A Future for Design Science?

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Abstract

In a world seemingly committed to more complex systems, design science should be embracing the ‘sciences of complexity’. Otherwise, its usefulness will be limited to those ‘tame’ problems amenable to its current methods, unable to address the ‘wicked’ problems which increasingly populate our world. There is already a large body of practical experience with complexity theory on which design scientists can draw. Placing complexity theory in an evolutionary context, based on General Evolution Theory (GET), could be the next frontier for design science. GET enriches time perspectives and ‘patterns’ in complexity theory, both elements useful to design practice. A particular benefit of Complexity and General Evolution Theories is that they span all dynamic systems, and thereby diminish the disciplinary barriers between the physical, biological and social sciences which have for so long bedevilled practice. The methodological issues in broadening design science to incorporate reductivist, systemic, and evolutionary perspectives are considered, and a meta-methodology based on Participatory Action Research is proposed as a way to integrate these very different epistemologies.

Keywords: Design Science, Complexity Theory, Evolutionary Systems Theory, Meta-Methodologies, and Futures

1.0 Introduction

‘The quality of a designed product is dependent on the pool of relevant science available for its design’

Willem (1990,47)

If we accept Willem’s thesis, then maybe science – design science specifically – is not doing a particularly good job. For it has been estimated by several authors that over 80% of all new products fail on launch, and another 10% fail during the next five years [50][54][23]. As Friedman [26] points out lower failure rates would have major benefits in terms of more sustainable development, less environmental impact, reduced waste, increased productivity. More simply, societies could better allocate their scarce resources.

In this paper, I propose some likely reasons for this situation, and suggest how the scientific input to design might be broadened. The paper is exploratory and, as such, will probably generate more questions than it answers. Nevertheless, it hopefully presents one plausible interpretation of design science futures; it may be seen as an elaboration of an earlier paper [12]. A brief historical reflection on design science is provided first, to contextualise what follows. The paper describes some database surveys, which are intended to be indicative rather than exhaustive; more thorough surveys would undoubtedly locate more resources. But I believe that the broad thrust of the paper is not impaired by the approach taken.

2.0 Historical perspectives

‘Design science comprises a collection(a system) of logically connected knowledge in the area of design, and contains concepts of technical information and of design methodology … Design science addresses the problem of determining and categorizing all regular phenomena of the systems to be
designed, and of the design process. Design science is also concerned with deriving from the applied knowledge of the natural sciences appropriate information in a form suitable for the designer’s use’

Hubka & Eder (1987,124)

Findeli [24] believes that the role of science in design can be traced back to the 19th century. According to Cross [21] conscious efforts to “scientise” design derive from the twentieth century modern movement in design. Educationally, it was when Hannes Meyer was director of the Bauhaus (1927/30) that scientific principles were first introduced into the design curriculum [56].

But it seems to have been Buckminster Fuller [27] who first used the term ‘design science – as ‘a comprehensive anticipatory design science’ – in a poem written in 1956. Fuller had developed ‘an enthusiasm for scientific methodology’ much earlier, while serving in the US Navy in the Great War [55]. But his use of ‘design science’ was very different from the more generally accepted understanding of Hubka & Eder above. In ‘comprehensive anticipatory design science’ Fuller viewed planet Earth as a single system, and comprehensiveness was reflected in his ‘Spaceship Earth’ project. Fuller wanted design scientists to be anticipatory because of the sometimes long lag times between invention and application. Fuller’s efforts culminated in a ‘design science decade’ in the 1960s, during which it was hoped science, technology and rationalism would overcome the human and environmental problems of the planet [21]. Fuller was percipient - and at least fifty years ahead of his time!

In the event, design science took a very different direction, with efforts to formulate coherent, rational, positivist design methods based on “the scientific method” [64][20]. In this, it found resonance with the design methods movement of the late 1950s and early 1960s [12]. The resultant hard system methods undoubtedly contribute to an improved design process in many ways, and their role continues to diversify. Nonetheless, this contribution is seen to be largely procedural and technical in nature, leaving large and critical parts of designing unsupported by science. Detractors of hard system methods point to fundamental differences between science and design and, hence, their associated methodologies. These severe limitations of positivist science for design had been clearly articulated by the mid-1960s/early 1970s.

3.0 Complexity theory

‘Our primary goal is to create models of design capable of consistently transforming and evolving, keeping pace with today’s rate of change, breaking deterministic expectations and constructing an adaptable matrix of tactics and techniques’

Rahim (2000,6)

3.1 Historical perspectives

While some in the design community were debating the role of science in design, some in the science community were exploring lines of inquiry which are now having far-reaching consequences for global society. These scientists were gaining an understanding of the so-called ‘sciences of complexity’ or, more simply, ‘complexity theory’. Table 1 gives a sense of the main contributors and the timing and nature of their inquiries.

While the initial developments closely followed WWII, most contributions were in the 1960s/1970s. These ‘new’ sciences were thus being established at a time when reductivist science was finding wide disfavour with the design community.

There has been a lag phase of 20-30 years between the development of complexity theory and its practical application in human affairs; over 70% of 2166 monographs selected with the keyword ‘complexity’
in the database ‘Global Books in Print’ were published in the last decade. Complex systems thinking now finds widespread application in such areas as:

### Table 1. Major contributions to complexity theory (based on Laszlo[49]; full citations in Reference section)

<table>
<thead>
<tr>
<th>Year</th>
<th>Contribution</th>
<th>Main contributors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1947</td>
<td>Irreversible processes</td>
<td>Prigogine</td>
</tr>
<tr>
<td>1948</td>
<td>Cybernetics</td>
<td>Weiner</td>
</tr>
<tr>
<td>1951</td>
<td>General System Theory</td>
<td>von Bertalanffy</td>
</tr>
<tr>
<td>early 1950s</td>
<td>Cellular automata</td>
<td>von Neumann</td>
</tr>
<tr>
<td>1960</td>
<td>Dynamical systems/Chaos theory</td>
<td>Abraham &amp; Shaw</td>
</tr>
<tr>
<td>1965</td>
<td>Non-equilibrium thermodynamics</td>
<td>Katchalsky &amp; Curran</td>
</tr>
<tr>
<td>1972</td>
<td>Morphogenesis</td>
<td>Thom</td>
</tr>
<tr>
<td>1975</td>
<td>Autopoiesis</td>
<td>Maturana &amp; Varela</td>
</tr>
<tr>
<td>1977</td>
<td>Self-organization</td>
<td>Nicolis &amp; Prigogine</td>
</tr>
<tr>
<td>1977</td>
<td>Catastrophe theory</td>
<td>Zeeman</td>
</tr>
<tr>
<td>1977</td>
<td>Fractals</td>
<td>Mandelbrot</td>
</tr>
<tr>
<td>1980</td>
<td>Interconnectedness/Wholeness</td>
<td>Bohm</td>
</tr>
<tr>
<td>1987</td>
<td>Self-organized criticality</td>
<td>Bak</td>
</tr>
<tr>
<td>1989</td>
<td>Artificial life</td>
<td>Langton</td>
</tr>
</tbody>
</table>

- Finance, business, manufacturing, economics
- Transportation and communications
- Governance, management, organizational change, industrial relations
- Computing, software engineering, information processing
- The natural sciences, medicine, and technology
- Environmental studies and industrial ecology
- Corporate responsibility and risk analysis

#### 3.2 Complexity theory and design

So what is the situation in respect of design? Regarding monographs, a recent search (October 2004) of ‘Global Books in Print’ with the keywords ‘Complexity’ and ‘Design’ elicited 32 citations. Of these, just three significantly relate complexity theory to design; they are listed in Table 2, with several others which may also be of interest. These texts range widely across design and related areas, but share a complexity theory approach.

### Table 2. Monographs which relate complexity theory to design and related disciplines

<table>
<thead>
<tr>
<th>Publication date</th>
<th>Author</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>Jencks, C.</td>
<td>The architecture of the jumping universe</td>
</tr>
<tr>
<td>1996</td>
<td>Stacey, R.D.</td>
<td>Complexity and creativity in organizations</td>
</tr>
<tr>
<td>1997</td>
<td>Goerzel, B.</td>
<td>From complexity to creativity: explorations in evolutionary, autopoietic, and cognitive dynamics</td>
</tr>
<tr>
<td>1998</td>
<td>Byrne, D.</td>
<td>Complexity theory and the social sciences: an introduction</td>
</tr>
<tr>
<td>1999</td>
<td>Rowland, G.</td>
<td>A tripartite seed: the future creating capacity of designing, learning and systems</td>
</tr>
<tr>
<td>1999</td>
<td>Stacey, D.</td>
<td>Strategic management and organizational dynamics(3rd edition)</td>
</tr>
<tr>
<td>2002</td>
<td>Minati, G. &amp; Pessa, E.</td>
<td>Emergence in complex, cognitive, social, and biological systems</td>
</tr>
<tr>
<td>2003</td>
<td>Nelson, H. &amp; Stolterman, E.</td>
<td>The design way: intentional change in an unpredictable world</td>
</tr>
<tr>
<td>2003</td>
<td>Midgley, G.</td>
<td>Systems thinking(3 volumes)</td>
</tr>
</tbody>
</table>
In respect of serial articles, a recent search (October 2004) of the database ‘Art Abstracts’ with the keywords ‘Complexity’ and ‘Design’ elicited 218 citations. Of these, 15 seemed to have design relevance and were reviewed. In the event, just six related design to complexity theory; they can be summarized as follows:

- Jencks has written extensively on the interaction between design and complexity theory [38][39][40][42]. His interest is in the metaphorical meaning of complexity theory for architectural design, creating what he calls ‘nonlinear architecture’. He does not consider whether and how complexity theory could influence the objectives and processes of architecture. He believes that nonlinear architecture encourages a plurality of styles and sees complexity theory as unifying nature and culture. While prone to hyperbole in his earlier accounts, Jencks may be correct when he recently observed that ‘… a wind is stirring architecture, and at least it is the beginning of a shift in theory and practice’ [42].
- Rahim [65] seeks to relate complexity theory to the design process, specifically in architecture. His writing, though, is abstract and does little to open up this important area of inquiry.
- Findeli [24] provides a thoughtful review of the nexus between design and complexity theory, with respect to contemporary design education. He comprehensively critiques contemporary design and sets out to identify another theoretical model as a basis for design education. He believes that systems and complexity theories have introduced a teleology into the otherwise ‘strictly causal sequence’ of design. He recognizes that the designer’s task is to work with the dynamic morphology of systems, rather than to act against it. He proposes that before a designer starts a new project, he/she should have ‘an adequate representation of the content, the structure, the evolutionary dynamics, and the trends[“patterns”] or “telos” of [the relevant] system’(p.11). These insights are clearly informing a new model of design education (see also Broadbent, [11]).

3.3 Methodological considerations

Not surprisingly, the methodologies developed for use with complex dynamic systems differ greatly from those of reductivist design science. Flood & Jackson [25] describe two methods for contextualising complex problems and six problem-solving methodologies. Jackson [35] has described methodologies in management science, mostly based on complexity theory. Both authors emphasise the usefulness of diverse problem-solving methodologies when tackling complex problems, a view formalized by Mingers & Brocklesby [57] as ‘multimethodology’. Although these developments have occurred in management science, they are likely to be of relevance to design science also. They are seen as a methodological response to the ‘wicked’ problems which challenged hard system methods 3-4 decades ago.

It was only in the late 1990s that soft system methods began to enter design methodology [66][62]. It is likely that some recontextualisation of such methodologies for use in design will be needed.

3.4 Discussion

The trend of human endeavour towards increasingly systemic activities seems inevitable as we become more aware of the interlinked nature of our world. It seems surprising that such a sea-change – from an objectivist reductionist to a subjectivist systemic view - has occurred methodologically in a matter of decades. Changes in society have always been constrained by current abilities and worldviews of the individuals who constitute that society [68]. As these abilities and worldviews change, so whole new vistas of what is possible emerge.

It seems that the design community considerably lags others in applying complexity theory to its practice. Interest at the confluence of design and complexity theory has been spasmodic at best and is of a mostly superficial nature. Whether this is a conscious decision by the design community is unclear; it may reflect a reluctance to interact with the sciences. Whatever, a systematic exploration of what complexity
theory can offer the design disciplines - in part based on what it has already offered other areas of society - now seems overdue. Such a study could energise the design community to fast-track its commitment to the ‘new sciences’.

4.0 General evolution theory(GET)

‘... and as men demonstrate competence
 and responsibilities as initiators
 of comprehensive, anticipatory design science –
 ... they gear men’s conscious efforts
 into nature’s ceaseless evolutionary processes
 thereby, progressively converting these inevitable
 and heretofore misapprehended
 and ofttimes vainly fought processes
 from painfully dissynchronous
 to happily synchronous events, ... ’

Buckminster Fuller (1971)

4.1 Historical perspectives

Buckminster Fuller repeatedly referred to the nexus between design and evolution in his writings. His views seem to have been intuitive, for he did not subject them to theoretical scrutiny.

While humans have been interested in evolution at least since the ancient greeks, the use of complexity theory to understand this phenomenon is, of course, recent. Ervin Laszlo published his explorations of a nexus between evolution and complexity theory as ‘Evolution: the grand synthesis’ in 1987 (revised in Laszlo, [49]). He proposed a common model of evolution for all dynamic systems: ‘In its new meaning evolution is not only the evolution of living species but the evolution of all things that emerge, persist, and change or decay in the known universe’ [47]. Laszlo’s work was a response to science’s search for a unitary principle. The unifying principle is, in his view, one of process rather than form, one of ‘becoming’ rather than of ‘being’. His evolutionary theory is, in terms of complexity theory, ‘the pattern of irreversible change manifest in all systems far from thermodynamic equilibrium [47]).

Laszlo [48] elsewhere describes evolution based on complexity theory more fully: ‘Evolution is triggered when a critical fluctuation pushes a far-from equilibrium system into a structurally new thermodynamic regime. The new order arises in the interplay of critical fluctuations during the crucial phase-change of an instability. If the system is to evolve rather than devolve, at least one out of the many possible fluctuations must “nucleate” – that is, diffuse rapidly throughout the system. If and when it does, the whole system undergoes a bifurcation: its evolutionary trajectory forks off into a new mode.

‘If, following a bifurcation, the system achieves a new dynamic regime, that regime is likely to be more resistant to the perturbation that triggered the bifurcation than the previous regime. In consequence destabilized far-from-equilibrium systems do not fall back to their previous modes of organization but grow in structure and in complexity. Their dynamic regime defines the norm around which their typical values will thereafter fluctuate’.

A benefit of General Evolution Theory (GET) is that all dynamic systems – physical, biological, biosocial, sociocultural, technological – are interpreted via a common model, even though the manifestations of that model differ widely between systems. Importantly, Laszlo believes that the basic dynamic and formative features of this evolutionary process are invariant across all these dynamic systems.
4.2 Complexity and evolution

A recent search (October 2004) of ‘Global Books in Print’ with the keywords ‘Evolution’ and ‘Complexity’ elicited 116 citations of which 77% had been published in the last decade. These texts address key issues in the nexus between complexity theory and evolution; a selection is given below.

Table 3. Selected monographs on evolution and complexity theory

<table>
<thead>
<tr>
<th>Year</th>
<th>Title</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>How the leopard changed its spots: the evolution of complexity</td>
<td>Goodwin, B.</td>
</tr>
<tr>
<td>1996</td>
<td>Evolution: foundations of a general theory</td>
<td>Laszlo, E.</td>
</tr>
<tr>
<td>1996</td>
<td>Evolution, order and complexity</td>
<td>Khalil, E.L. &amp; Boulding, K.E.</td>
</tr>
<tr>
<td>1996</td>
<td>The radiance of being: complexity, chaos and the evolution of consciousness</td>
<td>Combs, A.</td>
</tr>
<tr>
<td>1999</td>
<td>The evolution of complexity</td>
<td>Heylighen, F., Bollen, J. &amp; Riegler, A.</td>
</tr>
<tr>
<td>2001</td>
<td>Cosmic evolution: the rise of complexity in nature</td>
<td>Chaisson, E.J.</td>
</tr>
<tr>
<td>2002</td>
<td>The emergence of everything</td>
<td>Morowitz, H.J.</td>
</tr>
<tr>
<td>2002</td>
<td>The narrative universe</td>
<td>Bocchi, G. &amp; Ceruti, M.</td>
</tr>
<tr>
<td>2003</td>
<td>From complexity to life</td>
<td>Gregersen, N.H.(Ed.)</td>
</tr>
</tbody>
</table>

It is clear that the emergence of a literature on evolution from a complexity theory perspective is very recent, mostly within the last decade. Behind this though is a vast literature on evolution itself. There are over 22,000 monographs on evolution in ‘Global Books in Print’ alone, with a serials literature at least an order of magnitude greater. Evolutionary literatures now exist for almost every facet of socioculture, although they have been written from various epistemological perspectives. There is now a pressing need to critically synthesise the many positions present in this huge literature in a form that would give substance to the theoretical framework proposed by Laszlo almost two decades ago, and provide a firmer basis for practice as well. Cumulatively, these studies could provide an ecology of culture.

4.3 GET and design

In respect of a more specific relationship between design and evolution, a recent search (October, 2004) of ‘Global Books in Print’, using the keywords ‘Design’ and ‘Evolution’, elicited 279 citations. Perhaps 40 of these seemed relevant to design. A review of half these latter revealed that most were purely descriptive accounts, with little or no consideration of underlying evolutionary theory. Those which provide a theoretical perspective are listed in Table 4, together with others known to the author.

Table 4. Monographs which relate design to evolutionary theory (Full citations in Reference section)

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>Design for evolution</td>
<td>Jantsch, E.</td>
</tr>
<tr>
<td>1979</td>
<td>The evolution of designs</td>
<td>Steadman, P.</td>
</tr>
<tr>
<td>1990</td>
<td>The pencil: a history of design and circumstance</td>
<td>Petrosci, H.</td>
</tr>
<tr>
<td>1994</td>
<td>The evolution of useful things</td>
<td>Petrosci, H.</td>
</tr>
<tr>
<td>1996</td>
<td>Designing social systems in a changing world</td>
<td>Banathy, B.</td>
</tr>
<tr>
<td>1998</td>
<td>The evolution of allure</td>
<td>Hersey, G.L.</td>
</tr>
<tr>
<td>2000</td>
<td>Guided evolution of society: a systems view</td>
<td>Banathy, B.</td>
</tr>
<tr>
<td>2001</td>
<td>Simulating the evolution of language</td>
<td>Cangelosi, A. &amp; Parisi, D.</td>
</tr>
<tr>
<td>2003</td>
<td>The psychology of art and the evolution of the conscious brain</td>
<td>Solso, R.L.</td>
</tr>
</tbody>
</table>

Essentially all the critical concerns of design – aesthetics, communication, uncertainty, creativity, spirituality, decision making, behaviour, cognition, knowledge, management, methodology, philosophy, practice, processes, strategy, theory, technology, drawing, epistemology, evaluation, innovation, intuition, logic, perception, problem solving, analysis, psychology, reasoning – have evolutionary literatures, albeit
rarely in the context of design itself. An evolutionary systems perspective may better integrate these diverse considerations than has been possible to date.

4.4 Patterns and propositions

Buckminster Fuller sought “patterns” in the world around him, to better inform his design. Patterns are the substance of evolution, they provide form to seeming chaos. They are used by many, perhaps most, people to navigate through their daily lives. These patterns cumulatively, across populations, determine evolutionary futures. That is not to say that all patterns are a part of evolution, as patterns can be devolutionary. Patterns can be helpful to designing. One benefit of any rationalization of the diverse evolutionary literatures now accumulating would be a greater understanding and validation of recognized patterns with a consequent greater confidence in their practical use, e.g. in design.

Patterns are well recognized in the physical and biological sciences [59] as well as the social sciences [69][67]. To illustrate their usefulness to design practice, we can consider the design implications of propositions made by Sanderson [67] after an extensive study of human history. Sanderson identified 33 propositions, among them:

I.3. *World-historical transformations ... are not the unfolding of predetermined patterns ... Instead, they represent the grand aggregation and multiplication of the actions of individuals and groups in concrete historical circumstances as these individuals are responding to a multiplicity of biological, psychological, and social needs*

From a design perspective, it is very clear that the careful monitoring of consumer/user needs is essential to successful outcomes. Such monitoring must suitably capture the true complexity of whatever is of interest.

II.5. *The differences between social and biological evolution are great enough to require that social evolution be studied as a process in its own right, and not merely along the lines of an analogy with biological evolution*

The common tendency to apply Darwinian principles to social evolution is unlikely to lead to successful design outcomes.

III.1 *The principal causal factors in social evolution are the natural conditions of human existence, i.e., the demographic, ecological, technological, and economic forces at work in social life*

Design interacts substantively with all four causal factors and, in so doing, can significantly influence the course of social evolution in the communities it serves.

IV.8. *Individuals who originate(inherit, borrow) adaptations are not necessarily engaging in a process of attempted optimization. Individuals are frequently content with a satisfactory, rather than an optimal, way of meeting their needs and wants. In other words, adaptations are often (probably most often) the products of satisficing rather than optimizing behaviors*

A clear understanding of whether users are engaged in optimizing or satisficing behaviors is essential to establishing suitable design responses.

V.3. *The social structures and systems that individuals create through their purposive action reflect back on these and other individuals in the sense that they create new sets of constraints within which individually purposive action must operate*

Designers should be very aware that their work might alter the dialectic between human agency and social structure.
VII.1. Both "gradualist" and "punctuationalist" forms of change characterize social evolution. The pace of social evolution varies from one historical epoch and evolutionary stage to another, and is a matter for empirical study. Clearly designers must be aware of the phase of the societies for which they design, as this will significantly influence their strategy. Kondratieff Waves are a specific example of this phenomenon with major implications for strategy [13].

Other treatments of these and related issues are provided by Broadbent & Denison [14] and Broadbent & Harfield [15].

To the extent that design also is a complex dynamic system, it too should have ‘patterns’ through which it can be better understood. In this regard, Buchanan [17] has developed four ‘generative principles’ for design:

- Design which is shaped through experience and environment, these latter interactively influencing action in complex ways to generate multiple causes for that design. A pluralist process of ongoing reconstruction takes place during which environment and experience are themselves continually altered (Relates to Sanderson’s Proposition III.1)
- Design as an agent-driven process, which is ongoing and continuously interactive with other influences, this leading to 'new ways of designing, new intentions, and new products'(p.80). Exemplary in that it draws on successful models from the past or present to inspire the future(Relates to Sanderson’s Proposition V.3 and to other propositions not presented here)
- Design which is strongly influenced by trends in social and cultural life, including issues of taste and preferences ‘for aesthetic pleasure’
- Design which is strongly influenced by transcendent ideals, which may be spiritually, philosophically, or culturally derived. In doing so, ethical and moral values are addressed as well as issues of, say, usability and functionality. A largely prospective role.

Cumulatively, Buchanan’s propositions describe a complex dynamic system and, to a point, its evolution; they emphasise the important role that designers should consciously have in these evolutionary processes. Further, it is possible that the design-related evolutionary literatures mentioned already could together create Buchanan’s ‘Ecology of Design Culture’(p.76).

The propositions of both Sanderson and Buchanan are probabilistic rather than deterministic. One reason for this is that these propositions are highly interactive, thus engendering the complexity of the systems in question. Nonetheless, propositions derived from General Evolution Theory should help us to better understand and work with the complex systems which already comprise our natural world and which will increasingly constitute our artificial world.

4.5 Discussion

General Evolution Theory(GET) is an extension of Complexity Theory. A primary benefit, though, is that it emphasizes the patterned nature of evolution. This may make both theories more relevant and accessible to the design community. Regardless, the further development of GET seems a prerequisite to its use in design practice.

5.0 Methodological considerations

‘That there should be cycles of development to come, with the death of each cycle looking like a minor catastrophe at the time, ought not to have surprised us, but of course it did, and does’
5.1 Introduction

Preceding sections have considered developments historically in respect of traditional design science, and both historically and currently in the emerging fields of complexity and general evolution theory. Methodological considerations have been raised briefly along the way, but could benefit now from more formal consideration. It has been suggested elsewhere [12] that each new generation of methodology overlays rather than supplants its predecessor, thereby creating a system of methodologies which, being more inclusive of the real world, should also be more useful to practice. If this is so, then it may be helpful to develop a framework – a metamethodology – which formalises this situation.

5.2 Essential criteria

Several issues should be addressed in generating a metamethodology which incorporates the methodologies of traditional design science, complexity theory, and general evolution theory, it should:

- have an evolutionary capability; in other words, have the capacity to remain aligned with the system(s) to which it is being applied
- be able to bring about evolutionary change in the system(s) under study; that is, such change should be sustainable
- integrate diverse methodologies and epistemologies
- incorporate a critical awareness
- be realistic in terms of project timelines, financing, etc

5.3 An existing model

The search for an existing, suitable metamethodology started with a review of the qualitative methods described by Denzin & Lincoln [22]. Participatory Action Research (PAR) seemed to most closely satisfy the above criteria. It has an evolutionary history, in that it has been enriched by several theoretical perspectives over time. Its inherently evolutionary nature is evident not only in its repetitive four-phase cycle of planning, acting, observing and reflecting but also in the desire that action research remain developmental – that is, open to ongoing research and change [4]. Indeed, the open-ended nature of PAR renders it particularly well-suited to further evolution. PAR intentionally brings about evolutionary change in the systems to which it is applied, through its critical awareness.

These desired attributes are well-embodied in the metamethodology proposed by Kemmis & McTaggart [44], who have structured the practice of PAR into a taxonomy of three 'envelopes' which embrace each other like Russian dolls (Table 5). Simplifying their model somewhat:

<table>
<thead>
<tr>
<th>Influence</th>
<th>Methods</th>
<th>General features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positivism/Post-Positivism</td>
<td>Quasi-experimental-correlational/ use of descriptive-inferential statistics/psychometric-observational</td>
<td>‘Objective’-instrumentalist/technical/regulation-control/external to observer/individual or social/behaviorist-cognitivist/structural-functionalist/structure &amp; agency/process-oriented</td>
</tr>
<tr>
<td>Constructivist/Interpretive</td>
<td>Qualitative methods/idiographic, autobiographical, phenomenological/limited use of statistics/ethnographic/interview/questionnaire/diary/journals/self report/introspection/discourse and document analysis</td>
<td>‘Subjective’/practical/individual or social/participatory observer/involves values, intentions, judgements/motives/acknowledges ‘real’ world complexity/historically contextualised/structure &amp; agency/problem oriented</td>
</tr>
<tr>
<td>Critical</td>
<td>Reflexive, as in critical social science, collaborative action research, “memory” work/dialectical analysis</td>
<td>Reflexive-dialectical; seeks ‘change’ &amp; ‘evolution’/political/overarching/dynamic &amp; action-oriented/historically contextualised/creative/emancipatory/transformative, seeks improvement in theory &amp; practice/collaborative &amp; participatory/links past &amp; future/theorizing</td>
</tr>
</tbody>
</table>
The innermost envelope is ‘objective’ and ‘technical’. In our terms, it employs reductivist, hard systems methods in pursuit of its goals.

The middle envelope is seen as ‘subjective’ and ‘practical’. For our purposes, it is engaged with complex dynamic systems, for which soft system methodologies seem appropriate.

The outermost envelope they refer to as ‘reflexive/dialectical’ and ‘critical/emancipatory’ and relates to the critical systems practice of Jackson [35]. This is the element most concerned with change and evolution.

The Kemmis-McTaggart taxonomy, which they refer to as a ‘science of practice’ (albeit in human and social science) would seem to satisfy the essential criteria listed earlier. It is integrative to the extent that it incorporates hard and soft systems thinking into a framework mediated by critical systems thinking. It also has a capacity to accommodate diverse cosmologies from the specific to the most general, through its critical theory component. It has an intrinsically evolutionary nature.

5.4 Core module

The metamethodology of Kemmis & McTaggart [44] can be readily reformulated to accommodate past developments in design science and those mooted here for the future (Table 6).

<table>
<thead>
<tr>
<th>Influence</th>
<th>Methods</th>
<th>General features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positivism/Post-Positivism</td>
<td>Objective tree method/function analysis/specification/QFD/morphological charts/weighted objectives/value engineering/manufacture/marketing/design management</td>
<td>Grounded in natural sciences/reductionist/‘objective’/functionalist/inductive/suitable for ‘tame’ problems/‘real’ world/linear/surprise-free/methodology-driven/optimizing/static/intervention-based/external/systematic/explicit</td>
</tr>
<tr>
<td>Critical</td>
<td>Critical Systems Practice(CSP)</td>
<td>Overarching/dynamic/creative/emancipatory/transformative/collaborative/reflexive-dialectical/seeks ‘change’ and ‘evolution’</td>
</tr>
</tbody>
</table>

The ‘Russian doll’ model recognizes the continuing importance of traditional design science practice, but within the broader context of complexity theory. Thus, traditional hard system methods help inform the wider system view developed through constructivist/interpretive methodologies. The outcomes of these two phases in the design process engage with critical theory to clarify deeper sociocultural issues; for example, cultural imperialism may devalue designs from regions which seek to establish their own cultural and hence design identities.

The core module greatly enriches and broadens information flows from science into design, by engaging with not only the natural but also the social sciences. In doing so, it should result in designed products and services better suited to their user needs.
5.5. Evolutionary systems module

Inayatullah [33] has noted that it is important to acknowledge ‘patterns’ in socioculture, past and present, even if post-structuralism dislikes such universals. He believes that grand narratives and macrohistories give insights into patterns of the past and present, and how to look for them. In similar vein, Wilber & Harrison [76] recommended that practitioners and scholars alike should ‘allow the subject to impress upon them its norms and to instill within them its categories’. These considerations have been rehearsed already.

An appropriate response may be a module which supplements the core module, and subjects the relevant system to review from an evolutionary systems perspective. A framework for such a module is given in Table 7.

Table 7. An evolutionary systems module

<table>
<thead>
<tr>
<th>Influence</th>
<th>Methods</th>
<th>General features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positivism/</td>
<td>Evolutionary-genetic algorithms/Agent-based modeling/Probabilistic</td>
<td>Predictive/expert-based/‘objective’/seeks simplicity/hard systems/empirical-</td>
</tr>
<tr>
<td>post-Positivism</td>
<td>forecasts(Martino, [52])/Multi-criteria optimization/Viable system</td>
<td>analytical/preferably quantitative, with emphasis on precision, accuracy, &amp;</td>
</tr>
<tr>
<td></td>
<td>diagnosis (Flood &amp; Jackson, [25])</td>
<td>reliability/functionalist</td>
</tr>
<tr>
<td>Constructivist</td>
<td>Strategic Assumption/ Surfacing and Testing (SAST)(Flood &amp; Jackson, [25]</td>
<td>An evolutionary systems interpretation, emphasising the changing meanings of</td>
</tr>
<tr>
<td>/Interpretive</td>
<td>/Grand narratives/Macrohistories/Macrothinking</td>
<td>symbols, practices, behavior, institutions, norms and roles(Abel &amp; Sementelli, [1]</td>
</tr>
<tr>
<td>Critical</td>
<td>Evolutionary critical dialectics(Abel &amp; Sementelli, [1])</td>
<td>Enabling a non-teleological, non-determinist evolutionary social constructionism/</td>
</tr>
<tr>
<td></td>
<td></td>
<td>complementarist/embranipatory/sociologically aware</td>
</tr>
</tbody>
</table>

5.6. Futures module

Participatory Action Research, the basis of the metamethodology under consideration, seeks to establish ‘what ought to be’ [74]. It is a methodology to generate and realize desired futures. Yet, in most applications there is no structured consideration of these futures.

Bringing an explicit futures focus into PAR is important because it should:

- ensure more sustainable change strategies
- engage PAR with higher levels in systems of interest
- permit inclusion of future generations in contemporary decision-making [77][31]

This proposal is not novel. Banathy [8], for instance, adopted elements of Ackoff’s [3] interactive planning approach which, in turn, shares the participatory and change-initiating aspects of PAR. In essence, interactive planning is about conceptualizing a desired future and then determining how to realize it. Banathy placed these principles of interactive planning in an explicitly evolutionary context, to create a conscious, self-guided evolutionary process.

Inayatullah [33] also acknowledged that action learning seldom questions the future, and proposed anticipatory action learning as ‘a questioning process wherein the future is explicitly explored …’(p. 297). He regarded anticipatory action learning as a merging of classical participatory action research and action learning with futures studies.
Earlier, Inayatullah [30] provided a typology of futures studies methods, on which Table 8 is based. This typology anticipated those of Denzin & Lincoln [22] and Kemmis & McTaggart [44]. As with these authors, Inayatullah recognized the complementarity of the different methodologies he considered, and hence the multi-methodological/multi-epistemological nature of his metamethodology. He also realized that post-structuralism ‘problematises the validity of futures studies’ (p.130), but noted a symmetry between the examination of past practices for insights and the establishment of more effective future practices.

The role of post-structuralism in Inayatullah’s taxonomy of futures studies can be seen to bring evolutionary perspectives to this activity, through the creation of diversity. Further, a high level of complementarity is apparent between the metamethodologies of PAR and futures studies, making possible the systematic and indeed systemic incorporation of futures studies into PAR and permitting the explicit exploration of futures options.

### 5.7 Discussion


<table>
<thead>
<tr>
<th>Influence</th>
<th>Methods</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positivism/Post-Positivism</td>
<td>Extrapolation; scenarios/multidimensional scaling; Delphi; regression analysis; cross-impact analysis; simulation modeling</td>
<td>Linear; predictive; expert-based; seeks to domesticate time; ‘objective’; seeks simplicity</td>
</tr>
<tr>
<td>Constructivist/Interpretive</td>
<td>Images of the future; stories/narratives</td>
<td>Concerned with the meanings given to data and their cultural boundedness; dialectic; pluralist; participatory; phenomenological/hermeneutic; generates ‘open’, negotiable futures; engages with complexity; ‘subjective’; seeks mutual understanding</td>
</tr>
<tr>
<td>Critical</td>
<td>Critical dialectics</td>
<td>Deconstructs power; challenges worldviews/mindscapes; critiques dominant conceptualizations</td>
</tr>
<tr>
<td>Post-structural</td>
<td>Causal layered analysis</td>
<td>Concerned with what is missing in any nomination of the future; transdisciplinary/transcultural; encourages examination of ‘other’ practices, past or present; problematises time; engages with epistemological pluralism; transformative</td>
</tr>
</tbody>
</table>

Metamethodologies have emerged in the last decade or so in response to a growing need for methodologies which span several epistemologies. This approach is taken here for a metamethodology of design science which encompasses positivist, systemic, and critical methods. Clearly, the benefits of using such a metamethodology must be established in practice; in doing so, it is very possible that present conceptualizations will experience further development.

### 6.0 General discussion

‘A science that aims to support and strengthen practical reason
... addresses ... actors as persons – knowing subjects –
who could make wiser and more prudent decisions in the light of
a richer understanding of the situation in which they find themselves’

Kemmis & McTaggart (2000,584)
I have described ways in which design science could develop in coming years. These expectations are based on trends already evident in science.

The acceleration of humanity into more complex systems is one of the most striking features of contemporary civilization. Yet it is well to remember that the human body has some ten quadrillion (10^{15}) cells, each with well over a billion (10^9) molecules [16]. This amazing system operates without fatal error for some 79 years on average in Australians (a figure likely to approach 95 years by 2050). In light of these observations, two points should be made about complex systems:

- **the term ‘complexity’ is a relative one; what seems complex at a point in time is likely to be seen as progressively simpler thereafter**
- **complexity in human systems is still dwarfed by that in biological systems; we might reasonably expect human systems to become significantly more complex with time**

These two points lead one to conclude that we shall continue to improve our capacity to create complex systems and to need new methodologies for their design and management into the foreseeable future.

The reluctance of the design community, design scientists especially, to engage meaningfully with the ‘sciences of complexity’ is perplexing. Perhaps it simply needs someone to explain carefully and comprehensively why they should do so. Perhaps this community is content to solve ‘tame’ problems. Or perhaps the problem is more deep-seated, for example in the bruising design methods debates of the 1960s/early 1970s. Whatever the reason, there seems an imperative for that engagement to occur without further delay.

The lack of resonance of the design community with evolutionary systems theory is more understandable. The theoretical developments are more recent, less substantive, and their contribution to human wellbeing less evident. On the other hand, the affinity between design and evolution seems so strong and obvious – at least it was to Buckminster Fuller! Here, though, we may be touching on a very deep systemic problem with contemporary design. While all the evidence points to a much more central role for design, as an evolutionary guidance system for humanity [6], the reality of today is scarcely a shadow of this prospect.

Design science must continue to evolve. It is no more fixed in time than any of the other complex dynamic systems which inform design itself and, more widely, create the world we live in. It must also keep pace with accelerating technological and sociocultural change. Methodologies will always be found wanting because, in further exposing the complexity of the real world, they provide the rationale for the next generation of methodology. Nonetheless, the gap between reality and need should never become too great, or evolutionary fitness is lost.

The proposals made here all entail a significant complexification of current practice, well beyond the ‘real world’ constraints which many see around design today. This conservative view of design must be challenged if design science and, more widely, design itself are to realize their sociocultural potential.

Also militating against significant change is the lack of even an approximation of the costs of inadequacies in current design practice, both economically and socioculturally. These costs are probably very large and are both part of the problem – design is seen to poorly serve sociocultural needs – as well as the solution – a recognition of the real costs and hence a determination to do something about them.

The proposals made here may also seem daunting because many in society-at-large seem unaware of the very rapid and substantial developments in science today. Here, the failure of our educational systems generally to keep abreast of the accelerating rate of knowledge acquisition may be at issue. Professor Findeli’s mission to bring complexity theory into design education could be a breakthrough in this regard, and should be closely followed by other design schools as a possible model for their own futures.

Finally, global dynamics may be playing a role in our reluctance for change. Western societies, the recent fountainhead of design, are mostly on the defensive – in many ways. This seems to have triggered a
wave of conservatism, with an attendant reluctance to experiment with the new. My limited experience of east Asian societies is of an enthusiasm and capacity for change on a scale which is scarcely imaginable in the West today. Perhaps its time for a baton-change?

7.0 Acknowledgment

I thank Professor Ken Friedman for posting a concise summary of studies into the failure rates of new products and services on the PhD Design list, information used in my introductory comments.

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