

Design/Science/Research: Developing a Discipline

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Introduction

I am honoured to be invited to address the 5th Asian Design Conference, and I am grateful to Professor Kun-Pyo Lee and the conference organisers for creating

this opportunity. I will try to use the opportunity to develop the view of 'design as a discipline'. The underlying axiom of this discipline is that there are forms of knowledge peculiar to the awareness and ability of a designer. This means developing an awareness of 'designerly ways of knowing', different from those of either science or art. I apologise in advance for bringing a particularly Western and European viewpoint, and perhaps for overlooking many developments that have occurred here in the East.

Design and Science

I would like to begin with a brief review of some of the (Western) historical concerns with the relationship between design and science. These concerns emerged strongly at two important periods in the modern history of design: in the 1920s, with a search for scientific design products, and in the 1960s, with a search for scientific design process. The 40-year cycle in these concerns appears to be coming around again, and we might expect to see the re-emergence of design-science concerns in the 2000s.

A desire to 'scientise' design can be traced back to ideas in the 20th-Century modern movement of design. For example, in the early 1920s, the De Stijl protagonist, Theo van Doesburg expressed this perception of a new spirit in art and design: 'Our epoch is hostile to every subjective speculation in art, science, technology, etc. . . . In order to construct a new object we need a method, that is to say, an

objective system.' [1]

A little later, the modernist architect Le Corbusier wrote about the house as an objectively-designed 'machine for living': 'The use of the house consists of a regular sequence of definite functions. The regular sequence of these functions is a traffic phenomenon. To render that traffic exact, economical and rapid is the key effort of modern architectural science.' [2]

In both comments, and throughout much of the Modern Movement, we see a desire to produce works of art and design based on objectivity and rationality, that is, on the values of science.

These aspirations to scientise design surfaced strongly again in the 'design methods movement' of the 1960s. The Conference on Design Methods, held in London in September, 1962 [3] is generally regarded as the event which marked the launch of design methodology as a subject or field of enquiry. The desire of the new movement was even more strongly than before to base design process (as well as the products of design) on objectivity and rationality. The origins of this emergence of new design methods in the 1960s lay in the application of novel, scientific and computational methods to the novel and pressing problems of the 2nd World War - from which came civilian developments such as operations research and management decision-making techniques.

The 1960s was heralded as the 'design science decade' by the radical technologist Buckminster Fuller, who called for a 'design science revolution', based on science, technology and rationalism, to overcome the human and environmental problems that he believed could not be solved by politics and economics. From this perspective, the decade culminated with Herbert Simon's outline of 'the sciences of the artificial' and his specific plea for the development of 'a science of design' in the universities: 'a body of intellectually tough, analytic, partly formalizable, partly empirical, teachable doctrine about the design process.' [4]

However, in the 1970s there emerged a backlash against design methodology and a rejection of its underlying values, notably by some of the early pioneers of the movement. Christopher Alexander, who had originated a rational method for architecture and planning [5], now said: 'I've disassociated myself from the field... There is so little in what is called "design methods" that has anything useful to say about how to design buildings that I never even read the literature anymore... I would say forget it, forget the whole thing.' [6]

Another leading pioneer, J. Christopher Jones said: 'In the 1970s I reacted against design methods. I dislike the machine language, the behaviourism, the continual attempt to fix the whole of life into a logical framework.' [7]

To put the quotations of Alexander and Jones into context it may be necessary to recall the social/cultural climate in Europe and the USA in the late-1960s - the campus revolutions and radical political movements, the new liberal humanism and rejection of conservative values. But also it had to be acknowledged that there had been a lack of success in the application of 'scientific' methods to everyday design practice. Fundamental issues were also raised by Rittel and Webber [8], who characterised design and planning problems as 'wicked' problems, fundamentally un-amenable to the techniques of science and engineering, which dealt with 'tame' problems.

Nevertheless, design methodology continued to develop strongly, especially in engineering and some branches of industrial design. (Although there may still have been very limited evidence of practical applications and results.) The fruits of this work emerged in a series of books on engineering design methods and methodology in the 1980s. Just to mention some English-language ones, these included:

Tjalve; *A Short Course in Industrial Design* [9]
Hubka; *Principles of Engineering Design* [10]

Pahl and Beitz; *Engineering Design: A Systematic Approach* [11]

French; *Conceptual Design for Engineers* [12]

Cross; *Engineering Design Methods* (also available in Korean translation!) [13]

Pugh; *Total Design: Integrated Methods for Successful Product Engineering* [14]

Another significant development throughout the 1980s and into the 1990s was the emergence of new journals of design research, theory and methodology. Just to refer, again, to English-language publications, these included *Design Studies* in 1979, *Design Issues* in 1984, *Research in Engineering Design* in 1989, the *Journal of Engineering Design* and the *Journal of Design Management* in 1990, *Languages of Design* in 1993 and the *Design Journal* in 1997.

Despite the apparent scientific basis (or bias) of much of their work, design methodologists also sought from the earliest days to make distinctions between design and science, as reflected in the following quotations.

'Scientists try to identify the components of existing structures, designers try to shape the components of new structures.' Alexander [5]

'The scientific method is a pattern of problem-solving behaviour employed in finding out the nature of what exists, whereas the design method is a pattern of behaviour employed in inventing things...which do not yet exist. Science is analytic; design is constructive.' Gregory [15]

'The natural sciences are concerned with how things are...design on the other hand is concerned with how things ought to be.' Simon [4]

There may indeed be a critical distinction to be made: method may be vital to the practice of science (where it validates the results) but not to the practice of design (where results do not have to be repeatable, and in

most cases must not be repeated, or copied). The Design Research Society's 1980 conference on 'Design:Science:Method' [16] gave an opportunity to air many of these considerations. The general feeling from that conference was perhaps that it was time to move on from making simplistic comparisons and distinctions between science and design; that perhaps there was not so much for design to learn from science after all, and that perhaps science rather had something to learn from design. As Bruce Archer wrote in his paper for that conference, 'Design, like science, is a way of looking at the world and imposing structure upon it'. [17]

Both science and design, as Glynn later pointed out, are essentially based on acts of perception, and 'it is the epistemology of design that has inherited the task of developing the logic of creativity, hypothesis innovation or invention that has proved so elusive to the philosophers of science.' [18]

Let us at least try to clarify three different interpretations of this concern with the relationship between science and design: (a) scientific design, (b) design science, and (c) a science of design.

Scientific design

As I noted above, the origins of design methods lay in 'scientific' methods, similar to decision theory and the methods of operational research. The originators of the 'design methods movement' also realised that there had been a change from the craftwork of pre-industrial design to the mechanisation of industrial design - and perhaps some even foresaw the emergence of a post-industrial design. The reasons advanced for developing new methods were often based on the assumption that modern, industrial design had become too complex for intuitive methods.

The first half of the twentieth century had seen the rapid growth of scientific underpinnings in many types of design - e.g. materials science, engineering science,

building science, behavioural science. One view of the design-science relationship is that, through this reliance of modern design upon scientific knowledge, through the application of scientific knowledge in practical tasks, design 'makes science visible', as Willem suggested [19].

So we might agree that *scientific design* refers to modern, industrialised design - as distinct from pre-industrial, craft-oriented design - based on scientific knowledge but utilising a mix of both intuitive and rational design methods. 'Scientific design' is probably not a controversial concept, but merely a reflection of the reality of modern design practice.

Design science

'Design Science' was a term perhaps first used by Buckminster Fuller, but it was adapted by Gregory [15] into the context of the 1965 conference on 'The Design Method'. The concern to develop a design science thus led to attempts to formulate the design method - a single rationalised method, as 'the scientific method' was supposed to be. Others, too, have had the development of a 'design science' as their aim; for example, Hubka and Eder [20], originators in Europe of the *Workshop Design Konstruktion* (WDK) and a major, continuing series of international conferences on engineering design (ICED), also formed 'The International Society for Design Science'.

Hansen [21] had stated the aim of design science as being to 'recognize laws of design and its activities, and develop rules'. [18]

This would seem to be design science constituted simply as 'systematic design' - the procedures of designing organised in a systematic way. Hubka and Eder regarded this as a narrower interpretation of design science than their own: '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 categorising 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.'

[20]

This definition extends beyond 'scientific design', in including systematic knowledge of design process and methodology as well as the scientific/technological underpinnings of design of artefacts.

So we might conclude that *design science* refers to an explicitly organised, rational and wholly systematic approach to design; not just the utilisation of scientific knowledge of artefacts, but design in some sense a scientific activity itself. This is certainly a controversial concept, challenged by many designers and design theorists. As Grant wrote: 'Most opinion among design methodologists and among designers holds that the act of designing itself is not and will not ever be a scientific activity; that is, that designing is itself a non-scientific or a-scientific activity.' [22]

Science of design

However, Grant also made it clear that 'the study of designing may be a scientific activity; that is, design as an activity may be the subject of scientific investigation.'

There remains some confusion between concepts of design science and of a science of design, since a 'science of design' seems to imply (or for some people has an aim of) the development of a 'design science'. But the concept of a science of design has been clearly stated by Gasparski:

'The science of design (should be) understood, just like the science of science, as a federation of sub-disciplines having design as the subject of their cognitive interests'. [23]

In this latter view, therefore, the science of design is the study of design - something similar to what I have elsewhere defined 'design methodology' to be; the

study of the principles, practices and procedures of design. For me, design methodology 'includes the study of how designers work and think, the establishment of appropriate structures for the design process, the development and application of new design methods, techniques and procedures, and reflection on the nature and extent of design knowledge and its application to design problems'. [24] The *study* of design leaves open the interpretation of the nature of design.

So let us agree here that the *science of design* refers to that body of work which attempts to improve our understanding of design through 'scientific' (i.e., systematic, reliable) methods of investigation. And let us be clear that a 'science of design' is not the same as a 'design science'.

Design and Research

At the 1980 'Design: Science: Method' conference of the Design Research Society, Archer [17] gave a simple but useful definition of research, which is that 'Research is systematic enquiry, the goal of which is knowledge'. Our concern in design research has to be the development, articulation and communication of design knowledge. Where do we look for this knowledge? I believe that it has three sources: people, processes and products.

Design knowledge resides firstly in *people*: in designers especially, but also in everyone to some extent. Designing is a natural human ability. Other animals do not do it, and machines (so far) do not do it. We often overlook the fact that people are naturally very good at design. We should not underplay our abilities as designers: many of the most valued achievements of humankind are works of design, including anonymous, vernacular design as well as the 'high design' of professionals.

One immediate subject of design research, therefore, is the investigation of this human ability - of how people

design. This suggests, for example, empirical studies of design behaviour, but it also includes theoretical deliberation and reflection on the nature of design ability. It also relates strongly to considerations of how people learn to design, to studies of the development of design ability in individuals and how that development might best be nurtured in design education.

Design knowledge resides secondly in *processes*: in the tactics and strategies of designing. A major area of design research is methodology: the study of the processes of design, and the development and application of techniques which aid the designer. Much of this research revolves around the study of modelling for design purposes. Modelling is the 'language' of design. Traditional models are the sketches and drawings of proposed design solutions, but which in contemporary terms now extend to 'virtual reality' models. The use of computers has stimulated a wealth of research into design processes.

Thirdly, we must not forget that design knowledge resides in *products* themselves: in the forms and materials and finishes which embody design attributes. Much everyday design work entails the use of precedents or previous exemplars - not because of laziness by the designer but because the exemplars actually contain knowledge of what the product should be. This is certainly true in craft-based design: *traditional crafts are based on the knowledge implicit within the object itself of how best to shape, make and use it.* This is why craft-made products are usually copied very literally from one example to the next, from one generation to the next.

As with the design knowledge that resides in people, we would be foolish to disregard or overlook this informal product knowledge simply because it has not been made explicit yet - that is a task for design research. So too is the development of more formal knowledge of shape and configuration - theoretical studies of design morphology. These may be

concerned as much with the semantics as with the syntax of form, or may be concerned with prosaic matters of efficiency and economy, or with relationships between form and context - whether ergonomics or environment.

My own taxonomy of the field of design research would therefore fall into three main categories, based on people, process and products:

- design epistemology - study of designerly ways of knowing
- design praxiology - study of the practices and processes of design
- design phenomenology - study of the form and configuration of artefacts

What has been happening in the field of design research is that there has been a growing awareness of the intrinsic strengths and appropriateness of design thinking within its own context, of the validity of 'design intelligence'[25]. There has been a growing acceptance of design on its own terms, a growing acknowledgement and articulation of design as a discipline. We have come to realise that we do not have to turn design into an imitation of science; neither do we have to treat design as a mysterious, ineffable art. We recognise that design has its own distinct intellectual culture; to quote Bruce Archer again, it has its own distinct 'things to know, ways of knowing them, and ways of finding out about them.'[26]

One of the dangers in this new field of design research is that researchers from other, non-design, disciplines will import methods and approaches that are inappropriate to developing the understanding of design. Researchers from psychology or computer science, for example, have tended to assume that there is 'nothing special' about design as an activity for investigation, that it is just another form of 'problem solving' or 'information processing'. However, developments in artificial intelligence and other computer modelling in design have perhaps served mainly to demonstrate just how high-level and complex

is the cognitive ability of designers, and how much more research is needed to understand it. Better progress seems to be made by designer-researchers, and for this reason the recent growth of conferences, workshops and symposia, featuring a new generation of designer-researchers, is proving extremely useful in developing the methodology of design research. As design grows as a discipline with its own research base, so we can hope that there will be a growth in the number of emerging designer-researchers.

We are still building the appropriate paradigm for design research. My personal 'touch-stone' theory for this paradigm is that there are 'designerly ways of knowing'[27]. I believe that building such a paradigm will be helpful, in the long run, to design practice and design education, and to the broader development of the intellectual culture of our world of design: to the development of a discipline of design.

Design as a Discipline

Donald Schon [28] explicitly challenged the positivist doctrine underlying much of the 'design science' movement, and offered instead a constructivist paradigm. He criticised Simon's 'science of design' for being based on approaches to solving well-formed problems, whereas professional practice throughout design and technology and elsewhere has to face and deal with 'messy, problematic situations'. Schon proposed instead to search for 'an epistemology of practice implicit in the artistic, intuitive processes which some practitioners do bring to situations of uncertainty, instability, uniqueness, and value conflict,' which he characterised as 'reflective practice'. Schon appeared to be more prepared than his positivist predecessors to put trust in the abilities displayed by competent practitioners, and to try to explicate those competencies rather than to supplant them. This approach has been developed particularly in a series of conferences and publications in 'design thinking research symposia': Cross et al. [29, 30], Akin [31], Goldschmidt and Porter [32].

Despite the positivist, technical-rationality basis of *The Sciences of the Artificial*, Simon did propose that 'the science of design' could form a fundamental, common ground of intellectual endeavour and communication across the arts, sciences and technology. What he suggested was that the study of design could be an interdisciplinary study accessible to all those involved in the creative activity of making the artificial world (which effectively includes all mankind). For example, Simon wrote that 'Few engineers and composers . . . can carry on a mutually rewarding conversation about the content of each other's professional work. What I am suggesting is that they can carry on such a conversation about design, can begin to perceive the common creative activity in which they are both engaged, can begin to share their experiences of the creative, professional design process.' [4]

This, it seems to me, is the challenge for a broad and catholic approach to design research - to construct a way of conversing about design that is at the same time both interdisciplinary and disciplined. We do not want conversations that fail to connect between sub-disciplines, that fail to reach common understanding, and that fail to create new knowledge and perceptions of design. It is the paradoxical task of creating an interdisciplinary discipline. Design as a discipline, rather than design as a science. This discipline seeks to develop domain-independent approaches to theory and research in design. The underlying axiom of this discipline is that there are forms of knowledge peculiar to the awareness and ability of a designer, independent of the different professional domains of design practice. Just as the other intellectual cultures in the sciences and the arts concentrate on the underlying forms of knowledge peculiar to the scientist or the artist, so we must concentrate on the 'designerly' ways of knowing, thinking and acting.

Many researchers in the design world have been realising that design practice does indeed have its own strong and appropriate intellectual culture, and that we must avoid swamping our design research with different cultures imported either from the sciences or

the arts. This does not mean that we completely ignore these other cultures. On the contrary, they have much stronger histories of enquiry, scholarship and research than we have in design. We need to draw upon those histories and traditions where appropriate, whilst building our own intellectual culture, acceptable and defensible in the world on its own terms. We have to be able to demonstrate that standards of rigour in our intellectual culture at least match those of the others. We have to develop design as a discipline.

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Biographical Note

Nigel Cross is Professor of Design Studies in the Department of Design and Innovation at the Faculty of Technology, The Open University, UK. With academic and practical backgrounds in architecture and industrial design, Professor Cross has been engaged in design research since the nineteen-sixties, including work in computer-aided design and design methodology. His current principal research interest is in design cognition. During 1990-96 Nigel Cross was also Professor of Design Methodology at the Faculty of Industrial Design Engineering, Delft University of Technology, The Netherlands. Recent books by Professor Cross include his textbook on Engineering Design Methods, and he has been a co-editor of books on Research in Design Thinking, Design Methodology and Relations with Science and Analysing Design Activity. Professor Cross is Editor-in-Chief of the international research journal, Design Studies.

Profile

Qualifications

- B. Sc. (Architecture); Bath, 1966.
- M. Sc. (Industrial Design Technology); UMIST, 1967.
- Ph. D. (Computer-aided Design); UMIST, 1974.

Current Position

Professor of Design Studies, Department of Design and Innovation, The Open University, UK.
Numerous Open University published teaching texts, BBC TV and radio programmes, video and audio cassettes prepared for courses in Technology and Design, including Living With Technology, Man-Made Futures, Design: Processes and Products, Design: Principles and Practice, Computer Aided Design, Innovation: Design, Environment and Strategy, Communicating Technology.

Academic Editorial Work

Founding co-editor, Design Studies, 1979-83.

General editor of Design Studies, 1983-93; Editor-in-Chief of Design Studies, 1994- .

Member of Editorial Board of Journal of Design History, 1987-95.

Overseas Visiting Appointments

USA: Yale University, Newhaven, Department of Architecture, 1970; one-week invited visiting appointment to postgraduate course in environmental design.

USA: California State Polytechnic University, San Luis Obispo, Department of Architecture, 1974; one-week invited visiting appointment to undergraduate architecture course.

Malaysia: Universiti Teknologi Malaysia, Kuala Lumpur, Engineering Departments, 1986; one-week invited visiting appointment to interdisciplinary postgraduate workshop on industrial and engineering design.

Netherlands: University of Delft, Faculty of Industrial Design Engineering, 1990 - 96; (part time)

Professor of Design Methodology.

Australia: University of Sydney, Key Centre of Design Computing, Department of Architectural and Design Science, 1997; one-month invited Distinguished Visiting Scholar (Visiting Professor) appointment.

USA: North Carolina State University, Raleigh, School of Design, 2000; one-week visiting appointment to PhD programme in design.

Visiting Lectures

Invited lectures given in many UK universities and research centres, and in The Netherlands, Belgium, France, Germany, Spain, Greece, Sweden, Denmark, Ireland, Austria, Yugoslavia, Hungary, Turkey, Poland, India, Malaysia, Australia, USA.

Conferences

Invited and refereed papers and presentations given at many conferences in UK and abroad. Keynote speaker at Artificial Intelligence in Design AID98 International Conference, Lisbon, Portugal, July 1998; International Congress of Societies of Industrial Design, Seoul, Korea, October 2001.

PUBLICATIONS (selected list)

Books

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design (co-editor with D. Elliott and R. Roy), Hutchinson Educational Press, London, 1974.

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"Models of the Design Process: integrating across the disciplines" (with N. Roozenburg), *Design Studies*, Vol. 12, No. 4, 1991.

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"Science and Design Methodology: a review", *Research in Engineering Design*, Vol. 5, No. 2, pp. 63-69, 1993.

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