2010

Living Systems, Complexity & Information Systems Science

Shirlee-ann Knight
Edith Cowan University, s.knight@ecu.edu.au

Georgia K.B. Halkett
Curtin University, g.halkett@curtin.edu.au

Recommended Citation

Knight, Shirlee-ann and Halkett, Georgia K.B., "Living Systems, Complexity & Information Systems Science" (2010). *ACIS 2010 Proceedings*. 33.
http://aisel.aisnet.org/acis2010/33

Living Systems, Complexity & Information Systems Science

Shirlee-ann Knight
Faculty of Computing, Health & Science
Edith Cowan University
email: s.knight@ecu.edu.au

Georgia K. B. Halkett
WA Centre for Cancer and Palliative Care, Curtin Health Innovation Research Institute
Curtin University
email: g.halkett@curtin.edu.au

Abstract

The paper examines some of the significant new developments in the epistemological framing of systems theory, and their application within the information and management sciences. Specifically, the article argues that Information Systems (IS) – at its heart a systems-science – requires an ongoing discourse into how the metaphors of 'living systems', 'complex systems', and 'complexity' apply to the theoretical foundations of the IS discipline at large.

Pragmatically, the implications of developing a complex and living systems framework to investigate IS phenomena has the capacity to synthesise the very way information systems researchers consider their discipline, and the scientific inquiry of it. The "information system" becomes a decentralised, complex and evolving entity, where notions of chaos theory; system self-organisation; autopoietic and dissipative networks; emergence; entropy; and nonlinear dynamics; provide a rich and novel way to investigate system behaviours, human cognitive behaviours, and the management and business contexts in which those behaviours occur.

Keywords

Complex Systems; Complex Adaptive Systems; Living Systems Theory; Complexity; Research Philosophy; Epistemology; Methodology.

INTRODUCTION

Systems theory (von Bertalanffy, 1950) emerged in the middle of the 20th Century. Although divergent in discipline application, the core idea of systems theory was the importance placed on the contextual relationships between the entities in any given system (Hammond, 2003). The concept of the interconnectedness of system entities was quickly embraced by emergent fields such as software engineering; and management sciences; and became the driving paradigm underpinning the design of most modern software and information systems (Jackson, 2000).

A recently identified issue; however, is that where the Social Sciences have continued to push and mould systems-driven theories, developing new complex areas of discourse, such as systemics (François, 1999); systems psychology (Olds, 1992); cognitive and family systems theories (Cooper, 2004); and novel applications of Living Systems Theory (LST) (Bailey, 1994; 2001; 2005); the Information and Management Science driven disciplines have lagged behind, for the most part still utilising the original models employed to develop the first computer languages, business, systems and management models (Knight, 2008).

FITTING SQUARES INTO ROUND HOLES

Systems Theory: Exploring New Paradigms

The purpose of this paper is to examine some of the significant new developments in the epistemological framing of systems theory (Ossimitz, 1997; Olsson, 2004) since the 1990s, with the goal of understanding what application they might have to the current state of IS research. In so doing, new paradigms can be examined, particularly in relation to how emerging models and theory might apply to a richer understanding of "systems" – be they information or business systems; and human socio-cognitive interaction with those systems. The application, and implications, of such insights should not be understated. At the very heart of IS as a discipline, is the concept of a "*system*". Hence, the IS discipline, which examines the dynamic space between the human and ICT components of the information system, should be leading systems theory research from the forefront.

Complex Systems Theory

In simple terms, a system is a collection of organised parts. The parts, or entities, of a system can be; (1) objects – like the *planets* of a solar system; (2) concepts – *units* in a measurement system; (3) functions – *market forces* in an economic system; (4) controlling mechanisms – *beliefs* in a religious system; or (5) processes – like *feedback mechanisms* in a homeostatic system. Importantly, systems are seen to operate at multiple levels of "connectedness", in that the parts of a system are not just the pieces of the whole, but they are the way those pieces synergistically relate to each other as well.

Systems theory, and more recently, complex systems theory is the theoretical study of the dynamic relationships between the parts that make up a system. What separates the two modes of thinking is that where systems theory, or more accurately General Systems Theory (von Bertalanffy, 1955; Boulding, 1956), attempted to build a *mechanistic* framework for conceptualising the commonalities of phenomena in various systems, complex systems theory is also concerned with what Loosemore (2007) calls the "Global-Local Disconnect" (GLD) phenomenon of complex systems.

The GLD of a complex system is the gap in scientific understanding between the characteristics observed in a system at a "local" point of relationship, and the unseen – but to this point *assumed* – relationship to the global, or whole system. In other words, complex systems theory, while still governed by many of the same principles as the original systems theories (in that systems are described as a network of interactive component parts) postulates that there are parts of the system that may not be scientifically known (Loosemore, 2007). Moreover, there are parts of the system that may never be scientifically known. Given that one of the most fundamental assumptions of the scientific understanding of systems behaviour is that the global behaviour of each system is related in a lawful, comprehensible way to the local (observable) mechanisms of the system (von Bertalanffy, 1955), this shift in paradigm (Kuhn, 1968), represented a complete turnaround in systems science thinking.

The implications of the new systems theory, if its conjecture of the GLD in complex systems is true, is that many of the scientific assumptions made previously regarding how systems work, are not necessarily correct. Loosemore calls this the "*Complex Systems Problem*" (2007, p159).

The Complex Systems Problem

> "*The Complex Systems Problem is the single biggest reason why a human-level artificial intelligence has not been built in the last fifty years*"
>
> (Loosemore, 2007; p160)

Loosemore's assertion relates to the building of human-like characteristics into an 'artificially', or manufactured, technology-driven system. And the problem, as Loosemore describes it, lies in systems designers' flawed assumptions regarding how their created system will behave.

Figure 1 illustrates Loosemore's contention of the GLD between the scientifically observable objects and events of a system (local), and the scientifically unobservable objects and events of a system. Scientifically speaking, inferences are made of those phenomena not observed or understood, according to what *is* known about similar, local, phenomena.

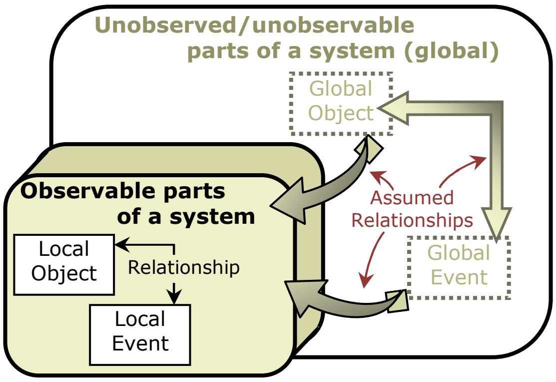

Figure 1: A principle assumption of Scientific Research, for the induction/deduction of knowledge and/or theory

The questions being addressed by Loosemore (2007) are no different to the scientific questions which have pushed and moulded scientific investigation since the birth of "modern science" during the 17th Century. That is; how can the scientist induce, or deduce, meaning about what *is not* known from what *is* known?

The "Static" Predictable System versus an Unpredictable System

Historically, the IS discipline has enjoyed a largely positivist-driven epistemology (Orlikowski & Baroudi, 1991; Chen & Hirschheim, 2004), so the assumption of a static, 'natural order' in the *systems* concept has philosophically not proved to be widely problematic within the field's research. The growing body of inductive, interpretivist-driven studies (Walsham, 1995; Chen & Hirschheim, 2004) over the last ten to fifteen years; however, has facilitated an epistemological shift within IS, resulting in the relatively wide acceptance of qualitative and mixed-method investigations. This same shift has occurred within many of the so-called 'softer' sciences (Donmoyer, 2006; Seymour, 2006; Contractor, 1999). It is somewhat puzzling then, that IS as a discipline, appears to have largely held a steadfast grip to the concept of the static, and therefore *predictable system*, which could be considered as somewhat of a paradox, in the context of the interpretivist researcher, who is said to hold to a non-predictable world-view.

The Epistemological Framing of Complex Systems

The incongruity of an interpretivist world-view within the context of a discipline-wide belief in the static, predictable system, is yet to be fully addressed in IS methodology or theory literature. Notwithstanding this point, the paradox has facilitated a growing acceptance of the *Critical Realistic* school of thought. Critical realism embraces a pluralistic world-view (Landry & Banville, 1992; Collier, 1994), where systems can be both predictable and unpredictable. The dissonance encountered by IS researchers using interpretivist methods in their research is able to be addressed in Critical Realism by the acceptance that reality itself is not just a social construct (as an interpretivist would believe) since it is able to pre-exist the social analysis of itself (Dobson, 2002). For the critical realist, only the knowledge of reality is subjective. Reality itself remains relatively objective and unchanging. This belief – that there exists a natural uniformity to 'reality' outside of the researcher's interpretation of it – allows the critical researcher to better address what Hume calls "*the problem with induction*" (*cited in* Rosenberg, 1993) by assuming a degree of scientific predictability in the phenomena being investigated. In relation to the "predictable system" then, common ground can be found between the interpretivist assumption that the system is not predictable and the positivist assumption that it is.

Significantly, it is the assumed predictability of systems – and the relationships between the entities existent within them – which has driven modern scientific inquiry. Based on the scientific assumption that "*the future will be like the past*" (Wood, 2000), it forms the basic philosophical assumptions of deductive research. In fact, reductionist, empirical scientific inquiry such as hypothesis formation and testing, which behoves the researcher to design methodology which will limit investigative variables, can only take place within such an epistemology. That is, a belief schema based on the paradigm of the "predictable system".

The possible limitations of this positivist world view has become increasingly apparent to numerous authors (Hjørland, 1998; Wallace, 1998; Pather & Remenyi, 2004) when it is applied to those systems which demonstrate themselves to have the capacity to evolve and change (Matthews, White & Long, 1999). These "complex *adaptive* systems", the concept of which has now been embraced by a diverse range of scientific disciplines, from the biological to the social sciences, are the context of a type of explorative scientific inquiry which (1) recognises the existent GLD of complex systems; and (2) requires a broader epistemological framing (Ossimitz, 1997; Olsson, 2004) of systems theory.

The Living System

Living Systems Theory (LST), developed by Miller (1978), is a theoretical framework designed to investigate the ecology of complex systems. A living system is conceptualised as such for the reason that, amongst other characteristics, it is able to maintain its *living* state through being open and self-organising in the context of stochastic, unplanned, events (Matthews *et al.*, 1999). More detailed descriptions of LST, and the eight system levels said to make up a living system can be found in Miller & Miller (1995) and Parent (1996). Miller & Miller (1995) also provide an extensive list of contextual applications of the theory.

The Information System as a Living System

As a living system, an information system would inherit the properties of all living systems, particularly those which enable them to be considered complex adaptive systems, with the ability to self-organise in the context of unplanned interactions. Significant to research within the IS discipline, is that the metaphoric constructs of a classified living system – called 'sub-systems' (Miller, 1978; Miller & Miller, 1992; 1995) potentially provide robust and novel frameworks by which to investigate a system's structure, processes, and their relational connections (Bailey, 1994). Associated information system characteristics such as *information input*, *user adoption* and *application*, *feedback patterns*, *system stress*, and the like, can be investigated using an evolving paradigm which could finally reveal something of the complex human and social components of information systems interaction.

EVOLVING THE INFORMATION SYSTEMS PARADIGM

The need to evolve the 'systems' paradigm in the information and management science disciplines has become particularly evident in the more 'human-centred' areas of study, since not only is this a typical *context* of complex or adaptive system behaviours, it is also the nexus where cross-pollination of scientific discipline thinking has so often taken place in the past. For example, the adoption of social science driven models such as the *Theory of Reasoned Action* (TRA) (Fishbein & Ajzen, 1975) and *Theory of Planned Behaviour* (TPB) (Ajzen, 1991) provided the backbone for the widely researched *Technology Acceptance Model* (TAM) (Davis, 1986 & 1989).

The adoption of social science models into the information systems realm, while helpful in broadening the mode of inquiry to include human/social components of the system, has ultimately proved to be limiting in recent years because of the *linear*, predictive systems, approach adopted by IS research in general. Human behaviour is, in fact, extremely complex, the understanding of which may require a more diverse set of applied theories and methodological approaches than is currently typically manifest in information systems and research (Choudrie & Dwivedi, 2005; Bagozzi, 2007).

An Example of the Problem: *Linear IS Models*

The linear application of adopted social science models is particularly apparent in the user-ICT adoption models developed within IS over the last two decades. Interestingly there typically exists a lack of "feedback" loops within many IS models and frameworks used to investigate user ICT adoption (Knight, ND). Proposed as part of Knight's (ND & 2008b) findings regarding the widely accepted Technology Acceptance Model (TAM) (Davis, 1986 & 1989) was the inclusion of an interactive, evolving construct, *Perception of Interaction* (PoI); and a feedback loop allowing for users' general perceptions of a technology to evolve and change, as a direct result of their interaction with that technology. Individual and relationally complex components of human behaviour – such as degrees of cognitive dissonance; habitual interactions; and evolving levels of self-efficacy or self-confidence become part of a cyclical, adaptive TAM.

Feedback loops are a central paradigm of many systems-driven theories, from biology (Jacob & Monod, 1964) to economics (Alderson, 1965). Their lack of inclusion in the major IS-driven models, such as the TAM, may be indicative of both the adoption of linear methodological approaches within IS, as well as of the choice to adopt particularly linear social cognitive models. The social science models previously cited – i.e., TRA (Fishbein & Ajzen, 1975) and TPB (Ajzen, 1991) both postulate a direct linear relationship between users' behavioural intention (BI) and actual behaviour (B). This same postulate is then appropriated by the TAM to statistically analyse the relationship between users' perceptions of *Perceived Usefulness* (PU) and *Perceived Ease of Use* (PEoU), to predict users' technology acceptance and future interactions. Literally thousands of research papers later, the model is still reinforcing that "*usefulness is useful*" (Benbasat & Barki, 2007), and the direct causal relationship between users' intention to behave a certain way and their actual behaviour remains one of the most "*uncritically accepted assumptions in social science research in general, and IS research in particular*" (Bagozzi, 2007). A fundamental problem with the TAM then, is that in the context of IS research, the theory which drives the model now needs to evolve and change in line with new systemic thinking (Bunge, 1979a & 1979b; Mugur-Schächter & Van der Merwe, 2002).

A Complexity Discourse

A few attempts to kick-start an IS driven academic discourse around complexity and associated topics have taken place, including special issues of the ACM's *Communications of the ACM* in 2005 (Desai, 2005) Emerald's *Information Technology & People* in 2006 (Jacucci, Hanseth & Lyytinen, 2006), and Palgrave's *Journal of Information Technology* also in 2006 (Merali & McKelvey, 2006). These ground-breaking groups of papers remain, sadly, under-cited – with the nineteen papers published in these three special issues averaging less than four citations per paper annually (Google Scholar, 2010). New areas of research, such as *Digital Ecosystems* (Fiorina, 2006), are attempting to address some of the applications of complexity and complex adaptive systems to the building of better information systems, but it is still early days in this evolving discourse, which tends to concentrate on the "harder" areas of systems science, such as artificial intelligence (AI) and algorithm development.

In short, the application of systemics, complexity, complex adaptive systems, and living systems theories, are yet to be fully discussed in relation to the human and management aspects of IS research, including their applicability to frame investigations into common topics such as *Information Management* (IM); *Human Computer Interaction* (HCI); *Business Systems Design*; *ICT Adoption*; and so on; which collectively represent the types of topics central to the IS discipline's impact on industry practice.

The Challenges involved in Developing a Complexity Discourse

The authors see three major challenges which need to be addressed before the IS field can engage a mature discourse around complexity and its application to our discipline. The first, relates to developing a better understanding of the basic constructs of complexity, particularly in relation to how differently those constructs frame typical IS research topics. The second challenge relates to how complexity theory fundamentally questions the fabric of predictable, reductionist science. And finally, the third challenge concerns a growing need for a degree of *unification* (Bridgeforth, 2005) between the various sub-constructs and concepts at hand in order to address what Goldstein (1994) and Contractor (1999) refer to as an increasing "*confusion in the metaphor*" of complex systems theory.

Challenge One: *Constructs of Complexity & their Implications to IS Phenomena*

Adaption & Emergence:

A central idea of the 'complex system' is that of *adaptive change*, the understanding of which involves the investigation of evolving, adapting and emergent behaviours and characteristics of a system (Gustavsson & Fredriksson, 2003). *Emergence* is the appearance of novel characteristics as system components interact with each other. Laszlo & Krippner (1998) describe this in terms of the *whole being greater than the sum of its parts*. The example Laszlo & Krippner (1998) use to illustrate their point is that of the human brain, made up of around ten thousand million individual neurons, with some hundred billion connections between them. The emergent properties of this dense system of neurons interacting together includes complex characteristics such as cognition, emotion, motion, and sensation. Significantly, Laszlo & Krippner conclude their illustration with a reminder that "*none of these characteristics and functions can be found in individual neurons*" (1998; p11). By articulating this point, the authors call into question the suitability of using the reductionist method of isolating sub-component parts of a system – in order to scientifically investigate them, since it is their *interconnectedness* that results in their emergent behaviours.

It is this apparent epistemological dispute with our scientific pre-disposition to isolate and conceptualise phenomena in terms of a mechanistic, cause/effect, predictable system; which places Complexity Theory squarely at the forefront of a *Kuhnian* paradigmatic shift (Merali, 2006), where required shifts in thinking are much more than methodological (De Green, 1996), but constitute an overhaul of the very assumptions made about how science and systems work.

The implications of developing a complex and living systems framework with which to investigate IS phenomena is therefore profound. Ultimately, it has the capacity to synthesise the very way information science researchers consider their discipline, and the scientific inquiry of it. The "*information system*" becomes a decentralised, non-linear, dynamic and adaptive entity; where notions of chaos theory (Lorenz, 1963; Francois, 1997); system self-organisation (Collinge, 1999); autopoietic and dissipative networks (Maturana, 2002); emergence (Minati *et al.*, 2001); entropy (Prigogine & Stengers, 1984) and nonlinear dynamics (Harter, 2003; Kozma & Tunstel, 2005) provide a unique and novel way to investigate the complex world of the information system

Redundancy:

The concept of "Redundancy" in the context of systems-science provides an example of how complex-systems thinking is able to impact on epistemological framing of an IS Research project – and how this can eventually lead to a Kuhnian type paradigm shift.

Redundancy in the Business and Management Sciences has had a long history of being viewed as inefficient and wasteful (Landau, 1969). The non-use of pathways within an information system in particular, and worse still any duplication of business process in the system is seen as a characteristic marked for removal. Significantly, in complex-systems thinking, redundancy is now being considered and theorised as an essential component of a living, adaptive system's capacity to cope with stochastic events. In the field of neurology, the plasticity of the brain is becoming increasingly apparent, as previously redundant, in-active, neurological pathways become engaged into action after a predominant neurological pathway is damaged from a brain injury (Stiles, 2000). In genetics, far from being a passive characteristic, recent research paints *redundancy* as an integral part of the ready-to-be-used arsenal of genetic material (Moss, 2006; Kafri, Springer & Pilpel, 2009). In fact it appears now that large amounts of genetic material sits dormant – as if dormant were the '*default*' position for much living matter. DNA waits for specific chemical reactions to switch it "on" so it can become a tail, or a pair of legs.

Why nature should keep so many of its redundancies is still a matter of conjecture, and represents an exciting area of biological and natural science research. It's application to the complexity scientific discourse within IS also promises to be profound, as previous models of business and systems which advocated the removal of system redundancy and duplication begin to demonstrate they may result in less resilient information and business systems.

Challenge Two: ***Broader Methodologies for Investigating the Complex System***

> "*if the new theories function just as new tools (like a new form of regression analysis), then the social sciences may find that the exciting and challenging aspects of social reality have been usurped... and that traditional economics, sociology, political science, and so on, have become increasingly irrelevant.*"
>
> (De Green, 1996; p292)

An important point to remember in understanding scientific investigation as a process, is that it is, itself, *constructed*, regardless of epistemological or methodological approach. The scientific understanding of specific systems and any of their interconnected characteristics, are abstracted concepts, imposed on the object(s) being observed. It is the conceptualisation then, of phenomena – at both a systems and system-component level – which lies at the heart of communicating scientific investigation. For the systems-scientist, the interconnected relationships between the component parts of a system, as well as the objects themselves, form the scientific constructions of systems investigation. This mode of inquiry – the understanding of the complex relationships between component parts of a system – requires the researcher consider a broader set of methodological approaches (De Greene, 1996; Mathews *et al.*, 1999; Priami, 2005) than is currently the overriding norm in IS research.

SOME IMPLICATIONS OF A COMPLEX SYSTEMS THEORY FOR IS

> "*From a very early age, we are taught to break apart problems, to fragment the world. This apparently makes complex tasks and subjects more manageable, but we pay a hidden, enormous price... we lose our intrinsic sense of connection to a larger whole.*"
>
> (Senge, 2006)

Outcome: Trans-disciplinary Approach to Scientific Practice

A systemics approach is – by its very nature – interdisciplinary. In fact, Capra's (1982) *theory of living systems* combines fields as diverse as thermodynamics/physics, bioscience, and cognitive science (Gunaratne, 2007). The use of complex systems theory then, engenders a researcher to engage multi-dimensional approaches in their research. This represents a significant shift in the practice of scientific investigation, given that scientists – in the interests of limiting variables; decreasing ambiguity (Seymour, 2006); and by default, increasing validity and generalisability; – typically study small, isolated parts of phenomena.

This forced interdisciplinary approach (Contractor, 1999) has the potential to provide what Laszlo & Krippner (1998) call a "*trans-disciplinary* framework" for simultaneous critical and normative exploration of scientific perceptions and conceptions of phenomena, and the evolving relationship between the two. This amounts to what could be described as an ongoing dialogue between the researcher and the researched, where the opportunity to discover something truly new is increased exponentially.

Authors like Contractor (1999) contend that this is where systemic approaches to investigating complex problems have the potential to bring together heterogeneous cohorts of scholars, who collectively have the manifold skills required. Certainly, the bringing together of researchers from multiple disciplines has historically proved to be an effective strategy in any dynamic research centre. The multi-researcher/multi-disciplinary strategy, in the context of a systemic approach however, is not only considered to be an absolute necessity, it also has the potential to become a serendipitous representation of a complex, dynamic, and living system (of knowledge) in its own right.

Challenge Three: ***Consistency in the language***

A natural outcome of bringing researchers from diverse disciplinary backgrounds into the same investigative space, is that there will inevitably be an increase in the variables of scientific language and understanding. Goldstein (1994) and Contractor (1999) both refer to this problem in terms of an increased "*confusion in the metaphor*" of complex systems. Johnson & Burton (1994) have been highly critical of complexity theory for this very reason, stating that the various discipline-specific discourses into complexity and complex systems theory can appear to be contradictory, making the metaphorical use of *complexity* in systems empirically problematic.

Bridgeforth (2005) contends that complex systems theory requires "unification", in much the same way that the physical sciences are attempting to unify Einstein's *Relativity* theory and *Quantum Physics* theories through concepts such as "String Theory" (Greene, 1999). Although a unified complex systems theory might well serve to address the considerable variations in discipline-specific terminology used to describe similar phenomena (Goldstein, 1995), it may yet do little to address discipline-driven differences in definitions of basic scientific constructs. A biologist's definition of the scientific term "structure", for example, is significantly different to that of a sociologist's (Gunaratne, 2007).

In the defence of complex systems theory, and complexity theory in general; however, it should be noted that the various scientific discourses pertaining to the topic are relatively new. It is important to remember that the physical sciences remained divided over a 'natural forces' unifying theory (the leading candidate now being *String Theory*) for almost the entire 20th Century. Not-withstanding this point, it could be suggested that there is a degree of irony in any attempt to "unify" a theory which holds to a philosophical world-view that to try and do so, is to attempt to unify that which might just be un-unifiable.

CONCLUSION

> "*The true value of the* (complex system theory) *approaches may lie more in a revision of our way of thinking about social science processes and how the study of those processes should be approached.*"
>
> (Mathews *et al.*, 1999)

The goal of this article was to examine some of the central themes within complex and living systems theories to raise the level of discourse associated with their applicability to paradigmatic IS theory. The implication that the complexity sciences challenge many of the fundamental principles upon which traditional scientific inquiry is founded (Kiel & Elliott, 1996) is paramount to the arguments presented herein. Which shape the contention that observed phenomena in science, and specifically the complex relational phenomena examined in the information sciences, invariably require the use of multi-disciplinary (Laszlo & Krippner, 1998), multi-method (Landry & Banville, 1992), approaches.

In the context of the IS discipline, the paper questioned the tenant assumption of the "stable" or "predictable" system, a paradigm central to the reductionist, positivist, school of thought which has driven scientific inquiry for the last four hundred, or so, years. In a time in human history, when science is being asked to solve some of the most complex problems ever faced, the social sciences in particular, are leading the way in a discourse which pushes scientific inquiry past what Contractor (1999) describes as "*typical hypotheses testing... in the 'deliberation of the obvious'*". (p164).

The same challenge presents itself to the information sciences, which typically examine multiple phenomena, in diverse and complex problem settings. Amongst other things, the development of a complex and living systems framework with which to investigate IS driven phenomena, involves the opening of a robust discourse, in which the discipline has the opportunity to become truly innovative and at the forefront of *explorative* systems thinking. Central to this paper then, is the implication that without this discourse, IS may stagnate in the detail, and (alas) the relative monotony, of the deductive analysis of that which is already known.

REFERENCES

Ajzen, I. (1991). The theory of planned behaviour. *Organizational Behaviour and Human Decision Processes, 50*, 179-211.

Alderson, W. (1965). Dynamic marketing behaviour: a functionalist theory of marketing: RD Irwin.

Bagozzi, R. P. (2007). The Legacy of the Technology Acceptance Model and a Proposal for a Paradigm Shift. *Journal of the Association for Information Systems, 8*(4), 244-254.

Bailey, K. (1994). Sociology and the New Systems Theory. *State University of New York Press, Albany.*

Bailey, K. (2001). Towards Unifying Science: Applying Concepts Across Disciplinary Boundaries, *Systems Research & Behavioural Science 18*(1): 41-62.

Bailey, K. (2005). Beyond System Internals: Expanding the Scope of Living Systems Theory, *Systems Research and Behavioural Science 22*(6): 497-508.

Benbasat, I., & Barki, H. (2007). Quo vadis, TAM? *Journal of the Association of Information Systems, 8*(4), 211-218.

Boulding, K. (1956). General Systems Theory: The Skeleton of Science. *Management Science, 2*(3), 197-208.

Bridgeforth, B. W. (2005). Toward a general theory of social systems. *International Journal of Sociology and Social Policy, 25*(10/11), 54.

Bunge, M. (1979a). A world of systems. *Dordrecht ; Boston, Reidel.*

Bunge, M. (1979b). Treatise on Basic Philosophy. Ontology II: A World of Systems (Vol. 4): *Reidel Publishing Co., Inc., New York*, NY.

Capra, F. (1982). *The Turning Point*. Simon & Schuster: New York.

Chen, W., & Hirschheim, R. (2004). A Paradigmatic and Methodological Examination of IS Research from 1991-2001. *Information Systems Journal, 14*(3), 197-235.

Choudrie, J., & Dwivedi, Y. K. (2005). Investigating the Research Approaches for Examining Technology Adoption Issues. *Journal of Research Practice, 1*(1), Article D1.

Collier, A. (1994). Critical realism: an introduction to the philosophy of Roy Bhaskar. *London: Verso.*

Collinge, C. (1999). Self-organisation of society by scale: a spatial reworking of regulation theory. *Environment and Planning D, 17*(5), 557-574.

Contractor, N. S. (1999). Self-Organizing Systems Research in the Social Sciences: Reconciling the Metaphors and the Models. *Management Communication Quarterly, 13*, 154-166.

Cooper, S. E. (2004). The Ties That Bind: Questioning Family Dynamics and Family Discourse. *University Press of America*, 13.

Davis, F.D. (1986) A Technology Acceptance Model for Empirically Testing New End-user Information Systems: Theory and Results, MIT Sloan School of Management, Cambridge, MA, 1986. (doctoral dissertation)

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*(3), p319.

De Greene, K. B. (1996). Field-theoretic framework for the interpretation of the evolution, instability, structural change and management of complex systems. *In Kiel, L. D., & Elliott, E. (eds.), Chaos theory in the social sciences., Ann Arbor: The University of Michigan Press*, 273-294.

Desai, A. (2005). Adaptive complex enterprises. *Communications of the ACM, 48*(5), 32 - 35

Dobson, P. J. (2002). Critical Realism and information systems research: why bother with philosophy? *Information Research, 7*(2), http://informationr.net/ir/7-2/paper124.html.

Dodig-Crnkovic, G. (2003). Shifting the paradigm of philosophy of science: philosophy of information and a new renaissance. *Minds and Machines, 13*(4), 521-536.

Donmoyer, R. (2006). Take my paradigm… please! The legacy of Kuhn's construct in educational research. *International journal of qualitative studies in education, 19*(1), 11-34.

Eymann, T., Padovan, B., & Schoder, D. (2000). The Catallaxy as a new Paradigm for the Design of Information Systems. *Proceedings of The World Computer Congress 2000 of the International Federation for Information Processing.*

Fiorina, C. (2006). The digital ecosystem. *Hewlett Packard.*

Fishbein, M., & Ajzen, I. (1975). Belief, Attitude, Intention and Behavior: An Introduction to Theory and Research. *Addison-Wesley, Reading, MA.*

François, C. (1997). A Systemic View of Systemic-Cybernetic Language. *CYBERNETICA*, 255-260.

François, C. (1999). Systemics and Cybernetics in a Historical Perspective. *Systems Research and Behavioural Science, 16*(3), 203-219.

Goldstein, J. (1994). The unshackled organisation: Facing the challenge of unpredictability through spontaneous reorganisation. *Portland, OR: Productivity Press.*

Goldstein, J. (1995). *The Tower of Babel in nonlinear dynamics: Toward the clarification of terms.* In R. Robertson & A. Combs (Eds.), Chaos theory in psychology and the life sciences, Mahwah, NJ: Lawrence Erlbaum, 39-48.

Google Scholar (2010). Citation Statistics from Query Results for 19 journal papers (Title searches) July 19, 2010.

Greene, B. (1999). The Elegant Universe : Superstrings, Hidden Dimensions, and the Quest for the Ultimate Theory. *New York; London: W. W. Norton & Company.*

Gunaratne, S. (2007). Systems approaches and communication research. The age of entropy. *Communications, 32*(1), 79-96.

Gustavsson, R., & Fredriksson, M. (2003). Sustainable Information Ecosystems. *Lecture Notes in Computer Science, 2603*, 123-138.

Hammond, D. (2003). The Science of Synthesis: Exploring the Social Implications of General Systems Theory, *Colorado: University Press of Colorado.*

Harter, D. (2003). Biological Limbic Systems: A Bottom-Up Model for Deliberative Action. in 8th international conference on the simulation of adaptive behavior (SAB'04), Los Angeles, CA.

Hjørland, B. (1998). Theory and meta-theory of information science: a new interpretation. *Journal of Documentation, 54*(5), 606-621.

Jackson, M. C. (2000). Systems Approaches to Management, Springer, p.43.

Jacob, F., & Monod, J. (1964). Biochemical And Genetic Mechanisms Of Regulation In The Bacterial Cell. *Bulletin de la Société de chimie biologique, 46*, 1499-1532.

Jacucci, E., Hanseth, O., & Lyytinen, K. (2006). Introduction: Taking complexity seriously in IS research. *Information Technology & People, 19*(1), 5-11.

Johnson, J. L., & Burton, B. K. (1994). Chaos and complexity theory for management: Caveat emptor. *Journal of Management Inquiry, 3*(4), 320-328.

Kafri, R., Springer, M., & Pilpel, Y. (2009). Genetic redundancy: new tricks for old genes. *Cell, 136*(3), 389-392.

Kiel, L. D., & Elliott, E. (1996). (eds.) Chaos theory in the social sciences: Foundations and applications. *Arbor: The University of Michigan Press.*

Knight, S. A. (ND). The OTAM: Exploring Users' Perceptions of their On-going Interaction with Adopted Technologies, (*Under Review at Australasian Journal of Information Systems), Submitted March, 2009.*

Knight, S. A. (2008). An Organic Approach to System-driven Information Management. *in Proceedings of 14th ANZSYS Conference, Perth Western Australia, Dec 1 – 3*

Knight, S. A. (2008b). *User Perceptions of Information Quality in World Wide Web Information Retrieval Behaviour*. Unpublished PhD, Edith Cowan University, Perth.

Kozma, R., & Tunstel, E. (2005). *A Novel Approach to Distributed Sensory Networks Using Biologically-Inspired Sensory Fusion.* Paper presented at the 2005 International Conference on IEEE Systems, Man and Cybernetics, Computational Neurodynamics Lab., Memphis State University, TN, USA.

Kuhn, T. S.(1968). *The structure of scientific revolutions*: University of Chicago Press Chicago.

Landau, M. (1969). Redundancy, rationality, and the problem of duplication and overlap. *Public Administration Review, 29*(4), 346-358

Landry, M., & Banville, C. (1992). A Disciplined Methodological Pluralism for MIS Research. *Accounting, Management and Information Technology, 2*(2), 77-97.

Laszlo, A., & Krippner, S. (1998). Systems Theories: Their origins, foundations, and development. *Advances in Psychology - Amsterdam, 126*, 47-76.

Loosemore, R. (2007). Complex Systems, Artificial Intelligence and Theoretical Psychology. *Frontiers in Artificial Intelligence and Applications, 157*, 159-173.

Lorenz, E. N. (1963). Deterministic non-periodic flow. *Journal of the Atmospheric Sciences, 20*, 130–141.

Mathews, K. M., White, M. C., & Long, R. G. (1999). Why study the complexity sciences in the social sciences? *Human Relations, 52*(4), 439-462.

Maturana, H. (2002). Autopoiesis, structural coupling and cognition: A history of these and other notions in the biology of cognition. *Cybernetics and Human Knowing, 9*(3), 5-34.

Merali, Y., & McKelvey, B. (2006). Using Complexity Science to effect a paradigm shift in Information Systems for the 21st century. *Journal of Information Technology, 21*(4), 211-215.

Merali, Y. (2006). Complexity and Information Systems: the emergent domain. *Journal of Information Technology, 21*(4), 216-228.

Miller, J. (1978). Living Systems. *McGraw-Hill, New York.*

Miller, J. L., & Miller, J. G. (1992). Greater Than the Sum of its Parts—I: Subsystems Which Process both Matter-Energy and Information. *Behavioural Science, 37*(1), 1-38.

Miller, J. G., & Miller, J. L. (1995). Applications of living systems theory. *Systemic Practice and Action Research, 8*(1), 19-45.

Minati, G., Penna, M. P., & Pessa, E. (2001). The Concept of Emergence in Systemics. *General Systems Bulletin, 30*, 15-19.

Moss, L. (2006). Redundancy, plasticity, and detachment: The implications of comparative genomics for evolutionary thinking. Philosophy of Science, 73(5), 930-946

Mugur-Schächter, M., & Van der Merwe, A. (2002). Quantum Mechanics, Mathematics, Cognition, and Action: Proposals for a Formalized Epistemology: *Springer*.

Olds, L. E. (1992). Metaphors of Interrelatedness: Toward a Systems Theory of Psychology. *SUNY Press,* .

Olsson, M.-O. (2004). Schools of Systems Thinking - Development Trends in Systems Methodology. *in M.-O. Olsson, & S. Gunnar (eds) Systems Approaches And Their Application, Springer*, 31-74.

Orlikowski, W. J., & Baroudi, J. J. (1991). Studying Information Technology in Organizations: Research Approaches and Assumptions. *Information Systems Research, 2*, 1-28.

Ossimitz, G. (1997): The Development of Systems Thinking Skills Using System Dynamics Modelling Tools. http://www.uni-klu.ac.at/users/gossimit/sdyn/gdm_eng.htm

Parent, E. (1996). The Living Systems Theory of James Grier Miller. *Primer project ISSS*, http://www.newciv.org/ISSS_Primer/asem14ep.html

Pather, S., & Remenyi, D. (2004). Some of the philosophical issues underpinning research in information systems: from positivism to critical realism. *In Proceedings of the 2004 Annual Research Conference of the South African institute of Computer Scientists and information Technologists on IT Research in Developing Countries (Stellenbosch, Western Cape, South Africa, October 04 - 06, 2004)*, 141 - 146.

Priami, C. (2005). Complexity and Systemics. Available online at: http://bbice.ibict.br/arquivos/kte_complexities.pdf (June, 2010)

Prigogine, I., & Stengers, I. (1984). Order out of chaos: Man's new dialogue with nature. *Toronto: Bantam Books*.

Rosenberg, A. (1993). Hume and the philosophy of science. In D. Norton (Ed), The Cambridge Companion to Hume Cambridge University Press, New York, 64–89.

Senge, P. (2006). The Fifth Discipline: The Art & Practice of the Learning Organization. http://www.randomhouse.com/doubleday/currency/catalog/display.pperl?isbn=9780385517256&view=excerpt

Seymour, G. E. (2006). Systems Thought in Psychology. *Online at: http://www.linking.to/PSY8412/Systems_Thought_in_Psychology.doc,* (retrieved: June, 2010).

Stiles, J. (2000). Neural plasticity and cognitive development. *Developmental Neuropsychology, 18*(2), 237-272.

von Bertalanffy, L. (1950). An Outline for General Systems Theory. *British Journal for the Philosophy of Science*, 1(2).

von Bertalanffy, L. (1955). An Essay on the Relativity of Categories. *Philosophy of Science, 22*(4), 243–263.

Wallace, D. (1998). Qualitative Research and the Editorial Tradition: A Mixed Metaphor - Qualitative Research. *Library Trends, Spring 1998*.

Walsham, G. (1995). The Emergence of Interpretivism in IS Research. Information *Systems Research, 6*(4), 376-394.

Wood, A. (2000). Hume: The Problem of Induction. Stanford University., August 31, 2002. URL: *http://www.stanford.edu/~allenw/Phil102/Hume - Induction.doc*

COPYRIGHT