Design Ability

by Nigel Cross

This paper reviews and summarises a variety of research studies into the nature of design ability. Six aspects of design ability are identified: coping with ill-defined problems, problem structuring, managing goals and constraints, generating solution concepts, thinking by drawing, and intuitive reasoning.

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Designing is something that *people* do. Animals do not do it, and machines (so far) do not do it. The ability to design is a part of human intelligence, and that ability is natural and widespread amongst the human population. We human beings have a long history of design ability, and it is only necessary to refer to the many examples of vernacular design and traditional craftwork to appreciate that design ability used to be somehow a collective or shared ability. In modern, industrial society, it appears that some people have their design ability more highly-developed than other people – either through some genetic endowment or through social and educational development. In fact, some people are very good at designing.

Research in Design Ability

For at least thirty years there has been a slow but steady growth in our understanding of design ability – the pioneering research paper in this field is perhaps the study of engineering designers by Marples (1960). Research methods that have been used have included the following:

• *Interviews with designers*

These have usually been with designers who are acknowledged as having well-developed design ability, and have usually been unstructured interviews which sought to obtain these designers' reflections on the processes and procedures they use – either in general, or with reference to particular works of design.

• *Observations and case studies*

These have usually been focused on one particular design project at a time, with observers recording the progress and development of the project either contemporaneously or post-hoc. Both participant and non-participant observation methods have been included, and both real and artificially-constructed design projects have been studied.

• Protocol studies

This more formal method has usually been applied to artificial projects, because of the stringent requirements of recording the protocols – the 'thinking-aloud' and associated actions of subjects asked to perform a set design task. Both inexperienced (usually student) designers and experienced designers have been studied in this way.

• Controlled tests

By these I mean the kinds of tests conducted under controlled, laboratory conditions, in which subjects are required to perform a specialised task, and data on their performance is recorded and analysed. The models for these kinds of tests are the controlled laboratory studies of psychology research. There are relatively few controlled tests in design research.

• Simulation trials

A relatively new development in research methodology has been the attempt to simulate human thinking through artificial intelligence techniques. There are as yet few examples of this method being used in design research. Although AI techniques may be meant to supplant human thinking, research in AI can also be a means of trying to understand human thinking.

• Reflection and theorising

As well as the empirical research methods listed above, there has been a modest history in design research of theoretical analysis and reflection upon the nature of design ability.

We therefore have a varied set of methods which have been used for researching design ability. The set ranges from the more abstract to the more concrete types of investigation, and from the more close to the more distant study of actual design practice. The studies themselves have ranged over naïve or non-designers, through inexperienced or student designers, to experienced and expert designers, and even on to forms of non-human, artificial intelligence.

Aspects of Design Ability

1. Ill-defined problems

What I would like to do in this paper is to show how the more scientific and/or reflective research studies tend to confirm the more intuitive statements made by designers themselves. Let me start with a quotation which I think is quite well known in architectural circles, a comment by the architect, Denys Lasdun (1972):

> Our job is to give the client, on time and on cost, not what he wants, but what he never dreamed he wanted; and when he gets it, he recognizes it as something he wanted all the time.

At first sight, this seems to be a rather arrogant statement by an architect who is prepared to over-ride 'what the client wants' because the architect 'knows better'. I prefer to see it more as reflecting a view that 'the problem' ('what the client wants') is ill-defined, and the designer finds it necessary to go beyond the problem statement in developing a solution that is something more than merely an adequate response to 'the problem'. In designing, 'the solution' does not arise directly from 'the problem'; the designer's attention oscillates, or commutes, between the two, and an understanding of both gradually develops, as Archer (1979) has suggested:

> The first thing to recognize is that "the problem" in a design problem, like any other ill-defined problem, is not the statement of requirements. Nor is "the solution" the means ultimately arrived at to meet those requirements. "The problem" is obscurity about the requirements, the practicability of envisageable provisions and/or misfit between the requirements and the provisions. "The solution" is a requirement/provision match that contains an acceptably small amount of residual misfit and obscurity. Thus the relationship between design problem and design requirements and design provision lies along one axis and the relationship between design problem and de-

sign solution lies along another axis. The design activity is commutative, the designer's attention oscillating between the emerging requirement ideas and the developing provision ideas, as he illuminates obscurity on both sides and reduces misfit between them.

Research studies have confirmed that designers' cognitive strategies for problem-solving are based upon their need to resolve ill-defined problems. For example, Thomas and Carroll (1979) carried out several observational and protocol studies of a variety of problem-solving tasks, including design tasks. One of their findings was that designers' behaviour was characterised by their treating the set problems *as though* they were ill-defined problems, even when they could also be treated as well-defined problems, for example by changing the goals and constraints. Thomas and Carroll concluded that:

> Design is a type of problem solving in which the problem solver views the problem or acts as though there is some ill-definedness in the goals, initial conditions or allowable transformations.

2. Problem structuring

The ill-defined nature of design problems means that they cannot be solved simply by collecting and synthesing information, as the architect Richard MacCormac (1976) has observed:

> I don't think you can design anything just by absorbing information and then hoping to synthesise it into a solution. What you need to know about the problem only becomes apparent as you're trying to solve it.

In early observational studies of urban designers and planners, Levin (1966) realised that they 'added information' to the problem as given, simply in order to make a resolution of the problem possible. Levin saw this as like adding a 'missing ingredient':

> The designer knows (consciously or unconsciously) that some ingredient must be added to the information that he already has in order to arrive at an unique solution. This knowledge is in itself not enough in design problems, of course. He has to look for the extra ingredient, and he uses his powers of conjecture and original thought to do so.

Since 'the problem' cannot be fully understood in isolation from consideration of 'the solution', it is natural that solution conjectures should be used as a means of helping to explore and understand the problem formulation. This was recognized by Marples (1960) from his observations of engineering designers, although it was also clear that the designers were not necessarily adept at generating several alternative solutions in order to expand their search space. Marples commented that:

> The nature of the problem can only be found by examining it through proposed solutions, and it seems likely that its examination through one, and only one, proposal gives a very biased view. It seems probable that at least two radically different solutions need to be attempted in order to get, through comparisons of subproblems, a clear picture of the "real nature" of the problem.

Designers tend to move rapidly to early solution conjectures, and use these conjectures as a way of exploring and defining problem-and-solution together. This is not a strategy employed by all problem-solvers, many of whom attempt to define or understand the problem fully before making solution attempts. This difference in cognitive strategies was observed by Lawson (1979), in his controlled tests of problem-solving behaviour in which he compared scientists with architects:

> The scientists were [attempting to] discover the structure of the problem; the architects were proceeding by generating a sequence of high-scoring solutions until one proved acceptable... [The scientists] operated what might be called a problem-focussing strategy ... architects by contrast adopted a solution-focussing strategy.

3. Goals and constraints

The slipperiness of the relationship between problem and solution in designing is also conveyed in the comments of the furniture designer Geoffrey Harcourt (Davies, 1985), discussing how a particular design emerged:

> As a matter of fact, the solution that I came up with wasn't a solution to the problem at all. I never saw it as that ... But when the chair was actually put together [it] in a way quite well solved the problem, but from a completely different angle, a completely different point of view.

Designers do not, therefore, work by a method of 'conjectures and refutations'; their solution conjectures are studied to see if they can be confirmed, rather than refuted. This behaviour was observed in an early protocol study of architects by Eastman (1970), who found that:

> One approach to the problem was consistently expressed in all protocols. Instead of generating abstract relationships and attributes, then deriving the appropriate object to be considered, the subjects always generated a design element and then determined its qualities.

A similar conclusion was reached by Darke (1979) from her interviews with successful architects. In discussing particular designs, she saw that they had all used solution conjectures early in the design process, as a means of narrowing the solution space:

> The greatest variety reduction or narrowing down of the range of solutions occurs early on in the design process, with a conjecture or conceptualization of a possible solution. Further understanding of the problem is gained by testing this conjectured solution.

Darke also concluded that the architects had all found, generated or imposed particular strong constraints, or narrow sets of objectives, upon the problem, in order to help generate the early solution concept. These constraints and objectives are the 'missing ingredient' of Levin; Darke called them the 'primary generators' of the solution concepts.

Problem goals and constraints are not sacrosanct, and designers exercise the freedom to change goals and constraints during solution generation, as understanding of the problem develops and definition of the solution proceeds. This was a feature of designer behaviour noted by Akin (1979) from his protocol studies:

> One of the unique aspects of design behaviour is the constant generation of new task goals and redefinition of task constraints.

An early case study of the design of a school, by Krauss and Myer (1970), had also noted this behaviour. They reported how one particular element – the school music room – was shifted around in its location in the plan, as the designers changed goals and constraints during the process of designing:

> For example, it moved south to take advantage of a dip in the site which permits it to have a greater volume, to get more sun, to have a distinctive view, and to be near the entry and circulation focus. Note that the designers have dropped one constraint: they no longer consider it necessary for the music room to be near the major play area. They have added other constraints: the music room should have a prominent location and greater volume. In other words, the designers are dropping old concerns and raising new ones, and they even change their minds again as they create forms and react to them.

4. Solution concepts

Although designers change goals and constraints as they design, they hang on to their major solution concept for as long as possible, even when detailed development of the scheme throws up difficult problems. Part of the changing of goals and constraints is associated with resolving such difficulties without having to start again with a major new concept.

From his case studies of architectural design, Rowe (1987) observed that:

> A dominant influence is exerted by initial design ideas on subsequent problem-solving directions ... Even when severe problems are encountered, a considerable effort is made to make the initial idea work, rather than to stand back and adopt a fresh point of departure.

This aspect of designer behaviour is also evident in engineering design. It may be viewed negatively as evidence of designers adjusting goals and constraints in order to make their solution concepts 'work', or more positively as a learning experience for the designer, which is inevitable in resolving ill-defined problems. The latter view is taken by Waldron and Waldron (1988), in their comments on an engineering design case study:

> The premises that were used in initial concept generation often proved, on subsequent investigation, to be wholly or partly fallacious. Nevertheless, they provided a necessary starting point. The process can be viewed as inherently self-correcting, since later work tends to clarify and correct earlier work.

5. Thinking by drawing

The principal working method that designers use in their work is, of course, the sketch drawing. They use this method in a form of simultaneous drawing-and-thinking. For example, the engineering designer, Jack Howe (Davies, 1985) said that, when his design thinking gets 'stuck',

> I draw something. Even if it's "potty", I draw it. The act of drawing seems to clarify my thoughts.

Schön's (1983) more recent observational studies of design tutors have also reinforced the central role of drawing as a modelling language of design, and of the way solution-and-problem are explored together through this medium. According to Schön, this exploration is almost conversational between the external representation and the designer's internal cognitive model of the problem-and-solution:

> [The designer] shapes the situation, in accordance with his initial appreciation of it; the situation "talks back", and he responds to the back-talk.

6. Intuitive reasoning

When talking about design and design processes, designers often refer to the röle of 'intuition' in their reasoning processes. Jack Howe commented:

> I believe in intuition. I think that's the difference between a designer and an engineer... I make a distinction between engineers and engineering designers... An engineering designer is just as creative as any other sort of designer.

Similarly, the industrial designer Richard Stevens has commented on the röle of intuition in engineering design and industrial design (Davies, 1985):

> A lot of engineering design is intuitive, based on subjective thinking. But an engineer is unhappy doing this. An engineer wants to test; test and measure. He's been brought up this way and he's unhappy if he can't prove something. Whereas an industrial designer, with his Art School training, is entirelt happy making judgements whiah are intuitive.

Several theoretical arguments have been advanced in support of the view that design reasoning is different from the conventionally-acknowledged forms of inductive and deductive reasoning. For example, March (1976) distinguished design's mode of reasoning from those of logic and science:

> Logic has interests in abstract forms. Science investigates extant forms. Design initiates novel forms. A scientific hypothesis is not the same thing as a design hypothesis. A logical proposition is not to be mistaken for a design proposal. A speculative design cannot be determined logically, because the mode of reasoning involved is essentially abductive.

March drew upon the work of the philosopher Peirce in identifying the appropriate mode of reasoning as 'abductive' in character. March himself preferred to use the term 'productive' reasoning for that type of thinking which *produces* a design proposal, but several other authors have taken up and developed the idea of 'abductive' thinking as being a key element of design reasoning. The important point is that design reasoning is understood as characteristic to itself, and that inappropriate modes of reaoning should not be forced upon it. The distinction between design reasoning and scientific reasoning, for example, has also been made by Simon (1969), on the basis that:

> The natural sciences are concerned with how things are... Design, on the other hand, is concerned with how things ought to be.

Conclusion

I have attempted to show that there is a reasonable history of research into the nature of design ability, with some some consistent patterns in the results upon which we can base our understanding of how designers think and work. At the moment, we seem to have a fairly rich picture of design ability, but we lack a successful, simplifying paradigm. Those simplifying paradigms which have been attempted in the past – such as viewing design as problem-solving, or information-processing, or decision-making, or pattern-recognition – have failed to capture the full complexity of design ability. The lack of an adequate, simplifying paradigm is perhaps something which inhibits the transfer of knowledge from research into practice and education. There is therefore a strong case for basing any further developments in design theory and methodology on the foundations which have been laid in understanding design ability, and I hope that this paper has shown where those foundations are.

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