Generations in design methodology

J. Broadbent University of Technology Sydney, Australia

Abstract

The relationship between design and science is examined through the lens of design methodology. The purpose is to foresee the next generation of design methodology and its attributes. Four generations in design methodology are recognized – craft, design-by-drawing, hard systems methods and soft systems methods – and each is characterized in terms of its benefits and limitations in respect of design practice. To the extent that each new generation overlays the preceding one, a system of design methodologies is created which, being more inclusive of the real world, should be increasingly useful to design practice.

The change process between generations appears to be a double exponential, suggesting that a fifth generation in design methodology is now emerging. Reasons are presented why this will likely be an evolutionary systems methodology. Such a development will position design as an evolutionary guidance system for socioculture, a much more central role in human affairs. It also has the potential, as we better understand the evolutionary nature of biological and sociocultural phenomena, to generate a profound and comprehensive relationship between design and science.

Generations in design methodology

Introduction

The relationship between design practice and science is ever-changing. Cross (2001) noted, perhaps playfully, a 40-year cycle of interest in this relationship, starting with attempts by the Modernists during the 1920s to produce works of design based on the seeming objectivity and rationality of science. A second wave of interest in the design/science relationship was embodied in the design methods movement of the 1960s. According to Cross: “We might expect to see the re-emergence of design-science concerns in the 2000s”(p. 16). A contemporary review of the relationship would seem timely indeed in view of the very substantial changes in our understanding of both design and science in the intervening 40 years.

In this account, this changing relationship is examined through the lens of design methodology. Checkland (1999: A32) described methodology as “a body of methods used in a particular activity”. It is thus a meta level with respect to method, it is about method. It is this more strategic approach that is adopted here.

The intent of this review is to determine whether changes through time in the relationship between design and science, as reflected through design methodology, exhibit patterns. If such exist, they may be helpful in discerning how design methodology could most likely develop in the near-future. Four generations of design methodology are reviewed – craft, design-by-drawing, hard systems and soft systems – primarily in terms of what they have offered design practice. These generations of design methodology are then compared to establish possible trends through time. These trends are extrapolated to define the most likely features of the next generation in design methodology.

Craft methods

The skilled craftsman was the earliest initiator of change in human-made things (Jones 1970: 15). Although crafted stone artifacts date from about 2.5 million years ago (Deacon and Deacon 1999:1), Banathy (2000:79) suggests that it was not until the Middle Stone Age, some 250,000 years ago, that “designlike thinking” emerged; this coincided with the evolution of consciousness (Laszlo 1996: 131). Such design was unconscious, in the sense that craftsmen learnt intuitively and informally - a process described well by Sturt (1923: 19): “There was nothing for it but practice and experience of every difficulty. Reasoned science for us did not exist … What we had to do was to live up to the local wisdom of our kind; to follow customs, and work to the measurements, which had been tested and corrected long before our time in every village shop all across the country”. Jones (1970: 19-20) listed the characteristics of this design methodology as follows:

- craftsmen did not, and often could not, draw their works and neither could they give adequate reasons for the decisions they took
- product information was instead stored in the form of the product itself and was transmitted through apprenticeship
- as neither the product nor the reasons for its form were recorded symbolically (e.g. by drawing), change could only occur through experimentation
- as a result, responsiveness to environmental change tended to be gradual
- thus, the form of an artefact was modified by trial-and-error over many centuries, in a slow and costly process

The incremental processes of change in products during this period have been viewed by some as possessing an evolutionary nature (e.g. Jones 1970; Norman 1988: 142). It led to high levels of product fitness for local circumstances and to considerable product diversity.

Design-by-drawing methods

Supplementation of craftsmanship with design-by-drawing occurred systematically (in architecture) from the mid-1450s (Perez-Gomez and Pelletier 1997: 17), making possible revolutionary changes in design practice (Jones 1970: 20-24):

- design became separate from production
- a division of labour within design emerged, especially for large and/or complex projects
- the 'perceptual span' of designers greatly increased; they could not only manipulate the design as a whole but could also easily import work from elsewhere
- for these reasons, design changes could be more substantive and accomplished in shorter time frames

The overlaying of crafting with drafting allowed design to keep pace with accelerating technological and sociocultural change. Major limitations to this development were that:

- initial development of drawings, during which critical decisions were made, was done mostly by a single designer. This was an increasing constraint as products became more complex and the needed expertise no longer resided in one person
- drawing has limited capacity to represent dynamic physical relationships (Heath 1984: 12)

Hard system methods (HSMs)

Introduction

The design methods movement, through which hard systems methods were introduced into design, came out of the work of Rittel and others at the Hochschule für Gestaltung, Ulm, West Germany in the 1950s (Moore 1973: 246). Its public emergence in Britain was through the First Conference on Design Methods, held in London in 1962 (Cross 1984a: viii). In the United States and Canada, the movement received its strongest support from Rittel, who had moved to Berkeley in 1963, and Alexander and others at Harvard/MIT (Moore 1973: 246). Cross's compendium of twenty-one articles broadly written around design methods, with excellent overview sections for each thematic collection, provides a rich picture of hard systems methods in design. The following account draws on several works used by Cross, but adopts a different perspective.

Hard systems methods have been described as "systematically-ordered thinking concerned with means-definition in well-structured problems in which desirable ends can be stated" (Checkland 1983: 667). Their origin can be located in the emergence of operational research/management science (OR/MS) about 1935. Initially applied to military matters, OR found commercial and industrial applications, including engineering design, in the period 1945 – 1975 (Checkland 1978; Keys 1995a&b). It was during the late 1950s/early 1960s that these methods were applied in design (Rittel 1972).

Perceived benefits and limitations

Today, with the help of hindsight, we can reflect more clearly on the benefits and limitations of this period in the relationship between design and science. We can identify more readily the role which the methods of this era have come to play in design practice. It should be noted that the insights collated below were largely of their time, were drawn only from the design community, and may not fully reflect current perceptions. The key point is, though, that these insights provided an incentive for the ongoing development of design methodology to the present.

The response of the design community to hard systems methods (HSMs) was swift.

The benefits of HSMs to design practice were seen to be largely procedural (Table 1).

- ***Improve response to growing complexity of design task, by:***
  - changing design emphasis from individual products to product systems
  - broadening design purview from local improvements to “the total situation”
  - more effectively incorporating other inputs into design process, e.g. ergonomics
  - allowing a more structured search of rapidly growing search spaces
  - managing better the interdependency between system levels

- ***Help concurrent/collaborative design, by:***
  - making design thinking explicit
  - engaging other minds at critical stages in design process

- ***Help designers to better meet shorter timelines, by:***
  - reducing design error
  - making easier the anticipation of side effects
  - lessening possibility of unintended omissions

Table 1: Hard systems methods: perceived benefits
(Sources: Archer 1965; Luckman 1967; Jones 1970; Alexander 1971; Rittel 1972**)**

By contrast, criticisms of hard systems methods were trenchant, centering on what were perceived as the very different roles of design and science in society (Table 2).

• ***Different intentions of scientific and design methodologies:*** - science seeks objective truth, design aims to satisfice - scientists seek global solutions, designers seek local ones - science is traditionally more concerned with theory, design with action - hard systems methodology, which seeks to optimize, may lessen sociocultural diversity - the reductionist nature of HSMs may stifle emergence - scientific methodology is well suited to determinate(‘tame’) problems, whereas design methodology addresses ill-defined, unique and context-dependent (‘wicked’) problems
• ***Different approaches of science and design to problem solving:*** - scientific observers seek objective detachment from the problem, whereas designers participate in the process - scientific method favours a linear process of inquiry, whereas the often complex, intertwined nature of design problems tends to defy such approaches - some aspects of the design process are not ‘conscious’, and so are not amenable to systematic processes - the conjecture-analysis approach of science is very different from the analysis-synthesis approach of design - science uses inductive reasoning, while design prefers abductive logic - science operates in a theoretical, systematic setting, whereas design operates in a real-world, intuitive setting - sequential, structured analysis sits uneasily with creative thought - science promotes an “expert-knows-best” approach, whereas design favours participatory practice - quantitative approaches are preferred in science, while qualitative considerations are often important in design

Table 2: Hard systems methods: perceived limitations
(**Sources:** Esherick 1963; Reed and Evans 1967; Alexander 1971; Hillier, Musgrove and O’Sullivan 1972; Rittel 1972; Rittel and Webber 1973; Akin 1979; Broadbent 1979; Lawson 1979; Daley 1982; Buchanan 1992; Cross 2001)

Hard systems methods proved largely unable to address the “unbound complexity” of the real world (Reed and Evans 1967). Doubts about the applicability and relevance of these methods became widespread in architectural education from the mid-1960s (Fowles 1977).

Design applications

Despite this unfavourable response, HSMs today play a significant role in the design process, e.g. CAD, ecodesign, collaborative design, ergonomics, anthronomics (Robinson and Nims 1996), virtual design, design information systems and knowledge management, quality management, user interface design. Nonetheless, these contributions remain largely procedural and are centred very much on the progressive computerization of design process; they do not address higher order attributes of the design activity.

Conclusions

In a scathing assessment of hard systems approaches to design problem solving, Alexander (1971: 4) observed: "In short, my feeling about [hard systems] methodology is that there are certain mundane problems which it has solved – and I mean incredibly mundane … Most of the difficulties of design are not of the computable sort". With the benefit of hindsight, such criticism seems too harsh. The First Conference on Design Methods in 1962 sought to allow, indeed encourage, "the fullest use of all the critical and creative faculties" (Slann 1963: xii). Jones (1963: 53) recognized the need for a systematic approach to design practice that was empathetic with creative practices, and was seeking "a unified system of design … that lies between the traditional methods, based on intuition and experience, on the one hand, and a rigorous mathematical or logical treatment, on the other". While this ambitious agenda of the design methods movement was never realised, this period can be seen as the time when a new generation of design methods was defined. Even so, the idea of "a monumental edifice of knowledge" had to be surrendered and, with it, a positivist science approach to design practice (Hillier et al. 1972: 29-3-4).

Soft Systems Methods (SSMs)

Introduction

Concern with hard systems methods centred on so-called "wicked problems", a term borrowed from Popper and re-contextualised by Rittel in the mid-1960s. Churchman (1967: B141) defined wicked problems as a "class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing". Khisty (2000: 121) more succinctly described wicked problems as a combination of uncertain goals and objectives and uncertain technologies or strategies. Cross (1984b: 102) more pithily still observed that "stating the problem *is* the problem".

According to Rittel and Webber (1973: 162-164), wicked problems were seen, *inter alia:*

- to be unique and context-specific
- to offer a host of courses for action
- to be without solution, only the opportunity to do better
- to rely upon political judgement for resolution

Many in the design community recognized that such problems are experienced by most people for most of the time in everyday life (e.g. Archer 1979: 17).

Simon (1973) suggested that the existence of wicked problems reflects our state of knowledge rather than something more intractable. It could, indeed, be argued that wicked problems arise only when the methods to "tame" them don't exist. Such thinking led to proposals by Rittel (1972) for another generation of design methods. He believed that the methods of Churchman, Popper and Boulding provided a basis for this next generation. Rittel and Webber (1973: 162) elaborated this proposal by observing that the next generation of design methods "should be based on a model of planning as an argumentative process in the course of which an image of the problem and of the solution emerges gradually among the participants, as a product of incessant judgement, subjected to critical argument". Rittel nevertheless acknowledged a considerable 'hangover' from the hard systems methods – in that designers (and others) were reluctant to engage with formal methods again.

The change process

Rittel's commitment to developing a new design methodology found expression as the Issue-Based Information System (IBIS) methodology in the early 1970s (Kunz and Rittel 1970). This was intended to support "the argumentative reasoning structure of designers" (Noble 1997a: 2497). The need to develop a new methodology was also recognized by some in the operational research/management science (OR/MS) community, from whom the design community had earlier adopted hard systems methodology. This need was responded to by Checkland (1999: A4) from 1972, Ackoff from 1973, and Churchman throughout the 1970s. It was not until the 1980s that systems-based approaches really emerged (e.g. Checkland, 1981). By 1990 several hundred applications of SSM had been made by a wide range of people in many different countries (Checkland and Scholes 1990). A survey by Mingers and Taylor (1992) into the use of SSM found that, at that time, it was established as a practical methodology but was "used by particular individuals who have some previous experience of it, rather than being a standard approach to the repertoire of OR groups" (p. 331). It was only in the mid-1990s that Keys (1995c: 335) felt able to observe that "there is now a sufficiently critical mass of distinctive and mutually informative work emerging to see this as a significant development". Even today, this change has not been reflected fundamentally in OR practice.

It had become clear through this period that problem complexity in organizational settings had again outstripped the capabilities of the available methods. Problem solving had shifted from 'tame' problems toward the increasingly 'wicked' problems of larger systems, to which SSMs were seen as an appropriate methodological response. There was also growing recognition of the breakdown of societal consensus(Toffler, 1970), which led to a desire to involve more diverse stakeholders in decision-making processes.

The holistic, systemic thinking of SSMs can be traced back to biology and medicine in the second half of the 19th century (Checkland 1983: 668). By the 1920s organismic biologists were arguing that reductionism was unsuited to understanding biological phenomena; this was a defining point in our understanding of the scientific endeavour. By the 1940s biologists like von Bertalanffy were generalizing this view to all systems (e.g. General Systems Theory). By the late 1940s systemic thinking was spreading into diverse fields, although it was not until the 1970s that it started to influence OR.

One reason why it took so long to adequately characterize and implement soft-systems methodology in OR was the transformative nature of the change. Indeed, it was not until the early 1980s that a clear distinction between "hard" and "soft" systems was made (Checkland 1999: A9). The extent of this development is evident from Table 3, in which characteristics of HSMs and SSMs are contrasted. Jackson(1982) and Checkland (1983) provide seminal accounts of the conceptualization of soft-system methodology.

HSMs	SSMs
Grounded in natural sciences	Grounded in social sciences(action research)
Reductionist, determinist, testable	Holistic, purposeful, judgemental, intuitive, descriptive, conjectural, normative, a matter of perception
"Objective", theory-based, positivist, functionalist	Subjective, wisdom/values-based, experiential, empirical, pragmatic, phenomenological, hermeneutic, action-based
Inductive, logical, rational, methodical, bottom-up	Abductive, inferential, intuitive, top-down <u>and</u> bottom-up
Suitable for isolated, relatively simple systems/ highly specific problems; 'tame' problems	Suitable for highly interactive, complex systems/ problems; 'wicked' problems
Directly involved in real-world; ontological; views systems as real	Simulates real-world through models; epistemology-dependent
Stepwise, linear, sequential	Iterative, non-linear
Surprise-free	Emergent
Methodology-driven, prescriptive	Largely guided by informal human judgement, situation-driven
Optimizes, singular outcomes	Satisfices, pluralist outcomes
Static	Evolutionary
Address rare <u>human</u> situations	Address common <u>human</u> situations
Intervention-based	Interactive
Externally applied to system	Internalized by system
Systematic	Systematic <u>and</u> systemic
Explicit	Tacit; implicit

Table 3: Comparison of HSMs and SSMs
(**Sources:** Checkland 1983, 1999; Vicente, Burns and Pawlak 1997; Khisty 2000)

Benefits and limitations

In view of the limited experience to date with soft systems methodology in design practice (see below), we must instead rely on evaluations from its application most especially in organizational design, information systems design, performance evaluation and education. SSMs seem highly consonant with many core aspects of designing (Table 4). They foster participation and the inclusion of beliefs, viewpoints, values etc; they are both systematic and systemic; they promote the emergence of fresh insights so central to design. In particular, they are well-suited to fuzzy, ill-defined or 'wicked' problems, unlike HSMs. They also seek to satisfice rather than optimize problem situations, in the knowledge that the systems under study are typically "open", thus interacting constantly with their environment and hence evolving over time (Jackson and Keys 1984: 475).

- ***Process characteristics***
  - a systemic as well as systematic approach to problem-solving
  - oriented to learning rather than just goal-seeking
  - provides structure to fuzzy, ill-defined situations with differing perceptions and views
  - makes beliefs and viewpoints open and explicit, thus admitting a number of viewpoints into the problem space
  - tends to generate shared understandings of problems
  - identifies ‘emergent’ potential in problem situations
  - embodies Schon’s notion of reflection in action

- ***Problem characteristics***
  - assumes that the world will remain problematical, but can be better understood and interacted with by using system models
  - thus talks about “issues” and “accommodations” rather than “problems” and “solutions”
  - is well-suited to the resolution of complex problems

- ***Scope of method***
  - draws attention to cultural aspects of a problem
  - inclusive of all stakeholders in a problem situation
  - “keeps in touch with the human content of problem situations” (Checkland 1985: 765)
  - thus extends the problem solving capabilities of HSMs into the social and psychological domains

Table 4: Soft systems methodology: perceived benefits
(Sources: Checkland 1985, 1999; Checkland and Scholes 1990; Mingers and Taylor 1992)

SSMs markedly broaden the role of the sciences in problem-solving, by introducing the social, psychological and, to some extent, behavioural sciences. They also particularly focus on understanding the wider situation in which a problem exists (Rowley 1998: 158). In these ways, SSMs may meet Cross’s (1986: 436) requirement: “that design methods must … be based on the ways of thinking and acting that are natural in design”, a view shared by others (e.g. Sless, 2002).

SSMs are widely seen as a front-end to hard systems methodology (e.g. Platt and Warwick 1995: 21). They thus let individuals with an interest in a problem become involved before hard systems methods are applied.

- ***Challenges worldviews***
  - requires participants to “see the world” through different perspectives, which can be difficult
  - can thus confront the worldviews of participants
  - can challenge the power structure and politics of a problem situation

- ***Less formal***
  - is subjective; it is never independent of the user, unlike the perceived objectivity of HSMs
  - does not produce final answers; accepts that inquiry is never-ending
  - thus aims to satisfice rather than optimize
  - is interpretive rather than functionalist

- ***Unfamiliar***
  - requires a way of thinking which is not always immediately evident to users
  - the methods can be time consuming and need considerable experience to apply

Table 5: Soft systems methodology: perceived limitations
(**Sources:** Checkland 1983, 1985, 1999; Mingers and Taylor 1992)

Some would view these considerations as benefits rather than limitations!

Design applications

Despite its development in the early 1970s, use of the Issue-Based Information System (IBIS) method of Kunz and Rittel (1970) was, as of 1997, still “limited to academic experiments and a small persistent group of planners” (Noble 1997b: 2485). Likewise Checkland’s soft systems methods appear to have entered traditional design practice only in the late 1990s, initially in visual communication and product design (e.g. Rowley 1998; Presley, Sarkis and Liles 2000). Maybe this is the embodiment of the “design-science concerns in the 2000s” anticipated by Cross (2001: 16). SSM should find particular application in complex design projects in which diverse stakeholders are perceived to have varied but legitimate interests in the outcome.

Conclusions

Just as hard-systems methodology is grounded in reductionist science, soft-systems methodology has been spawned by the sciences of complexity. SSM copes better with problem-solving in the ill-defined world of ‘wicked’ problems so familiar to designers, but it does so with a worldview very different from that of hard systems methodology. The mainstream adoption of SSM in design practice seems to be a matter of time, as is a fuller appreciation of their benefits and limitations in this application. It is clear that SSM should be seen as a still-maturing methodology, certainly in respect to its use in design. It also seems clear that SSM has yet to demonstrate the fullness of its application, with recent initiatives extending beyond its accepted business/ industrial applications into wider societal use (e.g Liebl, 2002).

Evolutionary Systems Methodology: the next generation?

Methodological advances will always be found wanting for, in further exposing the complexity of the real world, they provide the rationale for the next methodological generation. Rittel (1986: 371) put this well when he observed “ … there cannot exist anything like “the” design method which smoothly and automatically resolves all … difficulties. Those people who claim the existence of such a device postulate nothing less than the solution of all present and future problems of the world". It seems reasonable, then, to ponder the nature of this next generation of design methodology. If we chart the emergence of the four generations in design methodology described above against time (Table 6), we find that change is occurring exponentially.

Generation	**Emergence in design** (years before present)
Crafts	250,000
Design-by-drawing	550
Hard systems	40
Soft systems	20

Table 6: Generations in design methodology

Kurzweil's (2001) observations on this phenomenon are interesting, if sobering. He believes that all dynamic systems change exponentially over time (although he is particularly interested in technology): "a serious assessment of the history of technology shows that technological change is exponential … Exponential growth is a feature of any evolutionary process, of which technology is a primary example … Indeed, we find not just simple exponential growth, but "double" exponential growth, meaning that the rate of exponential growth is itself growing exponentially". Kurzweil continues: "[Today], paradigm shifts occur in only a few years time. The World Wide Web did not exist in anything like its present form just a few years ago, it didn't exist at all a decade ago". Kurzweil predicts that technological change over the 21st century will be equivalent to what would take some 200 centuries to achieve at today's rate of change! He also makes the interesting observation that the "returns" of an evolutionary process (e.g. speed, cost-effectiveness) also increase exponentially over time.

What are the implications of such observations for design methodology, indeed for all aspects of the phenomenon of design? If Kurzweil is correct, we may conclude that:

- the next generation of design methodology should have emerged already
- subsequent generations should appear at ever shorter time intervals
- these new generations should be increasingly useful to humanity

It is suggested that the emerging generation in design methodology is most likely evolutionary systems methodology (ESMs), because:

- the notion of societal evolution is a mature one, having existed since Herbert Spencer, in 1874, "set forth the idea of evolution as a cosmic process" (Banathy 2000: 21)
- the transition from evolutionary consciousness to conscious evolution has been proposed by eminent observers for almost 4 decades. Sir Julian Huxley (1964: 37), for example, proposed that: "man's [sic] true destiny emerges in a startling new form. It is to be the chief agent for the future of evolution on this planet. Only in and through man can any further major advance be achieved"
- observers of design have advocated a more central role for design in human affairs for some three decades. Jantsch (1975: 101), for example, noted that "Design is the core of purposeful and creative action of the active building of relations between man and his world"

- such a methodology already exists (Banathy 1996, 2000), although it seems likely that this will be refined as our understanding of related phenomena improves
- conscious evolution may be conceptually the means by which we transition effectively from the uncontrolled processes of double exponential change described Kurzweil, which seem now to be approaching a critical juncture

We can extrapolate from past generations of design methodology to predict the features of the newly-emerging generation (Table 7).

Feature	**Methodology**				
	Craft	***Design-by-drawing***	***Hard systems***	***Soft systems***	***Next generation***
Emerging cognitive state	Reflective consciousness	Reductionist science	Structured systems thinking	Holistic systems thinking	Evolutionary systems thinking
Scale	Local	Usually regional/national	National/global	National/global	Global and local
Grounding in science	Mostly pre-scientific; trial-and-error	Mathematical Sciences	Mathematical and Natural Sciences	Mathematical, Natural and Social Sciences (reductionist)	Holistic and reductionist sciences
Typical design cycle	Centuries	Decades/years	Years	Years/months	Months/weeks
Technological support	Simple hand tools	Manual/ mechanical	Mechanical/ electronic	Mostly electronic	Extensive electronic support
Knowledge base	Largely personal, tacit	Tacit and explicit; limited	Extensive information flows, mostly text-based	Huge information flows, mostly electronic	Knowledge management/ information visualization/ artificial intelligence
Interdisciplinarity	Mostly pre-discipline	Within design discipline	Interdisciplinary, across professions	Interdisciplinary, across professions and wider community	Inclusive of all stakeholders

Table 7: Features of four generations in design methodology, extrapolated to define the next such generation

These trends suggest that design may soon be realizing a fuller societal purpose, that of an evolutionary guidance system (Banathy, 1987). Buchanan (1998) recognized an historical progression in the societal role of design in his proposal for four orders of design – communication, construction, strategic planning, and systemic integration. We should be asking what fifth-order design might be. This account suggests that evolutionary systems design may be the next logical step in the broadening sociocultural role of design.

General conclusions

Cross (1972: 185) observed, in respect of design methodology: “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”. Indeed, we should not be surprised because change, indeed accelerating change, seems to characterize design methodology.

It appears, from the trends described above, that consecutive generations of design methodology have been towards more complex, higher level, and more influential roles for design in society, as might be anticipated from Laszlo’s (1996) General Evolution Theory. Further if we subscribe to

Laszlo's (1996: 1-2) view that evolution refers to "all things that emerge, persist, and change or decay in the known universe", we should expect that, in time, the reductionist and holistic sciences will together largely, perhaps completely, account for the design activity of humans.

References

Akin, Omer. 1979. "Exploration of the design process". *Design Methods and Theories*, 13(3/4): 115-119.

Alexander, Christopher. 1971. The state of the art in design methods. *DMG Newsletter*, 5(3): 3-7.

Archer, L. Bruce. 1965. "Systematic method for designers". Republished in *Developments in design methodology*, ed. N. Cross. Chichester, Sussex: Wiley.

Archer, L. Bruce. 1984b. Whatever became of design methodology? In *Developments in design methodology*, edited by N. Cross. Chichester, Sussex: Wiley. (Design Studies 1(1)(1979) 17-18)

Banathy, Bela H. 1987. The design of evolutionary guidance systems. Presentation to the *1987 Annual Meeting of the International Society for General Systems Research*, Budapest, 1-5th June 1987.

Banathy, Bela H. 2000. *Guided evolution of society: a systems view*. New York, NY: Kluwer/Plenum.

Broadbent, Geoffrey. 1979. "The development of design methods". *Design Methods and Theories*, 13(1):41-5.

Buchanan, Richard. 1992. "Wicked problems in design thinking". *Design Issues*, 8(2): 5-22.

Buchanan, Richard. 1998. "Branzi's dilemma: design in contemporary culture". *Design Issues*, 14(1): 3-20.

Cahn, Robert W. 2001. *The coming of materials science.* Oxford: Pergamon.

Checkland, Peter B. 1978. "The origins and nature of 'hard' systems thinking". *Journal of Applied Systems Analysis*, 5(2): 99-110.

Checkland, Peter B. 1981. *Systems thinking, systems practice.* Chichester, Sussex: Wiley.

Checkland, Peter B. 1983. "O.R. and the Systems Movement: mappings and conflicts". *Journal of the Operational Research Society*, 34(8): 661-675.

Checkland, Peter B. 1985. "From optimizing to learning: a development of systems thinking for the 1990s". *Journal of the Operational Research Society*, 36(9): 757-767.

Checkland, Peter B. 1999. *Soft Systems Methodology: a 30-year retrospective.* Chichester, Sussex: Wiley.

Checkland, Peter B. and Jim Scholes. 1990. *Soft systems methodology in action.* Chichester, Sussex: Wiley.

Churchman, C. West. 1967. "Wicked problems". *Management Science*, 14(4): B141-142.

Cross, Nigel. 1972. "The day the music died". *DMG-DRS Journal: Design Research and Methods*, 6(4):185.

Cross, Nigel. 1984a "Introduction". In *Developments in design methodology*, edited by N. Cross. Chichester, Sussex: Wiley.

Cross, Nigel. 1984b. "Part Two: The structure of design problems. Introduction". In *Developments in design methodology,* edited by N. Cross. Chichester, Sussex: Wiley.

Cross, Nigel. 1986. "Understanding design: the lessons of design methodology. *Design Methods and Theories: Journal of the DMG*, 20(2): 409-438.

Cross, Nigel. 2001. "Design/Science/Research: developing a discipline". *Keynote paper to the 5th Asian Design Conference,* Seoul, South Korea; 11-13th October 2001, pp.16-24.

Daley, Janet. 1982. "Design creativity and the understanding of objects".
Design Studies, 3(3): 133-7.

Deacon, Hilary and Jeanette Deacon. 1999. *Human beginnings in South Africa.* Walnut Creek, CA: AltaMira.

Esherick, Joseph. 1963. "Problems of the design of a design system". In *Conference on design methods*, edited by J.C. Jones and D.G. Thornley. London: Pergamon.

Fowles, Robert A. 1977. "What happened to design methods in architectural education? Part One – A survey of the literature. *Design Methods and Theories*, 11(1): 17-31.

Heath, Tom. 1984. *Method in architecture.* Chichester: Wiley.

Hillier, Bill, John Musgrove and Pat O'Sullivan. 1972. Knowledge and design. In *Environmental Design: Research and Practice*, Volume 2, edited by Mitchell, W.J. Los Angeles: University of California.

Huxley, Julian. 1964. *Essays of a humanist.* Harmondsworth, Middlesex: Penguin.

Jackson, Michael C. 1982. "The nature of 'soft' systems thinking: the work of Churchman, Ackoff and Checkland". *Journal of Applied Systems Analysis*, 9: 17-29.

Jackson, Michael C. and Paul Keys. 1984. "Towards a system of systems methodologies. *Journal of the Operational Research Society*, 35(6): 473-486.

Jantsch, Erich. 1975. *Design for evolution*. New York, NY: Braziller.

Jones, J. Christopher. 1963. "A method of systematic design". In *Conference on design methods,* edited by J.C. Jones and D.G. Thornley. London: Pergamon.

Jones, J. Christopher. 1970. *Design methods : seeds of human futures.* London: Wiley.

Keys, Paul. 1995a. "Preface". In *Understanding the process of operational research: collected readings,* edited by P. Keys. Chichester, Sussex: Wiley.

Keys, Paul. 1995b " Part 3: critique and revision, 1975-85 – Overview". In *Understanding the process of operational research: collected readings,* edited by P. Keys. Chichester, Sussex: Wiley.

Keys, Paul. 1995c "Conclusion: towards the future. In *Understanding the process of operational research: collected readings*, edited by P. Keys. Chichester, Sussex: Wiley.

Khisty, C. Jotin. 2000. "Can wicked problems be tackled through abductive inferencing?" *Journal of Urban Planning and Development*, 126(3): 104-118.

Kunz, W. and Horst Rittel. 1970. *Issues as elements of information systems*. Center for Planning and Development Research, University of California, Berkeley.

Kurzweil, Ray. 2001. "The law of accelerating returns". Available from URL: http://www.kurzweilai.net/articles/art0134.html?printable=1 [Accessed 2002 April 23rd]

Laszlo, Ervin. 1996. *Evolution: the general theory.* Cresskill, NJ: Hampton.

Lawson, Bryan R. 1979. "Cognitive strategies in architectural design". *Ergonomics*, 22(1): 59-68.

Liebl, Franz. 2002. "The anatomy of complex societal problems and its implications for OR. *Journal of the Operational Research Society*, 53(2): 161-184.

Luckman, John. 1967. "An approach to the management of design". *Operational Research Quarterly*, 18(4): 345-358.

Mingers, John and Sarah Taylor. 1992. "The use of soft systems methodology in practice. *Journal of the Operational Research Society*, 43(4): 321-332.

Moore, Gary. T. 1973. "Emerging methods of environmental design and planning: a comment on the occasion of the publication of the paperback edition". *DMG-DRS Journal: Design Research and Methods*, 7(3): 246-250.

Noble, Douglas. 1997a. "Structuring and navigating design information: towards a preliminary theory of generic issue-based information systems. *Design Methods: Theories, Research, Education and Practice*, 31(2): 2497-2507.

Noble, Douglas. 1997b. "Wayfinding in Issue-based Information Systems for design: pitfalls of graphical navigational aids. *Design Methods: Theories, Research, Education and Practice*, 31(2): 2484-2496.

Norman, Donald A. 1988. *The psychology of everyday things.* New York, NY: Basic.

Perez-Gomez, Alberto and Louise Pelletier. 1997. *Architectural representation and the perspective hinge*. Cambridge, Mass: MIT Press.

Platt, A. and S. Warwick. 1995. "Review of soft systems methodology". *Industrial Management and Data Systems*, 95(4): 9-21.

Presley, Adrien, Joseph Sarkis and Donald H. Liles. 2000. "A soft-systems methodology approach for product and process innovation". *IEEE Transactions on Engineering Management*, 47(3): 379-392.

Reed, Richard R. and David A. Evans. 1967. "Rational design: more than analysis?". *DMG Newsletter*, 1(8/9): 2.

Rittel, Horst. 1972. *State of the Art*. The DMG 5th Anniversary Report: DMG Occasional Paper No 1, pp. 5-10(Republished in *Developments in design methodology*, edited by N. Cross. Chichester, Sussex: Wiley. pp 317-327).

Rittel, Horst. 1986. "Some principles for the design of an educational system for design – Part II(Conclusion)". *Design Methods and Theories: Journal of the DMG*, 20(1): 366-375.

Rittel, Horst W.J. and Melvin M. Webber. 1973. "Dilemmas in a general theory of planning". *Policy Sciences*, 4: 155-169.

Robinson, Rick and Jason Nims. 1996. "Anthronomics: insight into what really matters". *Innovation*, 15(2): 18-21.

Rowley, Jennifer E. 1998. "Towards a methodology for the design of multimedia public access interfaces". *Journal of Information Science*, 24(3): 155-166.

Simon, Herbert. 1973. "The structure of ill-structured problems". *Artificial Intelligence*, 4(3): 181-200.

Slann, Peter.A. 1963. "Foreword". In *Conference on design methods,* edited by J.C. Jones and D.G. Thornley. London: Pergamon.

Sless, David. 2002. Philosophy as design: a project for our times. *3rd International Conference of the Design Education Association*, Cardiff, 14th March 2002.
Available from URL: http://www.communication.org.au/html/paper_33.html [Accessed 2002 April 23rd].

Sturt, George. 1923. *The wheelwright's shop*. London: Cambridge University Press.

Toffler, Alvin. 1970. *Future shock*. New York, NY: Random House.

Vicente, Kim J., Catherine M. Burns and William S. Pawlak. 1997. "Muddling through wicked design problems". *Ergonomics in Design*, 5(1): 25-30.