# A HISTORY OF DESIGN METHODOLOGY

N. CROSS
*The Open University*
*United Kingdom*
*and*
*University of Delft*
*the Netherlands*

ABSTRACT. This Workshop marks the thirtieth anniversary of the event which is normally regarded as the birth of modern design methodology and the design methods movement - the Conference on Design Methods held in London in 1962. The movement almost died in the 1970s, but seems now to have hung on to life and to have re-emerged and grown with some vigour in the last decade. This paper reviews this relatively short history of design methodology, maps out some of the major themes that have sustained it, and tries to establish some agreed understanding for the concepts of scientific design, design science and the science of design.

## 1. Introduction

This Workshop happens to coincide with the thirtieth anniversary of the *Conference on Design Methods*, held in London in September, 1962 (Jones and Thornley, 1963). This conference is generally regarded as the event which marked the launch of design methodology as a subject or field of enquiry. Of course, the field was based on some earlier work (the earliest reference in Design Methodology literature is probably Zwicky's 'Morphological Method' published in 1948 (Zwicky, 1948)), but the 1962 Conference was the first time that 'design methods' received substantial academic recognition.

So the history of design methodology is still rather a brief one. Some previous 'history' reviews have been by Broadbent (1979) and Cross (1980, 1984). In 1986, The Design Methods Group celebrated its twentieth anniversary with some special reviews, in its journal, *Design Methods and Theories*.



*M. J. de Vries et al. (eds.), Design Methodology and Relationships with Science,* 15–27.

## 2. A Brief Overview

The origins of the emergence of new design methods in the 1950s and 60s lay in the application of novel, 'scientific' methods to the novel and pressing problems of the 2nd World War - from which came OR and management decision-making techniques - and in the development of creativity techniques in the 1950s. (The latter was partly, in the USA, in response to the launch of the first satellite, the Soviet Union's 'Sputnik', which seemed to convince American scientists and engineers that they lacked creativity.)

The new 'Design Methods Movement' developed through a series of conferences in the 1960s and 70s - London, 1962 (Jones and Thornley, 1963); Birmingham, 1965 (Gregory, 1966); Portsmouth, 1967 (Broadbent and Ward, 1969); Cambridge, Mass., 1969 (Moore, 1970); London, 1973; New York, 1974 (Spillers, 1974); Berkeley, Cal., 1975, Portsmouth again in 1976 (Evans, Powell et al., 1982) and again in 1980 (Jacques and Powell, 1981) (notably, this latter conference had a similar theme - 'Design:Science:Method' - to that of this Workshop).

The first design methods or methodology books also appeared in this period - Hall (1962), Asimow (1962), Alexander (1964), Archer (1965), Jones (1970), Broadbent (1973) - and the first creativity books - Gordon (1961), Osborn (1963).

However, the 1970s also became notable for the rejection of design methodology by the early pioneers. Christopher Alexander 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... If you call it "It's A Good Idea To Do", I like it very much; if you call it "A Method", I like it but I'm beginning to get turned off; if you call it "A Methodology", I just don't want to talk about it.' (Alexander, 1971) And 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.' (Jones, 1977)

These were pretty harsh things for the founding fathers to say about their offspring, and were potentially devastating to those who were still nurturing the infant. To put the quotations of Alexander and Jones into context it may be necessary to recall the social/cultural climate of the late-1960s - the campus revolutions, the new liberal humanism and rejection of previous values. But also it had to be acknowledged (and it was) that there had been a lack of success in the application of 'scientific' methods to design. Fundamental issues were also raised by Rittel and Webber (1973), who characterised design and planning problems as 'wicked' problems, fundamentally un-amenable to the techniques of science and engineering, which dealt with 'tame' problems.

Design methodology was temporarily saved, however, by Rittel's (1973) brilliant proposal of 'generations' of methods. He suggested that the

developments of the 1960s had been only 'first generation' methods (which naturally, with hindsight, seemed a bit simplistic, but nonetheless had been a necessary beginning) and that a new second generation was beginning to emerge. This suggestion was brilliant because it let the new methodologists escape from their commitment to inadequate 'first generation' methods, and it opened a vista of an endless future of generation upon generation of new methods.

We might wonder what has happened to Rittel's theory of 'generations'. The first generation (of the 1960s) was based on the application of systematic, rational, 'scientific' methods. The second generation (of the early 1970s) moved away from attempts to optimize and from the omnipotence of the designer (especially for 'wicked problems'), towards recognition of satisfactory or appropriate solution-types (Simon (1969) had introduced the notion of 'satisficing') and an 'argumentative', participatory process in which designers are partners with the problem 'owners' (clients, customers, users, the community). However, this approach tends to be more relevant to architecture and planning than engineering and industrial design, and meanwhile these fields were still developing their methodologies in somewhat different directions.

Engineering design methodology developed strongly in the 1980s; for example, through ICED - the series of International Conferences on Engineering Design - and the work of the VDI - Verein Deutscher Ingenieure. These developments were especially strong in Europe and Japan (Hongo and Nakajima, 1991), if not in the USA. (Although there may still have been limited evidence of practical applications and results.) A series of books on engineering design methods and methodology began to appear. Just to mention some English-language ones, these included Hubka (1982), Pahl and Beitz (1984), French (1985), Cross (1989), Pugh (1991). It should also be acknowledged that in the USA there were some important conferences on design theory, and the National Science Foundation initiative on design theory and methods (perhaps in response to German and Japanese progress - like the earlier response to Sputnik?) led to substantial growth in engineering design methodology in the late-1980s. ASME, the American Society of Mechanical Engineers launched a series of conferences on *Design Theory and Methodology*, the most recent being in Miami, Florida (Stauffer, 1991).

So the development of 'second generations' of design methodology in architecture and engineering appeared to diverge from each other in the 1970s and 80s. Roozenburg and Cross (1991) have pointed out that these two fields have tended to diverge especially in their models of the design process, to the detriment of both. Perhaps a third generation of the 1990s might be based on a combination of the previous two; or, as in the model proposed by Cross (1989), on understanding the 'commutative' (Archer ,1979) nature of problem and solution in design. There was also a broader renewal of interest in design methodology in the late 1980s - especially in AI developments, where hope springs again for design automation and/or intelligent electronic design assistants.

A particularly significant development has been the emergence of new journals of design research, theory and methodology. Just to refer, again, to English-language publications, we have had *Design Studies* since 1979, *Design Issues* since 1984, *Research in Engineering Design* since 1989, the *Journal of Engineering Design* since 1990, and the *Journal of Design Management* since 1990.

## 3. Relationships Between Design Methodology And Science

From the earliest days, design methodologists have sought 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, 1964)

'The scientific method is a pattern of problemsolving 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, 1966)

'The natural sciences are concerned with how things are...design on the other hand is concerned with how things ought to be.' (Simon, 1969)

Glynn (1985) has pointed out that the above distinctions tend to be based on a positivistic (and possibly simplistic) view of the nature of science, and that scientists too, like designers, create their hypotheses and theories, and use these theories to guide their search for facts. Hillier, Musgrove et al. (1972) also criticized design methodologists for basing their ideas on outmoded concepts of scientific method and epistemology.

Cross, Naughton et al. (1981) went so far as to suggest that the current epistemology of science is in some confusion and therefore is a most unreliable guide for an epistemology of design. This conclusion was challenged by Levy (1985), who suggested that transformations within the epistemology of science should be seen as active growth and development rather than simply chaos, and that it would be naive to try to isolate design and technology from science and society.

However, there may still be a critical distinction to be made: method may be vital to science (where it validates the results) but not to design (where results do not have to be repeatable).

It is also clear that practitioners, whether in science or design, do not have to be methodologists. As Sir Frederick Bartlett pointed out, 'The experimenter must be able to use specific methods rigourously, but he need not be in the least concerned with methodology as a body of general principles. Outstanding "methodologists" have not themselves usually been successful experimenters.'

(Bartlett, 1958.) If 'designer' is substituted for 'experimenter', this observation also holds true in the context of design.

The Design Research Society's *Design:Science:Method* Conference of 1980 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 Archer (1981) wrote in his paper for that conference, 'Design, like science, is a way of looking at the world and imposing structure upon it'. Both science and design, as Glynn (1985) 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.'

More informed views of both science and design now exist than they did in the 1960s. As Levy (1985) wrote, 'Science is no longer perceived in terms of a single fixed methodology focused on a specific view of the world. It is more an expanded rationality for problem-identifying, -structuring and -solving activities.' This makes scientific methodology sound indistinguishable from design methodology. Thus the simple dichotomies expressed in the 1960s are being replaced by a more complex recognition of the web of interdependencies between knowledge, action and reflection.

But in some places, old attitudes die hard. The editorial in Volume 1, Issue 1, of *Research in Engineering Design* was clear about that journal's aim to change design from an art to a science: 'For the field of design to advance from art to science requires research...' (Dixon and Finger, 1989.)

Let us at least try to clarify some of the terminology that is used in discussing concepts such as 'scientific design', 'design science' and 'the science of design'.

### 3.1. SCIENTIFIC DESIGN

As I said earlier, 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 pre-industrial design to industrial design - and perhaps even to post-industrial design? The reasons advanced for developing new methods were often based on this assumption; modern, industrial design is too complex for intuitive methods.

The first half of this century had also seen the rapid growth of scientific underpinnings in many types of design - e.g. materials science, engineering science, building science, behavioural science. A relatively simple 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' (Willem, 1990).

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 non-intuitive design methods.

## 3.2. DESIGN SCIENCE

'Design Science' was a term perhaps first used by Gregory (1966), in the context of the 1965 Conference on The Design Method. Others, too, have the development of a 'design science' as their aim; for example, the originators of the ICED conferences, the *Workshop Design Konstruction* (WDK) are 'The International Society for Design Science'. The concern to develop a design science has led to attempts to formulate *the* design method - a single rationalised method, based on formal languages and theories. We have even had presented the concept of 'Creativity As An Exact Science' (Altshuller, 1984).

But a desire to 'scientise' design can be traced back to ideas in the modern movement of design. The designer Theo van Doesburg wrote in the 1920s: 'Our epoch is hostile to every subjective speculation in art, science, technology, etc. The new spirit, which already governs almost all modern life, is opposed to animal spontaneity, to nature's domination, to artistic flummery. In order to construct a new object we need a method, that is to say, an objective system.' (van Doesberg, 1923.) And a little later, the architect Le Corbusier wrote: '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.' (Le Corbusier, 1929.)

Hansen (1974), quoted by Hubka and Eder (1987), has stated the aim of design science as being to 'recognize laws of design and its activities, and develop rules'. This would seem to be design science constituted simply as 'systematic design' - the procedures of designing organized in a systematic way. Hubka and Eder regard 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 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.'

This definition extends beyond 'scientific design', in including systematic knowledge of design process and methodology as well as scientific/technological underpinnings of design of artefacts. For Hubka and Eder the important constituents of design science are: 1, Applied knowledge from natural and

human sciences; 2, Theory of technical systems; 3, Theory of design processes; 4, Design methodology.

Andreasen (1991) points to two important areas of theory in design science that are delineated by Hubka (for mechanical engineering): theory of the design process (general procedures, methods, tools) and theory of machine systems (classification, modelling, etc. of technical systems). This helps to define design science as including both process and product knowledge and theory.

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 as a scientific activity itself.

### 3.3. SCIENCE OF DESIGN

There is some confusion between concepts of Design Science and of a Science of Design, since 'Science of Design' seems to imply (or for some people has an aim of) the development of a 'Design Science'. For example, we have praxeology, 'the science of effective action', and in *The Sciences of the Artificial*, Simon (1969) defined 'the science of design' as '... a body of intellectually tough, analytic, partly formalizable, partly empirical, teachable doctrine about the design process.'

This view is controversial. As Grant (1979), 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.' 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.'

A similar view of 'the science of design' has also been clearly stated by Gasparski (1990): 'The science of design (should be) understood, just like the science of science, as a federation of subdisciplines having design as the subject of their cognitive interests'.

In this latter view, therefore, the science of design is the *study* of design - something similar to what I have elsewhere defined as 'design methodology'; 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'. (Cross, 1984.)

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.

## 4. Recent Developments In Design Methodology

I would like to conclude with a brief review of developments in design methodology over the last decade. I will use categories of work similar to those I used in *Developments in Design Methodology* (Cross, 1984), which covered the period 1962-82.

### 4.1. THE DEVELOPMENT OF DESIGN METHODS

*Origination and application of systematic methods*

In this category, the last decade has been notable for the development of product quality assurance methods, such as Taguchi methods (Ross, 1988) and Quality Function Deployment (Hauser and Clausing, 1988).

There has also been significant new work in design automation, using expert systems and other artificial intelligence techniques. A new series of conferences on AI and Design has been established, where this work is reported (Gero, 1991).

### 4.2. THE MANAGEMENT OF DESIGN PROCESS

*Models and strategies for executing design projects*

We have had a new generation of systematic models of the design process, particularly in engineering design, and particularly from Germany (Hubka (1982), Pahl and Beitz (1984), Verein Deutscher Ingenieure (VDI) (1987)). We have also seen the emergence of 'concurrent' models of product planning and development (Andreasen (1991), Pugh (1991)).

In architecture and planning there has been development of the 'argumentative' process models (McCall (1986), and the paper by Grant in this volume).

### 4.3. THE STRUCTURE OF DESIGN PROBLEMS

*Theoretical analysis of the nature of design problems*

There has been significant new work on problem 'types', for example by Schön (1988) and by Oxman (1990). In this category we might also include the new work on formal languages and grammars of design (Stiny (1980), Flemming (1987)).

### 4.4. THE NATURE OF DESIGN ACTIVITY

*Empirical observations of design practice*

There have been many more protocol and case studies made in this period. Examples include Schön (1984), Rowe (1987), Davies and Talbot (1987), Wallace and Hales (1987), Stauffer, Ullman et al. (1987), Eckersley (1988), Waldron and Waldron (1988). A conference in Delft on *Research in Design Thinking* brought together several related approaches and recent new work (Cross, Dorst et al., 1992).

### 4.5. THE PHILOSOPHY OF DESIGN METHOD

*Philosophical analysis and reflection on design activity*

Some of the comparative discussions of design and science have already been referred to earlier in this paper (Levy (1985), Glynn (1985)). There have been several new studies in the epistemology of design (Buchanan (1989), Zeng and Cheng (1991), Roozenburg (1992)), and we should also include here work in the praxeology of design (Gasparski, 1990).

Some of us have also been theory-building around the concept of 'designerly' ways of thinking and acting (A. Cross, 1984, 1986; Tovey, 1986; N. Cross 1990), although some aspects of this work have been challenged by Coyne and Snodgrass (1991).

## 5. Conclusion

For some people, design methodology appeared to have died in the 1970s; however, we can now see that it survived, and that there has been some particularly strong and healthy growth in the 1980s, especially in the engineering and product design fields. There is still some confusion and controversy over the use of terms such as design science, but I hope that the discussion here has helped to clarify this.

Design methodology has become a much more mature academic field, but still suffers from a lack of confidence in it by design practitioners and it has had little (acknowledged) practical application.

## References

Alexander, C. (1964), Notes on the Synthesis of Form. Cambridge, Ma., Harvard University Press.

Alexander, C. (1971), "The State of the Art in Design Methods." DMG Newsletter 5(3): 3-7.
Altshuller, G. S. (1984), Creativity as an Exact Science. Gordon and Breach.
Andreasen, M. M. (1991), "Design Methodology." Journal of Engineering Design 2(4): 321-335.
Archer, L. B. (1965), Systematic Method for Designers. London, The Design Council.
Archer, L. B. (1979), "Whatever Became of Design Methodology?" Design Studies 1(1): 17-18.
Archer, L. B. (1981), A View of the Nature of Design Research. In R. Jacques and J. Powell (ed.) Design:Science:Method. Guildford, UK, Westbury House.
Asimow, M. (1962), Introduction to Design. Englewood Cliffs, NJ., Prentice-Hall.
Bartlett, F. C. (1958), Thinking: an experimental and social study. London, UK, Allen and Unwin.
Broadbent, G. (1973), Design in Architecture. Chichester, UK, John Wiley & Sons Ltd.
Broadbent, G. (1979), "The Development of Design Methods." Design Methods and Theories 13(1): 41-45.
Broadbent, G. and A. Ward, (ed.) (1969), Design Methods in Architecture. London, UK, Lund Humphries.
Buchanan, R. (1989), Declaration by Design: rhetoric, argument and demonstration in design practice. In V. Margolin (ed.) Design Discourse. Chicago, Ill., University of Chicago Press.
Coyne, R. and A. Snodgrass (1991), "Is Designing Mysterious? Challenging the dual knowledge thesis." Design Studies 12(3): 124-131.
Cross, A. (1984), "Towards an Understanding of the Intrinsic Values of Design Education." Design Studies 5(1): 31-39.
Cross, A. (1986), "Design Intelligence: the use of codes and language systems in design." Design Studies 7(1): 14-19.
Cross, N. (1980), The Recent History of Post-industrial Design Methods. In N. Hamilton (ed.) Design and Industry. London, The Design Council.
Cross, N., (ed.) (1984), Developments in Design Methodology. Chichester, UK, John Wiley & Sons Ltd.
Cross, N. (1989), Engineering Design Methods. Chichester, UK, John Wiley & Sons Ltd.
Cross, N. (1990), "The Nature and Nurture of Design Ability." Design Studies 11(3): 127-140.
Cross, N., K. Dorst, N. Roozenburg, (ed.) (1992), Research in Design Thinking. Delft, Netherlands, Delft University Press.
Cross, N., J. Naughton, et al. (1981), Design Method and Scientific Method. In R. Jacques and J. Powell (ed.) Design:Science:Method. Guildford, UK, Westbury House.
Davies, R. and R. J. Talbot (1987), "Experiencing Ideas: identity, insight and the imago." Design Studies 8(1): 17-25.

Dixon, J. R. and S. Finger (1989), "Editorial." Research in Engineering Design 1(1): 1.
Eckersley, M. (1988), "The Form of Design Processes: a protocol analysis study." Design Studies 9(2): 86-94.
Evans, B., J. Powell, R. Talbot, (ed.) (1982), Changing Design. Chichester, UK, John Wiley & Sons Ltd.
Flemming, U. (1987), The Role of Shape Grammars in the Analysis and Creation of Designs. In Y. E. Kalay (ed.) Computability of Design. New York, John Wiley & Sons Ltd.
French, M. J. (1985), Conceptual Design for Engineers. London, UK, The Design Council.
Gasparski, W. (1990), "Editorial: Contributions to Design Science." Design Methods and Theories 24(2): 1186-1194.
Gasparski, W. (1990), "On the General Theory (Praxeology) of Design." Design Methods and Theories 24(2): 1195-1215.
Gero, J., (ed.) (1991), Artificial Intelligence in Design '91. Oxford, UK, Butterworth-Heinemann.
Glynn, S. (1985), "Science and Perception as Design." Design Studies 6(3): 122-133.
Gordon, W. J. J. (1961), Synectics. New York, Harper & Row.
Grant, D. P. (1979), "Design Methodology and Design Methods." Design Methods and Theories 13(1): 46-47.
Gregory, S. A., (ed.) (1966), The Design Method. London, Butterworth Press.
Gregory, S. A. (1966), Design Science. In S. A. Gregory (ed.) The Design Method. London, Butterworth.
Hall, A. D. (1962), A Methodology for Systems Engineering. Princeton, NJ, Van Nostrand.
Hansen, F. (1974), Konstruktionswissenschaft. Munich, Germany, Carl Hanser.
Hauser, J. R. and D. Clausing (1988), "The House of Quality." Harvard Business Review (May/June): 63-73.
Hillier, B., J. Musgrove, et al. (1972), Knowledge and Design. In W. J. Mitchell (ed.) Environmental Design: Research and Practice. Los Angeles, Ca., University of California.
Hongo, K. and N. Nakajima (1991), "Relevant Features of the Decade 1981-1991 for Theories of Design in Japan." Design Studies 12(4): 209-214.
Hubka, V. (1982), Principles of Engineering Design. Guildford, UK, Butterworth Scientific Press.
Hubka, V. and W. E. Eder (1987), "A Scientific Approach to Engineering Design." Design Studies 8(3): 123-137.
Jacques, R. and J. Powell, (ed.) (1981), Design:Science:Method. Guildford, UK, Westbury House.
Jones, J. C. (1970), Design Methods. Chichester, UK, John Wiley & Sons Ltd.
Jones, J. C. (1977), "How My Thoughts About Design methods Have Changed During the Years." Design Methods and Theories 11(1): 48-62.

Jones, J. C. and D. G. Thornley, (ed.) (1963), Conference on Design Methods. Oxford, UK, Pergamon Press.
Le Corbusier (1929), CIAM 2nd Congress, Frankfurt.
Levy, R. (1985), "Science, Technology and Design." Design Studies 6(2): 66-72.
McCall, R. (1986), "Issue-Serve Systems: a descriptive theory of design." Design Methods and Theories 20(3): 443-458.
Moore, G. T., (ed.) (1970), Emerging Methods in Environmental Design and Planning. Cambridge, Ma., MIT Press.
Osborn, A. F. (1963), Applied Imagination - Principles and Procedures of Creative Thinking. New York, Scribener's Sons.
Oxman, R. (1990), "Prior Knowledge in Design." Design Studies 11(1): 17-28.
Pahl, G. and W. Beitz (1984), Engineering Design. London, The Design Council.
Pugh, S. (1991), Total Design: Integrated Methods for Successful Product Engineering. Wokingham, UK, Addison-Wesley.
Rittel, H. (1973), "The State of the Art in Design Methods." Design Research and Methods (Design Methods and Theories) 7(2): 143-147.
Rittel, H. and M. Webber (1973), "Dilemmas in a General Theory of Planning." Policy Sciences 4: 155-169.
Roozenburg, N. (1992), On the Logic of Innovative Design. In N. Cross, C. Dorst and N. Roozenburg (ed.) Research in Design Thinking. Delft, NL, Delft University Press.
Roozenburg, N. and N. Cross (1991), "Models of the Design Process: integrating across the disciplines." Design Studies 12(4): 215-220.
Ross, P. J. (1988), Taguchi Techniques for Quality Engineering. New York, McGraw-Hill.
Rowe, P. (1987), Design Thinking. Cambridge, Ma., MIT Press.
Schön, D. (1984), "Problems, Frames and Perspectives on Designing." Design Studies 5(3): 132-136.
Schön, D. A. (1988), "Designing: rules, types and worlds." Design Studies 9(3): 181-190.
Simon, H. A. (1969), The Sciences of the Artificial. Cambridge, Ma., MIT Press.
Spillers, W. R., (ed.) (1974), Basic Questions of Design Theory. Amsterdam/New York, North-Holland/Elsevier.
Stauffer, L., D. Ullman, et al. (1987), Protocol Analysis of Mechanical Engineering Design. In W. E. Eder (ed.) Proceedings of International Conference on Engineering Design, Boston. New York, American Society of Mechanical Engineers.
Stauffer, L. A., (ed.) (1991), Design Theory and Methodology - DTM '91. New York, American Society of Mechanical Engineers.
Stiny, G. (1980), "Introduction to Shape and Shape Grammars." Environment and Planning B 7: 343-351.
Tovey, M. (1986), "Thinking Styles and Modelling Systems." Design Studies 7(1): 20-30.

van Doesberg, T. (1923), "Towards a Collective Construction." De Stijl : Quoted by Naylor, G. (1968) The Bauhaus, Studio Vista, London.
Verein Deutscher Ingenieure (VDI) (1987), Systematic Approach to the Design of Technical Systems and Products: Guideline VDI 2221. Berlin, Germany, Beuth Verlag.
Waldron, M. B. and K. J. Waldron (1988), "A Time Sequence Study of a Complex Mechanical System Design." Design Studies 9(2): 95-106.
Wallace, K. and C. Hales (1987), Detailed Analysis of an Engineering Design Project. In W. E. Eder (ed.) Proceedings of the International Conference on Engineering Design, Boston. New York, American Society of Mechanical Engineers.
Willem, R. A. (1990), "Design and Science." Design Studies 11(1): 43-47.
Zeng, Y. and G. D. Cheng (1991), "On the Logic of Design." Design Studies 12(3): 137-141.
Zwicky, F. (1948), The Morphological Method of Analysis and Construction. In Studies and Essays. New York, Interscience.