ACCESS: CONTEMPORARY ISSUES IN EDUCATION
2011, VOL. 30, NO. 1, 11–23

Learning in a Complex World[1]

Mark Olssen

University of Surrey

ABSTRACT
Today while there exists a multitude of different approaches and research centres across the globe, complexity research is generating a quiet revolution in both the physical and social sciences. One interest in the approach is that it liberates philosophy and social science from the prison-house of a constraining scientific past based on linear determinism, reductionism and methodological individualism. Another is that it presents a view of science that supports the social sciences claims that history and culture are important. This paper will endeavour to introduce complexity as an approach to both the physical and social sciences, presenting its main common features, and having done so, outline and critically assess the implications for learning and education. It will conclude by assessing the implications of complexity perspective for a normative global ethics of education.

Introduction

Central to representing the world as a complex dynamical system is to understand it as pertaining to an interdisciplinary approach to non-linear processes of change in both nature and society. Although complexity research takes its origins from its applications in physics, chemistry and mathematics and the 'hard' sciences, undergoing its formative development in the early and mid twentieth century, during the second half of the twentieth century it has exerted an effect on the social sciences as well. Today while there exists a multitude of different approaches and research centres across the globe, complexity research is generating a quiet revolution in both the physical and social sciences. One interest in the approach is that it liberates philosophy and social science from the prison-house of a constraining scientific past based on linear determinism, reductionism and methodological individualism. Another is that it presents a view of science that supports the social sciences claims that history and culture are important. Arguably, it permits an approach in the social sciences and philosophy that heralds the rise of a 'third-way' between the stark individualism of liberal philosophy, and what many consider to be the (equally) oppressive sociologicism of 'thick' communitarianism.[2] As an offshoot of this, complexivists also claim their new approach reinstates, and possibly elevates, a previously marginalised cadre of scholars within the western intellectual tradition.[3] In this paper my purpose is to elaborate the normative possibilities of complexity theory, firstly for learning theory and education, and secondly for a futuristic global ethics which can ground the project of life in the present horizon. Before turning to these tasks it is necessary to introduce complexity theory in order to familiarise the reader with its common features.[4]

An introduction to the science of complexity

The core distinctiveness of complexity approaches can be seen most easily in relation to traditional mechanical models of science in relation to the particular ontology they presuppose. This is because those who first generated complexity perspectives did so in opposition to the standard model. In Newton's science, the world is represented deterministically as a mechanical system, with parts comprised of particles subject to the unchanging influence of universal laws, and reducible to mathematical codification. Newtonian mechanics posited closed systems where time was 'reversible' which meant it was irrelevant to the laws, which were represented as capable of moving forwards or backwards, i.e., independently of time. Because Newton's model presumed a static, atemporal view of the universe, systems were assumed to be simple, i.e., not to be affected by outside events. Laws (for example, on temperature or the movement of the planets) were held to operate given constant conditions and not subject to interference. Hence, because the axioms of such systems were reducible to physics, once ascertained, the laws constituted a basis for prediction. Causation was represented in linear terms, much as Hume described the process, which requires that a trajectory is identified where a cause can be shown to precede the effect, where 'contiguity' operates in time, where a 'necessary connection' can be established.[5]

In a range of publications, from 1980s to 2004, Ilya Prigogine has developed a complexity formulation relevant to both the physical and social sciences. In works such as *Order Out of Chaos* (1984), written with Irene Stengers, and *Exploring Complexity* (1989) written with Grégoire Nicolis, it is claimed that complexity theory offers a bold new and more accurate conception of science and the universe. They claim that complexity theory offers a more advanced formulation of science and is superseding standard traditional models including quantum mechanics and relativity which came to prominence at the beginning of the twentieth century as "corrections to classical mechanics" (Nicolis & Prigogine, 1989: 5). Newtonian mechanics and quantum theory represented time as reversible, meaning that it was irrelevant to the adequacy of laws.[6] Complexity theory builds on and intensifies the "'temporal' turn" introduced by this 'correction'. Prigogine places central importance on time as real and irreversible. With Newton, say Prigogine and Stengers (1984), the universe is represented as closed and predictable. Its fundamental laws are deterministic and reversible. Temporality is held to be irrelevant to the truth and operation of the laws. As Prigogine and Stengers (1984: 11) say, "time … is reduced to a parameter, and future and past become equivalent". This is to say that basic laws, such as the law of the conservation of energy, or concerning the orbit of the planets, operate independently of time, and therefore would have so operated, in the past or in the future. To the extent that the mechanical model presumes systems are closed and artificial, time-reversibility applies as a core dimension of the system.

Prigogine's revolution in response to the classical and quantum paradigms stated in formal terms was to challenge the *principle of ergodicity* which resulted in Poincaré recurrence. This was the principle which, in conformity with the law of the conservation of energy, submits that system interactions in physics would eventually reproduce a state or states almost identical to earlier initial states of the system at some point in the future.[7] It was based on such an approach that time reversibility had been defined as real, and time irreversibility, an illusion. Prigogine challenged the applicability of these assumptions as relevant to classical or quantum measurement. If systems are never isolated or independent from their surroundings, then in theory, even small perturbations or changes in the surroundings could influence the system functioning or trajectory. Even *very* small perturbations could cause *major* changes.[8] "The consequences of this way of thinking are profound," says Alastair Rae (2009: 113), for they replace assumptions of reversibility with irreversibility (114), introduce notions of indeterminism into physics (113), and project future states of affairs in terms of multiple "consistent histories" (122).[9] Although quantum theory had introduced notions of indeterminacy, through the interaction with measurement, for Prigogine, such an indeterminism is more centrally associated with 'strong mixing' in initial system interactions.[10] Such ideas involve a revolutionary change in the way science and the universe has been conceptualised, says Rae:

> Instead of starting from the microscopic abstraction and trying to derive laws from it that describe both the coherent evolution of quantum states and the changes associated with measurements, he suggested that we do the opposite. Why not try taking as the primary reality those processes in the physical world that are actually observed—the cat's death, the blackening photograph emulsion, the formation of a bubble in the liquid-hydrogen bubble chamber? We may then treat as 'illusion', or at least as an approximation to reality, sub-atomic processes … (136)

What non-ergodicity means in less technical terms, as Stuart Kaufmann states, is that "at the level of the evolution of the species, of human economy, of human history, and human culture … the universe is vastly non-repeating, hence vastly nonergodic" (2008: 123, cited in Blyth, 2009: 457). Such a message was popularised recently by Nassim Taleb (2007) in his book *The Black Swan* in order to underscore the centrality of uncertainty and non-predictability in both science and human affairs. Although Taleb claims that traditional predictive models can be applied when predicting variables such as human weight, or height, and thus demonstrates the continued relevance of closed mechanical models, in relation to such phenomena as economies, the immune system, or the human brain, and life itself, where a system of specific parts can generate complex outcomes, traditional models and outcomes cannot be held to apply. One of Taleb's key points, in his book, as well as various specialist articles (Taleb & Pilpel, 2004; Taleb, 2008), is that algorithms cannot be utilised as the basis for predicting the future due to contingent contextual conditions, which are ceaselessly changing and cannot be predicted in advance. Invisible causal generators comprising the system produce different outcomes at different locations in space and time. In the 2004 article with Pilpel, they point to the problem of parameter estimates of probability distributions, and the problem of unobservable generators which, as Mark Blyth (2009: 450) puts it, "might produce different outcomes in the future than they did in the past." This means, says Blyth (457), that:

> causes are inconstant; they change over time, and they are emergent. New elements combine to create causes of future events that were impossible before—not just impossible to foresee, since they did not exist in the prior period. In short, 'the new' is not necessarily an informational problem.

Although regularity operates predictably for many purposes, it is thus never assured. The whole constitutes a context which is always changing, and where new and unique actions and events constantly *emerge*. For Taleb, this means that the world of the future is not simply *unknown*, but *unknowable*, and there is no basis for predictability of events, as either visible or invisible contingent factors may derail mechanical outcomes. In more formal academic terms, a somewhat similar thesis was formulated by writers like Alan Turing and Kurt Gödel.[11] Such a thesis will, as we shall see, have major implications for education.

In introducing a systems perspective on science, Prigogine's innovation to both the classical and quantum viewpoints was to distinguish macroscopic as well as microscopic processes in explaining system behaviours. Complex systems, in contrast to the classical mechanical and quantum models, are holistic in the sense that the whole is more than the sum of its parts, and where entities emerge from the interactions between part and part, and part(s) and whole. By defining order as a product of the system as a whole, as in a complex dynamical system, aspects of the system itself may affect outcomes of particular aspects of the system. In this case, the order or pattern associated with the macroscopic property of the entire system is not a property of the constituent elements of the system, yet can affect them through a variety of linear and non-linear processes involving feedback loops, 'strong mixing' and 'downward causation'.

Prigogine introduces the concept of *bifurcation* to explain the central importance of nonpredictability and indeterminancy in science. When a system enters far-from-equilibrium conditions, its structure may be threatened, and a 'critical condition' or what Prigogine and Stengers call a 'bifurcation point' is entered. At the bifurcation point, system contingencies may operate to determine outcomes in a way not causally linked to previous linear path trajectories. The trajectory is not therefore seen as determined in *one* particular pathway. Although this is *not* to claim an absence of antecedent causes, it is to say, says Prigogine (1997: 5), that "nothing in the macroscopic equations justifies the preferences for any one solution". Or, again, from *Exploring Complexity*, "[n]othing in the description of the experimental set up permits the observer to assign beforehand the state that will be chosen; only chance will decide, through the dynamics of fluctuations" (Nicolis & Prigogine, 1989: 72). Once the system 'chooses' "[it] becomes an historical object in the sense that its subsequent evolution depends on its critical choice" (72). In this description, they say, "we have succeeded in formulating, in abstract terms, the remarkable interplay of chance and constraint" (73).

A schematic diagram of *bifurcation* appears in Figure 1, reproduced from Nicolis and Prigogine (1989: 73). Highlighting their thesis of indeterminacy, Nicolis and Prigogine make the following comment upon the model:

> A ball moves in a valley, which at a particular point **c** becomes branched and leads to either of two valleys, branches b1 and b2 separated by a hill. Although it is too early for apologies and extrapolations … it is thought provoking to imagine for a moment that instead of the ball in Figure [1] we could have a dinosaur sitting there prior to the end of the Mesozoic era, or a group of our ancestors about to settle on either the ideographic or the symbolic mode of writing (73).

Although, due to system perturbations and fluctuations, it is impossible to precisely ascertain causes in advance, retrospectively, of course, we find the 'cause' there in the events that lead up to an event, in the sense that we look backwards and point to plausible antecedent factors that contributed to its occurrence. While therefore not undetermined by prior causes, the dislocation of linear deterministic trajectories and the opening-up of alternative possible pathways that cannot be *pre-ascertained* in open environments, is what Prigogine means by 'chance'.[12]

In thermodynamics, Nicolis and Prigogine give the examples of thermal convection, the evolution of the universe itself, as well as climate and all physical processes. They were also aware that their conclusions extended to the social and human sciences, embracing life, biological organisms, and to social, economic and political processes, as an illustration of non-equilibrium developments. Indeed, all systems, they say, (1984: 9) contain "essential elements of randomness and irreversibility". Central to such a model is the ability for new and novel developments to take place within systems through the emergence of new patterns and features. The model of

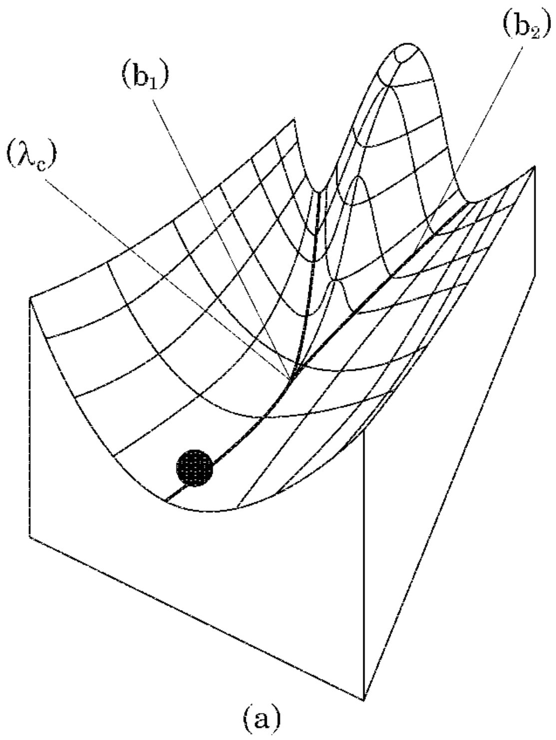

Figure 1. Mechanical illustration of the phenomenon of bifurcation (from Nicolis & Prigogine, 1989: 73)

explanation in complexity science places a greater importance on system affects and interactions, action from a distance, the unintended consequences of actions, the impossibility of predicting linear trajectories or the future, a restricted capacity of individual agents to understand system developments, and conveys new understanding of ignorance, restricted cognition, novelty, uniqueness, and creativity of action in open environments.

Two key ideas of complexity theory on which further comments can be usefully made include *self-organisation* and *emergence*. The idea of self-organisation entails that systems are not organised by anything external to themselves, in the sense of a foundation or essential principle, or anything outside the system, and it also explains how systems generate new patterns of activity through dynamic interactions over time. As such, self-organisation introduces the important distinction between mechanistic and deterministic approaches to science. Stuart Kauffman (1995) has argued that the laws of self-organisation must supplement natural selection in order to adequately explain Darwin's theory of evolution.

Complexity theorists also typically represent the world as stratified, characterised by levels of systems or sub-systems, interconnected by interactions. Within complex systems, the interconnectedness of part and whole means that interactions of various sorts will define relations at various levels. Interactions also characterise relations within the world as we live it, both at the microscopic (organisms, cellular life) and macroscopic levels. In this sense, interactions can be of qualitatively different orders and types, both linear and non-linear, and 'multi-referenential' in Edgar Morrin's (1977/1992: 47) sense. For Morin:

> Interactions (1) suppose elements, beings or material objects capable of encountering each other; (2) suppose conditions of encounter, that is to say agitation, turbulence, contrary fluxes, etc.; (3) obey determinations/constraints inherent to the nature of elements, objects or beings in encounter; (4) become in certain conditions interrelations (associations, linkages, combinations communications, etc.) that is to say give birth to phenomena of organization … (1977/1992: 47).

It is through interactions at different levels that ontological emergence[13] takes place, and it is this that defeats the possibilities of reductionism.[14] At its most basic sense, emergence describes the constitution of entities through their synthetic combination in time and space. As a consequence, as Kauffman (2008: 34) explains it, "[o]ntological emergence has to do with what constitutes a real entity in the universe: is a tiger a real entity or nothing but particles in motion, as the reductionists would claim?" Complexity theorists maintain, in opposition to classical physics, that many phenomena, including consciousness and life itself, must be considered as emergent, in the sense of being historically or cosmologically constituted as well as ontologically independent (in relation to its necessary genesis) from its physical basis.[15]

The normative consequences of complexity for learning theory

Central to the complexity perspective on learning theory is its opposition to traditional empiricist and rationalist models which assume that learning is an individual matter which is linear and non-generative. The tradition of empiricism, associated with Bacon, Locke, Berkeley and Hume challenged Aristotle for being too unconcerned with the world and with sensory experience and too concerned with reasoning according to established and fixed principles. In Hume's *associationist* psychology, simple ideas (*hard, soft, round, square*) are formed through basic sense impressions, which through associations form the basis of composite ideas. Central to all empiricist approaches, whether Hume, or Locke, or John Stuart Mill, is the priority on experience as the basis of ideas, that complex ideas can be reduced to simple ideas, that basic sensations lie at the foundation of all ideas, and that the rules of getting from simple to complex ideas and upon which predictions are made are additive. Rationalistic approaches, as sponsored by Descartes, Spinoza and Leibniz, rejected the strong emphasis on sensory experience made by empiricism, and suggested instead that our knowledge of the world came from innate ideas, which made reliable reasoning possible. The differences between these two approaches were not as great as the similarities: both were reductionist.[16] Complexity theories, while not denying a role for experience, including sensation, differ from both empiricist and rationalist approaches in that they are non- reductionist or holist. They emphasise that the system is more than the sum of its parts, and recognise system effects through 'downward causation' and non-linear feedback loops, as well as contingent assemblages of time and place, as being important.

Learning must be seen, in this sense, as a goal-directed activity, related to the evolution and survival of life. It involves a qualitatively different type of thinking, one that recognises uncertainty, unpredictability, novelty, and openness, a balance between order and disorder, and which represents discursive elements, such as concepts and words, as conventional and historical. Due to human fallibility and limitations, the type of knowledge that complex learning results in is bereft of the arrogance of the enlightenment claim to know (*aude sapere*) according to the new found faith in reason. Rather, it is more modest, humble, less self-assured, recognising 'partial knowledge', 'human error', and limited cognition. At the same time, it also encompasses processes of creativity and of possibilities of unexpected developments within situations. Complex education implies, say Trueit and Doll (2010: 138), a view of "education as a journey into the land of the unknown taken by ourselves but with others". Yet, within this paradigm, many questions are unanswerable and remain an impenetrable barrier of the human condition. Matters of determinism-free will, the existence of God, and issues of a metaphysical nature unlinked to human concerns must remain as Vico foresaw[17] beyond the limits of positive knowledge, and limits beyond which learning cannot form a bridge. Complexity's emphasis upon the nonlinearity, unpredictability and recursivity of educational processes, while not denying order, state that that the policy response to uncertainty and chance should be one of coordination through institutions. This entails managing elements within a system as well as recognising the political context in terms of which learning is situated.

How we characterise the processes of education and learning, or others forms of institutionalisation, is thus an important question. While we may discern some general implications from complexity of a non-normative character, when it comes to the question of how at the policy level one ought to respond to complexity, the question is capable of eliciting varied responses. The Amish in America demonstrate one possible response, by 'backing away' from the hurly-burly of mainstream society in an endeavour to simplify life. In recent times, some of the educational literature has focussed upon what is termed 'complexity- reduction' which potentially creates the view that the task of normative institutions in political society and education is to attempt to contain, reduce and even 'tame' the complex uncertainties of the world. The conservative politics of Burke comes to mind in such a situation. Burke endorses a conception of community as the taming of chaos, the ordering of life, and the constraint of danger. His emphasis on tradition is, as William Corlett (1989: 38) notes, an act of survival, in order to escape a "wild and dangerous politics", as a bulwark against "the terror of formlessness."

In his article 'Five theses on complexity reduction and its politics', Gert Biesta (2010, Chap. 2) utilises the concept of 'complexity reduction' which to my mind may place too much emphasis on control. Whether Biesta would agree that he intends such a description to entail normative and political senses as I recount above is perhaps problematic. For Biesta complexity reduction is inescapable. For him, as he states it in one place, it is a claim about *language use*. As he puts it: "*Learning is neither a noun nor a verb. To use the word 'learning' rather means that one makes a value judgment about change and identifies some changes as valuable. Such judgments can only be made retrospectively, which means that using the word 'learning' is itself a form of retrospective complexity reduction*" (2010: 11; emphasis in original). Earlier in the same article, however, he seems to assert a different claim as a strict thesis about the use of words, and specifies it as a claim about how *systems function*. As he states:

> Complexity reduction has to do with reducing the number of available options-for- action for 'elements' within a system. Fast food restaurants are a good example of a system with reduced complexity, as the number of available option for action—both for customers and staff—are

> significantly reduced to make a quick and smooth operation of the system possible … Education, particularly in the form of organised schooling, is another prominent example of a system operating under conditions of complexity reduction (2010: 7).

At one level then, Biesta intends complexity reduction as an elaboration of the way that words and concepts work, as well as of the way systems function. As there is an ineradicable discursive dimension to life through which the world is mediated, the consideration of the function of concepts in relation to complexity is indeed important. In addition, Biesta sees "the important question complexity … helps us to ask is how in a complex 'universe' it is possible to achieve a reduction of complexity" (7). Education processes "work […] to reduce complexity of human learning and bring [it] under control" (7). Although Biesta stresses that "the reduction of complexity is, in itself, neither good nor bad" (8), the reader is also left with the impression that the normative aim that orientates educators' approaches to their task is that complexity should ideally be reduced in *good* ways. Although Biesta may intend this as an elaboration of the way that words and concepts work, or perhaps of system imperatives, his failure to distinguish his claims from the possible normative and political senses in which education and learning operate is problematic in my view. Besides, he muddies the waters still further by speaking of a "politics of complexity reduction" (7), and states the central question as concerned with "… how complexity reduction is achieved. Particularly (but not exclusively) with regard to the social world complexity helps us ask who is reducing complexity for whom and in whose interest" (7). Further, he claims that "complexity reduction is about the exercise of power and should therefore be understood as a political act" (8).

This is all in my view highly problematic. While he may intend it as a sort of Deleuzean *mot d'ordre* there is a strong risk that it functions as an inserted metaphysic! My concern here is that as he fails to distinguish the possible uses—the conceptual, normative and political— that therefore in his analysis they risk becoming elided. We can slip quite easily, after all, from a statement about how a particular word *works,* to one about how educationalists *do* act, to another about how they *must* act, to how they *ought to* act. In addition, so long as one is pursuing 'good' complexity reduction, there is little doubt that it *is* reduction one must pursue! Yet, even with respect to the way words and concepts work or operate, I would rather say that concepts like 'learning' (or 'education') *organise* (rather than *reduce*) the complexity of the world. For Biesta, the focus on 'complexity reduction' is of concern to the extent that it *both* assumes the status of a metaphysical claim (entailing an unsupported if implicit claim about the nature of the world) and, *as a politics*, which entails a conservative political organization of education, which comes to be seen as a *protective* institution.

My own preference, here, is to speak of 'complexity management' as a more appropriate label in order to theorise how institutionalisation ought to proceed. I think of words, concepts and discourses as *organising* complexity, and of actions (which are normative and end-orientated) as *organising* or *managing* or (even) as *controlling* complexity. To speak of 'reduction' devalues diversity and difference and prejudges policy. Given that complexity introduces uncertainty, partial knowledge, and various forms of dependence and powerlessness, the necessity of collective institutional structures to enable and facilitate learning is imperative. As the welfare state liberals in the late nineteenth and early twentieth century noted, there is a 'social element' in all areas of life, in that both children and adults, groups and businesses are dependent to varying extents on others, and on the structures of social and community support. A century before the welfare state liberals, David Hume had appreciated that cooperation and institutional coordination constituted an essential basis upon which learning and development could proceed. In Part II of Book III of the *Treatise of Human Nature* (1978), Hume notes how justice is essentially a coordinative virtue in that it is concerned with the allocation of resources. Cooperation was made possible operationally through institutional coordination which constitutes for Hume the precondition of assuring the future of peace and prosperity. Coordination thus improves life. Institutions such as libraries, schools, universities, museums, the Internet, welfare agencies, and schools, are thus pivotal structures without which a learning society will be greatly diminished as a social force.

Institutionalisation is thus one central normative imperative for the management of a complex world.

Biesta (2009) is on more solid ground when he emphasises that a theory of learning should not be considered independently of a theory of education.[18] For him, questions of learning *are* questions of education. While much learning takes place outside of any formal education, necessarily, as part of being in the world, the issue of what sort of education is implied or suggested by complexity is still open to debate. Learning historically certainly entails education. In this quest for "thinking complexly" (Truett & Doll, 2010: 138), education is a central institution, as was recognised by John Dewey, who explored the role and function of education in adapting to and coping with uncertainties of the environment.

For Dewey (1958, 1997), education was conceptualised, not as a discipline-based mode of instruction in 'the basics,' but according to an inter-disciplinary, discovery-based curricula, defined according to obstacles in the existing environment. As Dewey says in *Experience and Nature*, "The world must actually be such as to generate ignorance and inquiry: doubt and hypothesis, trial and temporal conclusions …" (1958: 41). The rules of living and habits of mind represent a "quest for certainty" in an unpredictable, uncertain and dangerous world (41). For Dewey, the ability to organise experience proceeded functionally in terms of problems encountered which needed to be overcome in order to construct and navigate a future. This was the basis of his 'problem-centred' pedagogy of learning. While it could be seen to concentrate on transferable skills from a complexity perspective of coping with an environment, Dewey can be criticised for an overly functionalist concern with system adaptation, in the same way that structural-functionalist sociologists, like Talcott Parsons, or contemporary systems theorists, such as Niklas Luhmann can be. By focussing on a 'problem-centred' approach runs the risk, in other words, of neglecting the critical tasks of ideological reflexivity and criticism, which are so important to the educative tasks of myth demystification and cleansing the discursive template of history from its distorted and ideological elements.

There is little in Dewey, for instance, that suggests any parallel with Gramsci's distinction between 'good sense' and 'folklore' as the basis of a critical pedagogy. Dewey's functionalism is further reinforced through his utilisation of terms such as 'interaction' and 'growth' which run the risk of contributing to a naive enlightenment conception of 'progress,' leading inevitably to the successful resolution of both individual and societal problems and leading, onward and upward, to ever higher levels of experience. Yet, while Dewey runs a risk, like Hegel, of being identified with a progressive evolutionary theory of history and development, unlike Hegel, Dewey posited no end point, or resting place; for the end of growth was more growth; and the end of learning was further learning. In terms of learning theory, Dewey used the concept of 'continuity' in order to theorise the link between existing experience and the future based upon the "interdependence of all organic structures and processes with one another" (1958: 295). Learning for Dewey thus represented a cooperative and collaborative activity centred upon experiential, creative responses to contingent sets of relations to cope with uncertainty in a never-ending quest. It is in this sense that the processes of iteration are central for Dewey. As such, Dewey's approach conceptualises part and whole in a dynamic interaction, posits the learner as interdependent with the environment, as always in a state of becoming, giving rise to a dynamic and forward-looking notion of agency as experiential and collaborative. In such a model learning is situational in the sense of always being concerned with contingent and unique events in time.

Central to such a complexity approach, is that learning must deal with the uncertainty of contingently assembled actions and states of affairs, and by so doing transform itself from an undertaking by discrete individuals into one that is a shared and collective activity. In terms of navigating a future in relation to economics, politics, or social decisions, it places the educational emphasis upon the arts of coordination. It is through plan or pattern coordination that institutions function and that the learning experiences of future generations are embarked upon. Because in planning one must assume incomplete information due to the dispersal of knowledge across social systems, such coordination can be more or less exact or loosely stochastic and probabilistic in terms of overcoming uncertainty. Learning will be invariably situational and involve experiences that are always unique. It will involve what Aristotle called *phroneˉsis,* that is, practical judgement within a context. Such practical judgement is holistic and goal-orientated action sensitive to the exigencies of time and place. In elucidating the tasks of *phroneˉsis*, Aristotle emphasises the integrity of the speaker, their skills as a communicator, the context of the message, as well as the interests and dispositions of the audience. In Biesta's (2010) view, "complexity not only enables us to understand the complex character of the physical and social world, but provides us with a different understanding of those aspects of the physical and social world that are or appear to be not complex" (7). Because learning is time-dependent, and individuals and communities are always experiencing unique features of their worlds, uncertainty cannot be eliminated. Hence, all that is possible is skills of coping, problem-solving, and pattern coordination in open-ended systems, where planning is formed around 'typical' rather than 'actual' features. Such plan or pattern coordination can only be a constructed order. Constructing plans becomes the agenda for education both individuals and societies in Dewey's sense. Dewey ultimately held to the faith that despite unpredictability and uncertainty, the macro-societal (or macro-economic) coordination of core social problems was possible.

In addition to a new model of learning, complexity posits a model of the global citizen who has knowledge of global processes, procedures, and forces, well-developed *agentic* skills and abilities, as well as a multidimensional global identity which is both local and global. By *agentic* skills, I mean to refer to such things as the capacity to understand and access global knowledge systems; the awareness of multi-perspectival orientations to self and culture, based upon an understanding of diverse human experiences, as well as the ability to construct new ideas. Cognitively and intellectually, such an education must develop a knowledge and sensitivity to global concerns and issues; an awareness of emerging conflicts and disputes, issues and problems, as well as the capabilities for critical deconstruction and judgement in relation to historical documents, identities and systems. One way or another, the global citizen must learn the methods of coping with a global world. The curriculum implications are not simply for a 'problem-centred' approach, but one that incorporates knowledge of new technologies and systems; includes study abroad, work placements, and travel; and incorporates knowledge of world politics, the law, and international relations.

In that complexity posits human subjects that are the product of evolution—in what can be described as a consistent nominalist historical materialism—human intervention may conceivably steer or seek to influence the direction of evolution in ways that maximise survival and well-being of all for the future. The identification that we are the products of history, formed through the genealogical structures of the past, while certainly suggesting a conception of relativism, is not necessarily incompatible with an ethical or moral theory. In that human agency is one factor among many through which the course of history is shaped, 'taking stock of the present', and 'acting toward the future' becomes imperative.

Although the world is constantly changing and that uniqueness and uncertainty constitute core ontological postulates, we can still posit some educationally relevant universal postulates concerned with the ubiquity of certain types of experience that will need to be confronted, certain dispositions that will be important and certain virtues and values that students will profit from. Such dispositions and virtues that constitute the ethics of continuance might include a will to learn, to critically engage and inquire, to be receptive, to be open, and to actively negotiate the future. Virtues might include criticality, creativity, carefulness, care toward others and the environment, courage, self-discipline, equity, equality, integrity, caution, respect, flexibility and openness.

Consistent with complexity, also, Nietzsche stresses the limitations on knowledge, and the need for caution. It was fundamentally due to the complexity of the world, and the consequent uniqueness of events and actions in time, that Nietzsche rejected Kant's own deontological conception of ethics, as postulated in the universal principle of the Categorical Imperative. In Nietzsche's view, this is nothing more than a consistency maxim, and specifies no content about how to live, adapted to each situation, guided solely by the dictates as to what furthers life. In this sense, it ignores the complexity emphasis on contingency and the central emphasis on uniqueness and novelty of the process of iteration in history. Hence, in *The Gay Science* (1974: §335) Nietzsche argues against Kant's Categorical Imperative that it presupposes the constancy of time and context, and therefore neglects "that every action that has ever been done was done in an altogether unique and irretrievable way, and that this will be equally true of every future action" and further, arguing against the very basis of Kant's moral law, "that in any particular case the law of their mechanism is indemonstrable". Such a perspective also generates insight in to the types of virtues that should in the future inform ethical education. With regard to humans we are the sorts of beings who are too prone to rush to judgement and force our opinions on situations. As Nietzsche expresses it, "all [of our] evaluations are premature, and must be so; no experience of man can be complete." "[W]e are from the start illogical and therefore unfair beings, and this we can know; it is one of the greatest and most insoluble disharmonies of existence" (Nietzsche, 1986, §32). As he concludes:

> Since man no longer believes that a God is guiding the destiny of the world as a whole, or that despite all apparent twists, the path of mankind is treading somewhere glorious; men must set themselves ecumenical goals, embracing the whole earth (1986, §25).

Notes

1. This article draws significantly upon a paper with the same title published in *The Routledge International Handbook of Learning*, edited by Peter Jarvis (2011). The author would like to thank the publishers for reproducing sections of that work in this forum.
2. My own work has promoted writers like Nietzsche and Foucault as representing a 'third-way' between Kant and Hegel in philosophy (see Olssen, 2009, 2010).
3. Those recently identified as marking a possible elevation include John Stuart Mill, Alexander Bain, C.D. Broad, Samuel Alexander, Friedrich Hayek, Friedrich Nietzsche, Charles Babbage, George Herbert Mead, Charles Sanders Pierce, Martin Heidegger, Michel Foucault, Jacques Derrida and John Maynard Keynes, to name but some.
4. Although numerous accounts of complexity theory and Prigogine's relevance for Education already exist, ranging from the writings of William E. Doll (1986, 1989, 1993) to the many amongst the contributors to Deborah Osberg and Gert Biesta (2010) *Complexity Theory and the Politics of Education*, it is important to reconstruct an account here that specifically accommodates the purposes of this essay, as well as in order to provide the reader with an internally complete account.
5. Always providing that Humean scepticism can be offset by the specification of the appropriate operational force – which enlightenment science was quick to do!
6. If a film can represent motion running backwards in the same way as running forwards, then it is said in physics that time is reversible. The rotation of the hands of a clock is reversible, whereas tearing a piece of paper is irreversible. Prigogine does not deny that time reversibility has relevance but wishes to add that in many areas including life itself time is irreversible.
7. The amount of time taken for repeatability is known as 'Poincare cycle time'
8. This is the phenomenon of 'strong mixing.' (See footnote 10 for a definition).
9. The main idea of the 'consistent histories' approach in Prigoginian physics is that new knowledge must connect with already consistent histories of possibilities to be taken as valid. It therefore is not just the results of 'measurements' as it was for the quantum theorists. Rae (p. 123) says that it thus "has the advantage of being more general as well as more objective." "The consistent-histories approach claims that we have reached the point where a purely mathematical map is unable to give a unique description of the physical universe. It can, however, provide a map book containing all possible histories and their probabilities. Perhaps this is the best we can expect to achieve" (p. 127).

Prigogine, says Rae (p. 126), is also more materialist in that he is not simply concerned with how the world can be observed, but how it can be.

10. 'Strong mixing' refers to the effect of influences or instabilities on a system, which is frequently chaotic, small and arbitrary.
11. In 1931, Kurt Gödel, a twenty-five year old mathematician, presented his 'incompleteness' theorem which demonstrated the mathematical inability to predict future events. Alan Turing's basic claim was that decisions regarding methodology in mathematics were always in excess of the programme or algorithm that generated them, and hence could not be determined axiomatically from such an algorithm. Turing also reiterated a point made by Heisenberg that "when we are dealing with atoms and electrons we are quite unable to know the exact state of them; our instruments being made of atoms and electrons themselves" (Turing, cited in Hodges, 2000: 497). This means that there are limitations to what it is possible to compute and to know (see Mitchell, 2009: 60-70; Hodges, 2000: 493-545).
12. At times Prigogine appears to suggest that the limitation is fundamentally epistemological, and concerned with measurement, as it was for Heisenberg. But, at other times, he notes that as fluctuations and perturbations occur in open environments are theoretically without limit in terms of their reinvestment within a system, the indeterminism is also ontological, not in the sense of there being no antecedent conditions, but in terms of there being alternative options available which can be determined by contingent variables.
13. Kauffman (2008: 34) also refers to "epistemological emergence," which he defines as "an inability to deduce or infer the emergent higher-level phenomenon from underlying physics."
14. In physics, the reductionist programme maintained that all social, biological, chemical and physical reality could be explained by physics, ultimately reducing to particles and laws.
15. Kauffman (2008, Chap. 3-5) cites a "quiet rebellion" within existing physics, and science more generally, as to adherence to reductionism. He notes various Nobel Laureates, such as Philip W. Anderson (1972), Robert Laughlan (2005), and Leonard Susskind (2006) who all argue for versions of emergentism and against reduction to physical laws in order to explain life processes, biology, or forms of social organisation. Anderson's research concerned "symmetry-breaking" which he concluded was emergent as "the fundamental laws of physics [cannot] tell us which way the symmetry will be broken" (Kauffman, p. 20). Laughlan argues that "temperature arises as a 'collective emergent' property of a gas system, a property that is not present in any of its constituent particles but only in the whole. The defining character of such emergent properties is that their measurement becomes more precise as particle number increases. … For example, rigidity is not a property of a single iron atom but is a collective property of an iron bar" (Kauffman, p. 24-25). Susskind shows that new developments in string theory are also anti-reductionist (Kauffman, p. 29). Kauffman stresses that to argue for emergence does not invalidate physical laws, but simply asserts they cannot be seen as a sufficient basis for 'higher' characteristics or forms (p. 24).
16. Descartes (1960) reductionism can be seen evident in *A Discourse on Method* (pp. 15 - 16) where he describes his method as being: "to conduct my thoughts in such order that, by commencing with objects the simplest and easiest to know, I might ascend by little and little, and, as it were, step by step, to the knowledge of the more complex … ." Similarly, as Fritjof Capra (1983: 55) says, "Locke developed an atomistic view of society, describing it in terms of its basic building black, the human being."
17. In his writing *On the Study Methods of Our Time*, in the context of attacking design arguments for the universe, Giovanni Vico (1965) distinguishes between the world as it is *in-itself* and the world as it *appears to us*. Knowledge of the real could only be had of artefacts and models we have made. Only God can know everything else. Vico influenced Kant (2005) who expounds a similar thesis in his *Critique of Judgment*. Many metaphysical issues, such as concerning free will and determinism, the nature of the universe, etc., are beyond the limits of what can be known. Such a view represents a cautious challenge to the arrogance of the Enlightenment.
18. He makes a similar point in his 2004 article, where he notes that "something has been lost in the shift from a language of education to a language of learning" (See Biesta, 2004: 71).

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