youngsters. (McDevitt & Ormrod, 2007, 23).

McDevitt & Ormrod's reference to the importance of teachers engaging in *developmentally appropriate practice* has, as mentioned at the beginning of this paper, sustained the place of child development in teacher education over many years. But the assumption embedded in this claim, that development theory can be appropriately applied to the practice of teaching, begs a more fundamental questions regarding the status of the theories that teachers are being taught. Or as we have said, there is a need to be very clear what we mean by development; what precisely is it that

develops and how? We believe that these questions cannot be adequately answered so long as the study of human and child development remains as a descriptive collection of perspectives, approaches and dimensions, with 'no fundamental developmental mechanism', as Van Geert depicted it above, and human development is portrayed as a transit through phases, stages and ages towards a pre-specifiable end-point. In this paper we have tried to address those questions, putting the case for a dynamic systems approach, as a comprehensive and coherent mechanism of development.

The DSA is comprehensive. It provides a unified theory of development, working at all levels of description; from the neurobiological through the psychological to the social and cultural levels. One important implication of this is that the processes that lead to functional outcomes are precisely the same as those that lead to dysfunctional outcomes. One does not need additional theories to explain dysfunction. The DSA is also a coherent metatheory. Thus, we would question the apparent distinction made by McDevitt & Ormrod, between understanding 'how children *generally* progress' and the need to show sensitivity to children's *individual* needs. We have been critical of group average measures that are said to show how children generally progress. There is no 'general' child. There are individual children, each with their own distinctive developmental trajectory, and not simply individual needs as McDevitt & Ormrod suppose.

Imagine the difference it would make if teachers began to make this seemingly small yet fundamental shift in their thinking, when viewing the children they encounter in school. [9] When, that is, they see each child as an individual, self-organising organism moving on a trajectory through a shifting landscape, of home, school, peer, multi-media and other attractor basins, some of which are shallow and some deep. Imagine how teachers would be better empowered to handle the complexities of professional life when, instead of viewing development as predictable, linear, orderly, progressive and incremental, and guided by some inner mechanism of design, they view human beings as largely unpredictable, non-linear, dynamic, emergent, self-organising, context-sensitive, complex organisms. When, that is, they start to see development through the eyes of dynamic systems theory.

Our concern is that, in perpetuating the traditional model, student teachers are not being given access to the DSA and its core concept of emergent self-organisation as a metatheory that is able to accommodate and transform much previous theory, while also directly challenging some of its assumptions. Perhaps the problem is simply that 'when assumptions have dominated thinking so profoundly and for so long it is no small matter to give them up' (Richardson, 2000, p.5). The reaction we have found when presenting the DSA in different academic settings is frequently one of denial (there is nothing new in the DSA) or of defence (nobody believes in the traditional model anymore).

We hope we have shown that the DSA stands in considerable contrast to the traditional cognitive model and, if nobody believes in the traditional model anymore, there would seem to be a pressing need to begin reconceptualising child development theory in teacher education. We

believe it is time for a very big change.

Notes:

[1] The Training and Development Agency for Schools (TDA) is responsible for the initial and in-service training of teachers and other school staff in England. Website www.tda.gov.uk In Scotland, the *Guidelines for Initial Teacher Education* require that newly qualifying teachers 'have knowledge and understanding of children's learning and development' www.scotland.gov.uk

[2] *Professional Teaching Standards* , New South Wales Institute of Teachers, Australia. Page 5.

[3] There are those who question whether the notion of development properly applies to human minds; see, for example, John White (2002) The Child's Mind.

[4] Invented by Sir David Brewster in 1817, the kaleidoscope consists of two to four reflecting surfaces placed in a tube at the end of which are pieces of coloured glass. When the tube is turned numerous reflections are seen producing an array of brightly coloured patterns.

[5] For a recent popular review of the new science of epigenetics, see *Time* magazine, January 5th, 2010. 27-31.

[6] If there is mystery it is that ultimate mystery that occasions the deep sense of wonder in the face of the teeming complexity that comprises the natural order.

[7] For a demonstration, see http://www.youtube.com/watch?v=IBa4kgXI4Cg&feature=related

[8] The terms weak emergence and strong emergence refer to the degree of emergence in a given system not the strength of the argument for emergence. Weak or 'epistemological' emergence refers to our current inability to explain or predict a certain property by reference to its constituent parts, although it is conceded that this could change in the future. Philosophers of mind require a notion of strong or 'ontological' emergence in claiming that knowledge of higher level processes (consciousness) cannot in principle be derived from knowledge of lower level processes (neurobiology). For a recent discussion see Clayton & Davies, 2006.

[9] We resist the standard linear and dualistic *theory-into-practice model* of teacher education, based on the notion that student teachers need to learn pre-established theory before entering classrooms to practice. From the perspective of the DSA, theory and practice are dynamically interactive and emergent from the historical and contingent circumstances that apply at any given time.

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