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The Nature and Nurture of Design Ability

Nigel Cross

Understanding the nature of design ability can better enable design educators to nurture its development in their students. Such understanding has been promoted by a wide variety of studies of design activity and designer behaviour. From a review of these studies, design ability is summarised as comprising resolving ill-defined problems, adopting solution-focussed cognitive strategies, employing abductive or oppositional thinking and using non-verbal modelling media. These abilities are highly developed in skilled designers, but are also possessed in some degree by everyone. A case is therefore made for design ability as a fundamental form of human intelligence. The nurture of this ability through design education is discussed, with particular reference to the problem of providing design education through the distance-learning media of the Open University.

This paper is based on the author's Inaugural Lecture as Professor of Design Studies, given 31 May 1989 at The Open University.

I hope that the title of my lecture makes clear that it really has two parts. The first is concerned with the nature of design ability - the particular ways of thinking and behaving that designers, and all of us, adopt in tackling certain kinds of problems in certain kinds of ways. The second part is concerned with the nurture of design ability - that is, with the development of that ability through design education, and in particular with the attempts we have made here at the Open University to nurture design ability through distance-learning media.

My view is that through better understanding the nature of design ability, design educators may be better able to nurture it. I therefore see these two - nature and nurture - as complementary interests, and I do not intend to venture into those corners of psychology where fights go on over nature vs nurture in the context of general intelligence. However, I shall try to make a claim that design ability is, in fact, one of the several forms or fundamental aspects of human intelligence.

The appellation 'designer' has been helping to sell products for some time now. I think it started with 'designer jeans' - trousers which, though derived from workmen's garments, were clearly not meant for working in. A wide range of 'designer' products then appeared - from designer cars to designer pens. However, the appellation has now become virtually a term of abuse - ranging from the 'designer stubble' seen on the faces of fashion victims to the 'designer socialism' seen in some sections of the British Labour Party. I even saw a magazine article about 'designer diseases' such as the 'Stendahl syndrome' which is supposed to afflict those overcome by the beauty of Florence. 'Designer' products are now recognizable by their dominance of form over function.

'Designer' therefore currently seems to mean something trendy, fashionable and insubstantial. But fortunately the idea that good design can actually be a selling point does seem to have penetrated to producers and advertisers. For example, the new Renault 19 car was advertised as having been 'Designed without compromise'. I like this slogan, because too often designing is said to be the art of compromising between conflicting requirements, whereas I believe that good design actually resolves conflicts without compromise.

Is design important?

Everything we have around us - environments, clothes, furniture, machines, communication systems, even much of our food - has been designed. The quality of that design effort therefore profoundly affects our quality of life.

It has also been suggested that design is important as a factor in national economic regeneration - on the large scale - and in the business performance of individual companies and firms - on the smaller scale. Is there any truth in this suggestion? Robin Roy and his colleagues in the Design Innovation Group (DIG) at the Open University have been researching this question for the past few years. They have found (as researchers usually do) that the relationship between design and business performance is a complex one. However, some things have become clear. For

example, a DIG survey compared the business performances of ‘design-conscious’ British firms with a representative sample of other British firms¹. The ‘design-conscious’ firms had won design awards for their products and gave the design function an important role in the company’s policies. The survey showed that the design-conscious firms had much better business performance on indicators such as profit margin and return on capital (Figure 1).

Other surveys by the Design Innovation Group have elicited from managers their attitudes towards design². For example, they were asked to say what factors they considered gave products a ‘competitive edge’ over rival products. A comparison of representative British firms with foreign market leaders revealed significant differences. As Figure 2 shows, the foreign leaders’ managers mentioned design factors such as technical performance, overall quality and value for money much more frequently than did British managers. The more successful market leaders therefore seem to be more design conscious. The only factors mentioned more often by British managers than their foreign competitors were price and innovation - perhaps revealing an inadequate conception of what buyers really value in products.

A related DIG survey inquired about the factors that firms included in the product brief to their designers. Again comparing British firms with foreign leaders (Figure 3), selling price is again the only factor included more often by British firms. The foreign leaders gave more attention to design factors such as function, size, appearance, materials and ergonomics.

These surveys therefore suggest that design is indeed important in business success. This cannot be naively interpreted as good design equals good business, but it does indicate that successful firms treat design as an important element of business strategy.

I NATURE

What do designers do?

If design is important, what is it that designers do?

The most essential thing that any designer does is to provide, for those who will make the artefact, a description of what that artefact should be like. Usually, little or nothing is left to the discretion of the makers - the designer specifies the artefact’s dimensions, materials, finishes and colours. When a client asks a designer for ‘a design’, that is what they want - the description. The focus of all design activity is that end-point.

The designer’s aim, therefore, is the communication of a specific design proposal. Usually, this is in the form of a drawing or drawings, giving both an overview of the artefact and particular details. Even the most imaginative design proposals must usually be communicated in rather prosaic working drawings, lists of parts, and so on.

Sometimes, it is necessary to make full-scale mockups of design proposals in order that they can be communicated sufficiently accurately. In the motor industry, for example, full-scale models of new car bodies are made to communicate the complex three-dimensional shapes. These shapes are then digitized via a 3-D probe and the data communicated to computers for the production of drawings for making the body-panel moulds. Increasingly, in many industries, computerisation of both design and manufacture is substantially changing the mode of communication between designer and manufacturer, sometimes with the complete elimination of conventional detail drawings.

Before the final design proposal is communicated for manufacture, it will have gone through some form of testing, and alternative proposals may also have been tested and rejected. A major part of the designer's work is therefore concerned with the evaluation of design proposals. Again, full-scale models may have been made - the motorcar industry uses them extensively for evaluating aesthetics and ergonomics, as well as for production purposes. Small-scale 3-D models are also often used in many industries - from architecture to chemical process plants.

However, drawings of various kinds are still the most extensively used modelling medium for evaluating designs - both informally in the designer's skilled reading of drawings and imagining their implications, and more formally in measuring dimensions, calculating stresses, and so on. In evaluating designs, a large body of scientific and technical knowledge can be brought to bear; and again computers are having significant effects through techniques such as finite element analysis. This modelling and testing is the central, iterative activity of the design process.

Before a proposal can be tested, it has to be originated somehow. The generation of design proposals is therefore the fundamental activity of designers, and that for which they become famous or infamous. Although design is usually associated with novelty and originality, most run-of-the-mill designing is actually based on making variations on previous designs. Drawings again feature heavily in this generative phase of the design process, although at the earliest stages they will be just the designer's 'thinking with a pencil' and perhaps comprehensible only to him or her.

The kind of thinking that is going on is multi-faceted and multi-levelled. The designer is thinking of the whole range of design criteria and requirements set by the client's brief, of technical and legal issues, and of self-imposed criteria such as the aesthetic and formal attributes of the proposal. Often, the problem as set by the client's brief will be vague, and it is only by the designer suggesting possible solutions that the client's requirements and criteria become clear. The designer's very first conceptualizations and representations of problem and solution are therefore critical to the procedures that will follow - the alternatives that may be considered, the testing and evaluating, and the final design proposal.

Designers on designing

Although there is such a great deal of design activity going on in the world, the nature of design ability is rather poorly understood. It has been taken to be a mysterious talent. Dictionary definitions of design (as a verb) usually refer to the importance of

‘constructive forethought’, or, as Gregory puts it, ‘Design generally implies the action of intentional intelligence’³.

When designers are asked to discuss their abilities and to explain how they work, a few common themes emerge. One theme is the importance of creativity and ‘intuition’. For example, the engineering designer Jack Howe has said:

‘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.’⁴

Some rather similar comments have been made by the industrial designer Richard Stevens:

‘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 entirely happy making judgements which are intuitive.’⁴

Another theme that emerges from designers’ own comments is based on the recognition that problems and solutions in design are closely interwoven - that ‘the solution’ is not always a straightforward answer to ‘the problem’. For example, commenting on one of his more creative designs, the furniture designer Geoffrey Harcourt said:

‘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.’⁴

A third common theme is the need to use sketches, drawings and models of all kinds as a way of exploring problem and solution together, and of making some progress when faced with the complexity of design. For example, Jack Howe has said that, when uncertain how to proceed:

‘I draw something. Even if it’s “potty” I draw it. The act of drawing seems to clarify my thoughts.’⁴

Given the complex nature of design activity, therefore, it hardly seems surprising that the structural engineering designer Ted Happold should suggest that:

‘I really have, perhaps, one real talent; that is that I don’t mind at all living in the area of total uncertainty.’⁴

If that seems a little too modest, there are certainly other designers who seem to make more arrogant claims, such as the architect Denys Lasdun:

‘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 recognises it as something he wanted all the time.’⁵

Despite the apparent arrogance, there is the truth in this statement that clients often do want designers to transcend the obvious and the mundane, and to produce proposals which are exciting and stimulating as well as merely practical.

From this brief review so far, we can summarize the major aspects of what designers do as follows. Designers

- produce novel, unexpected solutions
- tolerate uncertainty, working with incomplete information
- apply imagination and constructive forethought to practical problems
- use drawings and other modelling media as means of problem solving.

Studies of designing

For thirty years now, there has been a slowly growing body of understanding about the ways designers work, based on a wide variety of studies of designing⁶. Some of these studies rely on the reports of designers themselves, such as those we have just seen, but there is also a broad spectrum running through observations of designers at work, experimental studies based on protocol analysis, to theorising about the nature of design ability.

Arranged in order, from the most direct contact with working designers to the most abstract and theoretical, such studies include the following types:

- interviews with designers
- case studies of particular design projects
- observations of designers at work
- protocol studies of design activity
- laboratory experiments based on selected features of design ability
- theorising

Such studies often confirm the comments of designers themselves, but try also to add another layer of explanation of the nature of designing. For example, one feature of design activity that is frequently confirmed by such studies is the importance of the use of conjectured solutions by the designer. In his pioneering case studies of engineering design, Marples suggested 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 sub-problems, a clear picture of the “real nature” of the problem.’⁷

This view emphasises the role of the conjectured solution as a way of gaining understanding of the design problem, and the need, therefore, to generate a variety of solutions precisely as a means of problem-analysis. It has been confirmed by Darke's interviews with architects, where she observed how they imposed a limited set of objectives or a specific solution concept as a 'primary generator' for an initial solution:

'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.'⁸

The freedom - and necessity - of the designer to re-define the problem through the means of solution-conjecture was also observed in protocol studies of architects by Akin, who commented:

'One of the unique aspects of design behaviour is the constant generation of new task goals and redefinition of task constraints.'⁹

It has been suggested that this feature of design behaviour arises from the nature of design problems: they are not the sort of problems or puzzles that provide all the necessary and sufficient information for their solution. Some of the relevant information can only be found by generating and testing solutions; some information, or 'missing ingredient', has to be provided by the designer himself, as suggested by Levin from his observations of urban designers:

'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.'¹⁰

Levin suggested that this extra ingredient is often an 'ordering principle' and hence we find the formal properties that are so often evident in designers' work, from towns designed as simple stars to teacups designed as regular cylinders.

However, designers do not always find it easy to generate a range of alternative solutions in order that they better understand the problem. Their 'ordering principles' or 'primary generators' can, of course, be found to be inappropriate, but they often try to hang on to them because of the difficulties of going back and starting afresh. From his case studies of architectural design, Rowe observed:

'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.'¹¹

This tenacity is understandable but undesirable, given the necessity of using alternative solutions as a means of understanding the 'real nature' of the problem.

However, Waldron and Waldron, from their engineering design case study, came to a more optimistic view about the ‘self-correcting’ nature of the design process:

‘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.’¹²

It becomes clear from these studies of designing that architects, engineers, and other designers adopt a problem-solving strategy based on generating and testing potential solutions. In an experiment based on a specific problem-solving task, Lawson compared the strategies of architects with those of scientists, and found a noticeable difference:

‘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.’¹³

In a supplementary experiment, Lawson found that these different strategies developed during the architects’ and scientists’ education; whilst the difference was clear between fifth-year, postgraduate students, it was not clear between first-year students. The architects had therefore learned their solution-focussing strategy, during their design education, as an appropriate response to the problems they were set. This is presumably because design problems are inherently ill-defined, and trying to define or comprehensively to understand the problem (the scientists’ approach) is quite likely to be fruitless in terms of generating an appropriate solution within a limited timescale.

The difference between a scientific approach and a design approach has also been emphasised in theoretical studies, such as Simon’s, who pointed out that:

‘The natural sciences are concerned with how things are....Design, on the other hand, is concerned with how things ought to be.’¹⁴

And March has categorised the differences between design, science and logic:

‘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.’¹⁵

This ‘abductive’ reasoning is a concept from the philosopher Peirce, who distinguished it from the other more well-known modes of inductive and deductive reasoning. Peirce suggested that ‘Deduction proves that something must be; induction shows that something actually is operative; abduction merely suggests that something may be.’¹⁶ It is therefore the logic of conjecture. March prefers to use the

term ‘productive’ reasoning. Others have used terms such as ‘appositional’ reasoning in contra-distinction to propositional reasoning¹⁷.

Although March, Simon and others have attempted to construct various forms of ‘design science’, they have been careful to distinguish this from popular conceptions of deductive scientific activity. John Naughton and I have also pointed to the potential error of basing models of design activity on naive views of the epistemology of science¹⁸, and Simon Glynn has suggested that scientists actually might have something to learn from the epistemology of design¹⁹.

Design ability is founded on the resolution of ill-defined problems by adopting a solution-focussing strategy and productive or appositional styles of thinking. However, the design approach is not necessarily limited to ill-defined problems. Thomas and Carroll conducted a number of experiments and protocol studies of designing and concluded that a fundamental aspect is the nature of the approach taken to problems, rather than the nature of the problems themselves:

‘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.’²⁰

There is also, of course, the reliance in design upon the media of sketching, drawing and modelling as aids to the generation of solutions and to the very processes of thinking about the problem and its solution. The process involves what Schön has called ‘a reflective conversation with the situation’. From his observations of the way design tutors work, Schön commented that, through sketches,

‘[The designer] shapes the situation, in accordance with his initial appreciation of it; the situation “talks back”, and he responds to the back-talk.’²¹

Design ability therefore relies fundamentally on non-verbal media of thought and communication. There may even be distinct limits to the amount of verbalising that we can productively engage in about design ability. Daley has suggested that:

‘The way designers work may be inexplicable, not for some romantic or mystical reason, but simply because these processes lie outside the bounds of verbal discourse: they are literally indescribable in linguistic terms.’²²

This review of studies of designing enables us to summarise the core features of design ability as comprising the ability to

- resolve ill-defined problems
- adopt solution-focussing strategies
- employ abductive/productive/appositional thinking
- use non-verbal, graphic/spatial modelling media.

Design ability is possessed by everyone

Although professional designers might naturally be expected to have highly developed design abilities, it is also clear that non-designers also possess at least some aspects, or lower levels of design ability. Everyone makes decisions about arrangements and combinations of clothes, furniture, etc. - although in industrial societies it is rare for this to extend beyond making selections from available goods that have already been designed by someone else.

However, in other societies, especially non-industrial ones, there is often no clear distinction between professional and amateur design abilities - the role of the professional designer may not exist. In craft-based societies, for example, craftspeople make objects that are not only highly practical but often also very beautiful. They would therefore seem to possess high levels of design ability - although in such cases, the ability is collective rather than individual: the beautiful-functional objects have evolved by gradual development over a very long time, and the forms of the objects are rigidly adhered to from one generation to the next.

Even in industrial societies, with a developed class of professional designers, there are often examples of vernacular design persisting, usually following implicit rules of how things should be done, similar to craftwork.

Occasionally there are examples of 'naive' design breaking out in industrial societies, with many of the positive attributes that 'naive' art has. A classic example is the 'Watts Towers' - an environmental fantasy created by Simon Rodia in his Los Angeles backyard between the nineteen-twenties and fifties.

Recently, in architecture especially, there have been moves to incorporate non-professionals into the design process - through design participation²³ or community architecture²⁴. Although the experiments have not always been successful - in either process or product - there is at least a recognition that the professionals could, and should, collaborate with the non-professionals. Knowledge about design is certainly not exclusive to the professionals.

A strong indication of how widespread design ability is comes from the introduction of design as a subject in schools. It is clear from the often very competent design work of schoolchildren of all ages that design ability is inherent in everyone.

Design ability can be damaged or lost

Although some aspects of design ability can be seen to be widespread in the general population, it has also become clear that the cognitive functions upon which design ability depends can be damaged or lost. This has been learned from experiments and observations in the field of neuropsychology, particularly the work which has become known as 'split-brain' studies²⁵.

These studies have shown that the two hemispheres of the brain have preferences and specialisations for different types of perceptions and knowledge. Normally, the large bundle of nerves (the corpus callosum) which connects the two hemispheres ensures

rapid and comprehensive communication between them, so that it is impossible to study the workings of either hemisphere in isolation from its mate. However, in order to cure epilepsy, some people have had their corpus callosum surgically severed, and became subjects for some remarkable experiments to investigate the isolated functions of the two hemispheres²⁶.

Studies of other people who had suffered damage to one or other hemisphere had already revealed some knowledge of the different specialisations. In the main, these studies had shown the fundamental importance of the left hemisphere - it controlled speech functions and the verbal reasoning normally associated with logical thought. The right hemisphere appeared to have no such important functions. Indeed, the right became known as the 'minor' hemisphere, and the left as the 'major' hemisphere. Nevertheless, there is an equal sharing of control of the body; the left hemisphere controls the right side, and vice versa, for some perverse reason known only to the Grand Designer in the Sky.

This left-right crossover means that sensory reception on the left side of the body is communicated to the brain's right hemisphere, and vice versa. This even applies, in a more complex way, to visual reception; it is not simply that the left eye communicates with the right hemisphere, and vice versa, but that, for both eyes, reception from the left visual field is communicated to the right hemisphere, and vice versa. Ingenious experiments were therefore devised in which visual stimuli could be sent exclusively to either the left or right hemisphere of the split-brain subjects.

These experiments showed that the separated hemispheres could receive, and therefore 'know', separate items of information. The problem was how to get the hemispheres to communicate what they knew back to the experimenter. The left hemisphere, of course, can communicate verbally, but the right hemisphere is mute. Some experimenters resolved this problem by visually communicating a word or image to the right hemisphere, and asking it to identify a matching object by touch with the left hand.

From experiments such as these, neuropsychologists developed a much better understanding of the functions and abilities of the right hemisphere²⁷. Although mute, it is by no means stupid, and it perceives and knows things that the left hemisphere does not. In general, this is the kind of knowledge that we categorise as intuitive. The right hemisphere excels in emotional and aesthetic perception, in the recognition of faces and objects, and in visuo-spatial and constructional tasks. This scientific, rational evidence therefore supports our own personal, intuitive understanding of ourselves, and also supports the (often poorly articulated) view of artists and many designers that verbalisation (i.e. allowing the left hemisphere to dominate) obstructs intuitive creation.

Anita Cross has drawn attention to the relevance of 'split-brain' studies to improving our understanding of design ability²⁸. One set of experiments which seems to be particularly relevant to design ability tested split-brain subjects on their recognition and intuitive comprehension of shapes and objects belonging to different geometrical classes²⁹. No formal knowledge of geometry was required, but the shapes were presented in sets corresponding to euclidean, affine, projective and topological geometries. Each subject was presented visually with five shapes in each set, and

then asked to select from three further shapes, by touch only, one which belonged to the same set. In comparing the performance of left and right hands, the left hand (i.e. right hemisphere) is clearly superior (Figure 4). However, the superiority also varies consistently over the four geometrical categories, from euclidean, through affine and projective to topological, suggesting that the left hemisphere becomes progressively less able to identify the more complex, subtle and unconstrained geometries (Figure 5).

Several examples of the problematic behaviour and perception of people with right-brain damage have been reported by Sacks, including 'the man who mistook his wife for a hat' and who could not recognise a glove³⁰. When Sacks held up a glove and asked 'What is this?', the patient described it as 'A continuous surface, . . . infolded on itself. It appears to have five outpouchings, if that is the word . . . A container of some sort.' There is a weird logic to this reasoning, but no intuitive perception of the object and its obvious function.

It is now known, therefore, that damage to the right hemisphere can impair brain functions that relate strongly to intuitive, artistic and design abilities. This has been confirmed by studies of, for instance, drawing ability. One classic case is that of an artist who suffered right-brain damage³¹. Although he could make an adequate sketch of an object such as a telephone when he had it in front of him, he could not draw the same object from memory and resorted instead to 'reasoning' about what such an object might be like (Figure 6).

Studies of split-brain subjects have also shown, in general, that they can draw better with their left hand (even though they are not naturally left-handed people) than their right³². Recognition of this right-brain ability has been put to constructive use in art education by Betty Edwards, who trains students to 'draw on the right side of the brain'³³.

There is also, of course, a long history of studies in psychology of cognitive styles, which are usually polarised into dichotomies such as

- convergent - divergent
- focussed - flexible
- linear - lateral
- serialist - holist
- propositional - appositional.

Such natural dichotomies may reflect the underlying dual structure of the human brain and its apparent dual modes of information processing. Mike Nathenson and I have drawn attention to the importance of understanding cognitive styles for design education and design methodology³⁴. This work has also been taken up by James Powell and his colleagues in the design of information systems for designers³⁵.

Design as a form of intelligence

What I have attempted to show is that design ability is a multi-faceted cognitive skill, possessed in some degree by everyone. I believe that there is enough evidence to make a reasonable claim that there are particular, 'designerly' ways of knowing,

thinking and acting³⁶. In fact, it seems possible to make a reasonable claim that design ability is a form of natural intelligence, of the kind that the psychologist Howard Gardner has identified³⁷.

Gardner's view is that there is not just one form of intelligence, but several, relatively autonomous human intellectual competences. He distinguishes six forms of intelligence:

- , linguistic
- , logical-mathematical
- spatial
- musical
- bodily-kinaesthetic
- personal.

Aspects of design ability seem to be spread through these six forms in a way that does not always seem entirely satisfactory. For example, spatial abilities in problem-solving (including thinking 'in the mind's eye') are classified under spatial intelligence, whereas many other aspects of practical problem-solving ability (including examples from engineering) are classified under bodily-kinaesthetic intelligence. In this classification, the inventor appears alongside the dancer and the actor, which doesn't seem appropriate.

It seems reasonable, therefore, to try to separate out design ability as a form of intelligence in its own right.

Gardner proposes a set of criteria against which claims for a distinct form of intelligence can be judged. These criteria are as follows, with my attempts to match 'design intelligence' against them.

Potential isolation by brain damage. Gardner seeks to base forms of intelligence in discrete brain-centres, which means that particular faculties can be destroyed (or spared) in isolation by brain damage. The evidence here for design intelligence draws upon the work with 'split-brain' and brain-damaged patients, which shows that abilities such as geometric reasoning, 3-dimensional problem solving and visuo-spatial thinking are indeed located in specific brain-centres.

The existence of *idiots savants*, prodigies and other exceptional individuals. Here, Gardner is looking for evidence of unique abilities which sometimes stand out in individuals against a background of retarded or immature general development. In design, there are indeed examples of otherwise ordinary individuals who demonstrate high levels of ability in forming their own environments - the 'naive' designers.

An identifiable core operation or set of operations. By this, Gardner means some basic mental information-processing operation(s) which deal with specific kinds of input. In design, this might be the operation of transforming the input of the problem brief into the output of conjectured solutions, or the ability to generate alternative solutions. Gardner suggests that 'Simulation on a computer is one promising way of

establishing that a core operation exists.’ Work on the automatic generation of designs by computer is therefore helping to clarify the concept of design intelligence.

A distinctive developmental history, and a definable set of expert, end-state performances. This means recognisable levels of development or expertise in the individual. Clearly, there are recognisable differences between novices and experts in design, and stages of development amongst design students. But a clarification of the developmental stages of design ability is something that we still await, and is sorely needed in design education.

An evolutionary history. Gardner argues that the forms of intelligence must have arisen through evolutionary antecedents, including capacities that are shared with other organisms besides human beings. In design, we do have examples of animals and insects that construct shelters and environments, and use and devise tools. We also have the long tradition of vernacular and craft design as a precursor to modern, innovative design ability.

Susceptibility to encoding in a symbol system. This criterion looks for a coherent, culturally-shared system of symbols which capture and communicate information relevant to the form of intelligence. Clearly, in design we have the use of sketches, drawings and other models which constitute a coherent, symbolic media system for thinking and communicating.

Support from experimental psychological tasks. Finally, Gardner looks for evidence of abilities that transfer across different contexts, of specific forms of memory, attention or perception. We only have a few psychological studies of design behaviour or thinking, but aspects such as solution-focussed thinking have been identified. More work in this area needs to be done.

If asked to judge the case for design intelligence on this set of criteria, we might have to conclude that the case is ‘not proven’. Whilst there is good evidence to meet most of the criteria, on some there is a lack of substantial or reliable evidence. However, I think that viewing designing as a ‘form of intelligence’ is productive; it helps to identify and clarify features of the nature of design ability, and it offers a framework for understanding and developing the nurture of design ability.

II NURTURE

Learning to design

How do people learn to design, and on what principles should design education be based?

Clearly, some development of design ability does take place in students - certainly at the level of tertiary, professional education, where we can compare the work of the

same student over the years of his or her course. The crude, simple work of the first-year student develops into sophisticated, complex work by the final year. But the educational processes which nurture this development are poorly understood - if at all - and rely heavily on the project method.

Modern design education owes much to the experimental work of the Bauhaus - the German design school of the nineteen-twenties and early thirties - in particular, the radical 'basic course' introduced by Johannes Itten. As Anita Cross has suggested, many of the basic course's educational principles may well have been developed from the work of educational innovators such as Froebel, Montessori and Dewey³⁸. The Bauhaus also integrated design education with aesthetic cultures such as dance, theatre and music, as well as cultures of technology and industry. Itten himself incorporated physical exercises and dietary regimens in his courses, and required his students, for example, to swing their arms and bodies in circular movements before attempting to draw freehand circles. He and other tutors also encouraged tactile perception and the construction of collages from randomly-collected junk and other materials. From what we now know of the development of the thought-modes of the right hemisphere of the brain, these non-verbal, tactile, analogical experiences were intuitively correct aspects of design education.

Most of the Bauhaus innovations are now severely watered-down in conventional design education, usually retaining just a few vestiges of exercises in colour, form and composition. With the possible exception of the HfG at Ulm in the nineteen-sixties, there have been no comparable innovations in curriculum development in design education since the Nazis closed the Bauhaus in 1933.

In fact, the increased attention on design education in the last decade has exposed the lack of any clearly-articulated and well-understood principles of design education³⁹. This lack of clear principles has become particularly evident as design has been taken up as a subject in secondary and primary education.

In general education it is particularly important that teachers have a fundamental understanding of the abilities that they are seeking to develop in their students. In tertiary, professional education, teachers can get by as long as their students are reasonably competent enough to enter their profession at the end of their course. In professional education the distinctions between education and training are perhaps less clear-cut than they are in general education, where no particular profession is the goal. Professional education has instrumental, or extrinsic aims, whereas general education has to pursue intrinsic aims that are somehow inherently good for the individual³⁶.

I would suggest that it is through understanding the nature of design ability that we can begin to construct an understanding of the intrinsic values of design education. For example, we can make a strong justification for design based on its development of personal abilities in resolving ill-defined problems - which are quite different from the well-defined problems dealt with in other areas of the curriculum. We can also justify the designer's solution-focussed strategies and appositional thinking styles as promoting a certain type of cognitive development - in educational terms, the concrete/iconic modes that are often assumed to be the 'earlier' or 'minor' modes of cognition, and less important than the formal/symbolic modes. Furthermore, there is

a sound justification in the educational value of design in its development of the whole area of non-verbal thought and communication.

There is a wider view of all this which suggests that conventional education is still rigidly divided between the two cultures of the Arts and the Sciences. However, Technology - centred on design ability - can be viewed as a third culture, with its own things to know, ways of knowing them, and ways of finding out about them⁴⁰. The knowledge, values and skills of these three cultures can be distinguished as follows:

Field of knowledge

Arts - human experience
Science - the natural world
Technology - the artificial, human-made world

Range of values

Arts - subjectivity, imagination, commitment, and a concern for 'justice'
Science - objectivity, rationality, neutrality, and a concern for 'truth'
Technology - practicality, ingenuity, empathy, and a concern for 'appropriateness'

Types of skills

Arts - criticism, analogy, evaluation
Science - experiment, classification, analysis
Technology - modelling, pattern forming, synthesis

Learning design at a distance

To attempt design education 'at a distance' has been a great challenge. At first, we had real doubts about how to teach design through the new distance-learning system of the Open University⁴¹. We were not alone: there were certainly those who said that it could not be done! However, as the design work of many of our OU students now shows, some development of design ability does take place through our distance-learning courses, just as it does in conventional courses.

The problem as we perceived it in the OU in 1970 was that 'the medium is the message', and the media of the OU seemed to impose a student role as the passive receiver of pre-packaged knowledge. Such a role is particularly inappropriate in design education; design ability cannot simply be transmitted through a communication medium - the student needs to engage actively with the designing/learning process. Our first attempts at distance-teaching design were therefore rather tentative; we tended to concentrate on raising design awareness rather than developing design ability.

Certainly, traditional design education has little in common with the approaches demanded by the OU. It relies heavily on face-to-face teaching, on project work and

on 'over-the-drawing-board' tuition and informal learning in the design studio. The only major aspect that fits without too much difficulty into the OU system is project work, although even here our students lack the intensive support - from both tutors and fellow students - that can be provided in conventional education.

However, there are, of course, many positive aspects to the OU. One of the most important is the students themselves, who are highly motivated and committed learners. Also, our students are not seeking the kind of vocational design education that is provided by the schools of professional design such as architecture or industrial design. Design education in the Open University therefore has much in common with other new forms of education elsewhere, such as in the schools, and we can see our own efforts as a major contribution to design in general education. This means that we, too, must normally concentrate on the intrinsic values of learning to design, such as appropriate forms of cognitive development, non-verbal thought and skills for resolving ill-defined problems. Of course, this doesn't make our task any easier!

If we look at the range of media available to us in the Open University, then some are better than others at meeting different kinds of educational purpose (Figure 7). The medium that is used most heavily is text, which is very good for imparting knowledge, less good at transmitting values, and very poor at developing skills. Broadcast TV, however, can be a strong communicator of values, and can be very helpful in demonstrating skills, but is a poor medium for transmitting factual knowledge. The best distance learning medium for skills is one that is under the student's control, allowing them to stop and practice what has been demonstrated, and to replay the demonstration again and again. Some forms of audio-visual media allow this, particularly the video-cassette, which is fundamentally different from broadcast TV. Recently, we have also been able to experiment with computer-based learning, where students have been able to have a personal microcomputer at home.

Using text

In the early days we were limited to text, and to broadcast TV and radio. We used text to develop design awareness and knowledge about design; we also had to use it to try to develop some aspects of design skill. For this, we invented novel forms of text, such as PIG - the Problem Identification Game, developed by Reg Talbot and Robin Jacques. This was designed to support the early stages of student project work - clarifying a problem for their project which was interesting, feasible and worthwhile. Although it included a game-like component, with a board, cards and a die, it actually offered a structured systems approach to defining a clear problem from within a messy problem area.

Some aspects of design ability have been codified into 'design methods'. Without those methods, it would have been much harder for us to clarify and to try to teach some elements of design ability. The approach we adopted in our early OU courses was to provide manuals of design methods. These presented a variety of methods in 'teach-yourself' formats, and the idea was that - as with other kinds of reference manuals - the student looked up, and learned, a method as and when it was relevant to his or her project work. Of course, this approach also needed to provide guidance on how and when to choose appropriate methods.

However, we found that our OU students - more mature and committed than most conventional undergraduates - did not seem to need such elaborate project support materials, and in our more recent courses project guidance and design methods are presented in rather more straightforward formats.

Using television

From the beginning of teaching design in the OU, we were concerned about the role that broadcast television could play. It could clearly play a substantial role in developing design awareness (its strong role as a values educator), but how could it be used to develop design ability (its weaker role as a skills educator)?

In the first Open University TV programme on design (part of the Technology Foundation Course, made in 1972) I shared this concern with the students. After an introductory sequence on 'design failures', which was aimed at raising students' awareness of the role of design in technology and particularly in some of the shortcomings of modern technology, I asked for the camera to pull back to show the TV studio with its other cameras and operators, microphones, lights, etc., so as to demonstrate the restrictions of studio-TV. I then went on to emphasize that learning to design meant actively engaging with designing, and that therefore it could hardly be learned from passively watching TV.

After this and other experiments, we did find better uses for TV in our first full Design course, *Man-Made Futures*, first presented in 1975. As well as programmes in raising design awareness, we also made some efforts to help develop design ability in our students. For example, we used TV to demonstrate the approach to playing PIG - the Problem Identification Game - and the kind of creative, relaxed attitude of mind that was necessary to its success. I also made a TV programme which sought to demonstrate the skills of using design methods; the design of the programme itself became the self-referential topic on which I conducted my design exercise. That is, I applied design methods to the problem of designing a TV programme on design skills, and demonstrated my own use of the methods, my information-gathering, my pursuit of analogies for design skill, etc., and in these ways demonstrated design skill to the students.

We have also used more conventional approaches to using TV in design teaching. For example, we have shown designers at work, and interviewed them, and we have made programmes about the design of a variety of products, from telephones to trains. Reflecting the predominantly layperson's perception of our OU students, many of these product-orientated programmes have taken the user's point of view in evaluating products, rather than the designer's point of view which predominates in conventional design education.

In conventional design education, however, I believe that students gain considerable educational benefit from working alongside fellow-students, seeing the range of work that is produced, and hearing tutors criticize the whole body of work produced by a year-group of students on a project. For another of our Design courses, therefore, I made a pair of TV programmes which showed groups of design students at Polytechnics tackling similar problems to those which we set our OU students. These

surrogate peer-group experiences not only included examples of student work but also student-to-student feedback, advice and tips on how to tackle the design project.

From early uncertainties about the use of TV, therefore, over a 10-year period there was considerable learning from experience and experiment, growing confidence, and an increasingly positive attitude towards TV. Working with our BBC colleagues, we have found ways in which OU students can benefit from the TV medium in developing both design awareness and design ability.

Using video and other audio-visual media

An important recent development has been a shift from broadcast TV to video-cassette. Student response to this shift is overwhelmingly positive. In our most recent course, *Computer Aided Design*, we were able to use video-cassettes instead of broadcast TV, and this enabled us to demonstrate both the principles and the practice of CAD in formats which would not always be appropriate for broadcast TV. For instance, we can expect student to view video-cassette sequences of various lengths at the most appropriate study-points; we can expect them to observe demonstrations closely, and to replay them until they are happy that they have understood; we can ask them to stop the tape whilst they reflect and answer study questions, refer to other sources, or think about the next sequence before they see it. In these ways, television becomes an interactive learning medium, and has a much stronger role in helping to develop design ability.

In recent years, several of my OU colleagues have also developed specific design skill-tutoring packages using both video-cassettes and audio-cassettes backed up with graphic materials. For example, teaching of both informal and formal drawing techniques has been approached through these media.

Using computers

The video screen is, of course, similar to the computer screen, and this made video perhaps particularly appropriate in a course in computer aided design. But the other important development in our CAD course was the use of the computer itself. We have been very fortunate in being able to loan students on this course a Nimbus personal computer, with colour monitor, and the new and original teaching developed by Jeff Johnson on the Nimbus has been an outstanding feature of the course.

There are two conventional roles for the computer in design education. Firstly there is CAD - students learn to operate a computer aided draughting/design system as part of their training in design skills. Secondly there is CAL - computer assisted learning of relevant scientific and technical knowledge. A possible third role, relatively unexplored, is CAD-Ed - using the computer in design education to develop design ability and designerly ways of thinking. This latter role is the most difficult to develop, not least because it is easy to allow the computer to dominate and to force students into inappropriate learning styles. The challenge is to design CAD-Ed systems that are not just educational but also designerly⁴².

The computer-based learning in our *Computer Aided Design* course includes CAD and CAL, but it also has some features that I would regard as examples of CAD-Ed.

For one thing, the documentation for the suite of 'CADPAC' exercises in the course is not a 'computer manual', but is in fact a teaching text, which encourages and requires students to reflect on the lessons they learn about design as they work through the exercises.

For example, the role and nature of constraints in design is raised in discussion of the evaluation criteria used in CADPAC for checking designs created by the student and for selecting designs created by its own automatic design-generation routines. The possibilities and limitations of designing by rule-following are also raised by these automatic synthesis routines, and discussed in the accompanying text.

The creation of designs by the student is made easier by the CAD facilities of CADPAC, particularly through the on-screen manipulation of icons. Both architectural and electronic design is facilitated in this way. Icons can easily be moved, rotated, replaced, etc., and so the generation of revised and alternative configurations is made considerably easier. This facility should therefore make much easier the necessary generation of alternatives at an early stage of the design process, and encourage students to experiment with alternatives.

Many aspects of draughting are made easier by CAD systems (and many made much harder by some systems!). Draughting systems (such as the Scribe system incorporated in CADPAC) clearly enable students to generate both 2D and 3D representations of designs that they might otherwise find difficult to draw. This is a particular advantage in the OU, where we are not able to provide the lengthy apprenticeship in draughting techniques that is included in conventional design education.

However, replacing manual draughting skills by computer draughting techniques does raise important questions for design education and the development of design ability. It may be that learning to draw is an essential aspect of learning to design, particularly with regard to the development of visuo-spatial cognitive abilities⁴³.

Some development of such abilities may nevertheless be helped by CAD-Ed systems. For example, 3D visualisation in the mind's eye is crucial when using a CAD modelling system. The ability to imagine a 3D form, then orientate and position it relative to other 3D forms requires quite precise mental imagery, which is then quickly verified or contradicted by the computer representation. Other aspects of visuo-spatial ability, such as the exploration of perspective or the movement of objects in space and time, are also helped through the relevant CADPAC exercises.

We have shown, therefore, that the computer can quite properly play a role as a medium in design education.

The development of design ability

When I started my first courses as an undergraduate student in engineering I was bitterly disappointed to discover that they included nothing remotely resembling design work. Very soon, I changed to studying architecture, in which the great majority of time was devoted to design project work of all kinds. But I was

disappointed there, too, by the lack of tuition in actually 'how to do it' - students could sink or swim in unguided project work, and sometimes I sank!

At around the same time, the new topic of 'design methods' was appearing, and I found some of the methods helpful as lifejackets. I went on to further study and research in such methods, and that was how I became interested in the nature and nurture of design ability. What I hope we shall achieve through academic design studies is that design education will become a reliably successful means for the development of design ability in everyone.

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Figures

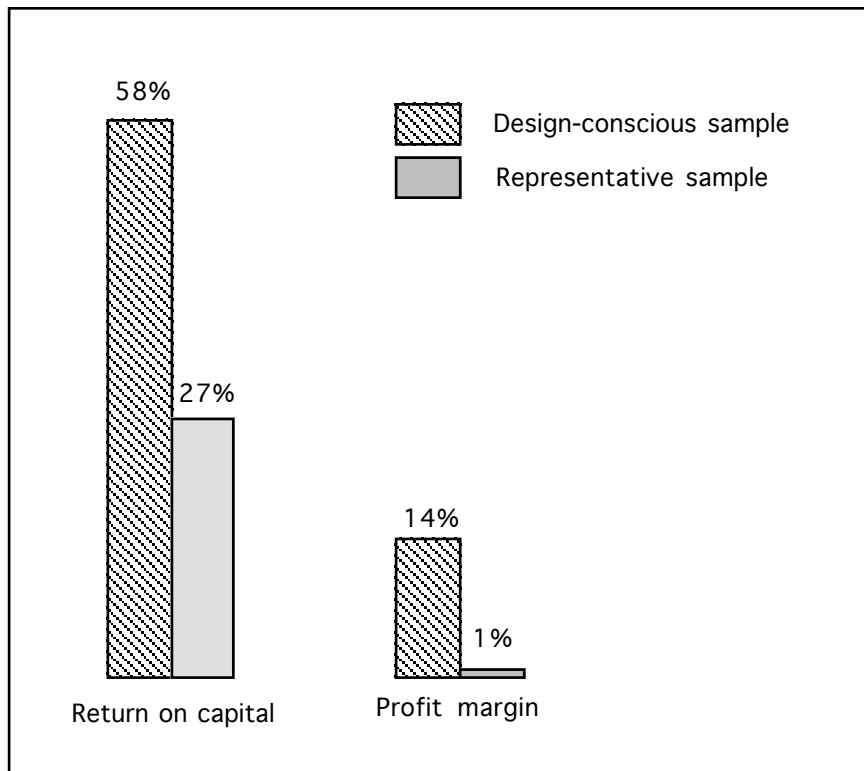


Figure 1

Business performance of UK firms (1976 - 82)
(Heating, Office furniture, Electronic business equipment)

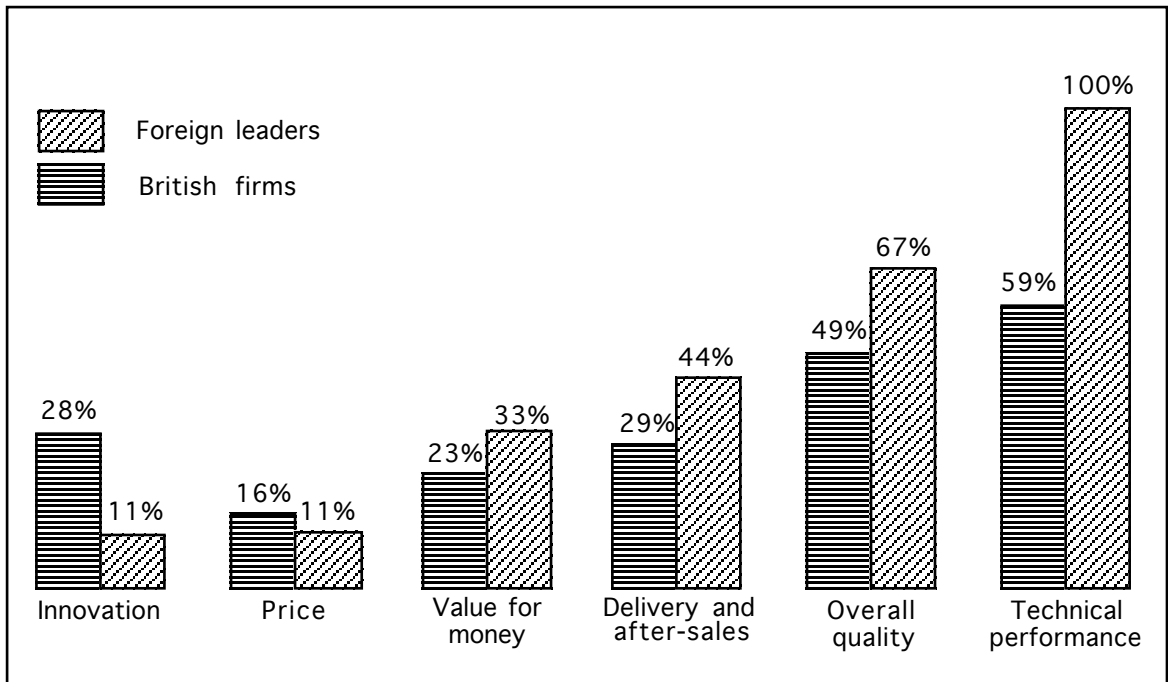


Figure 2

Product factors considered to give a 'competitive edge'

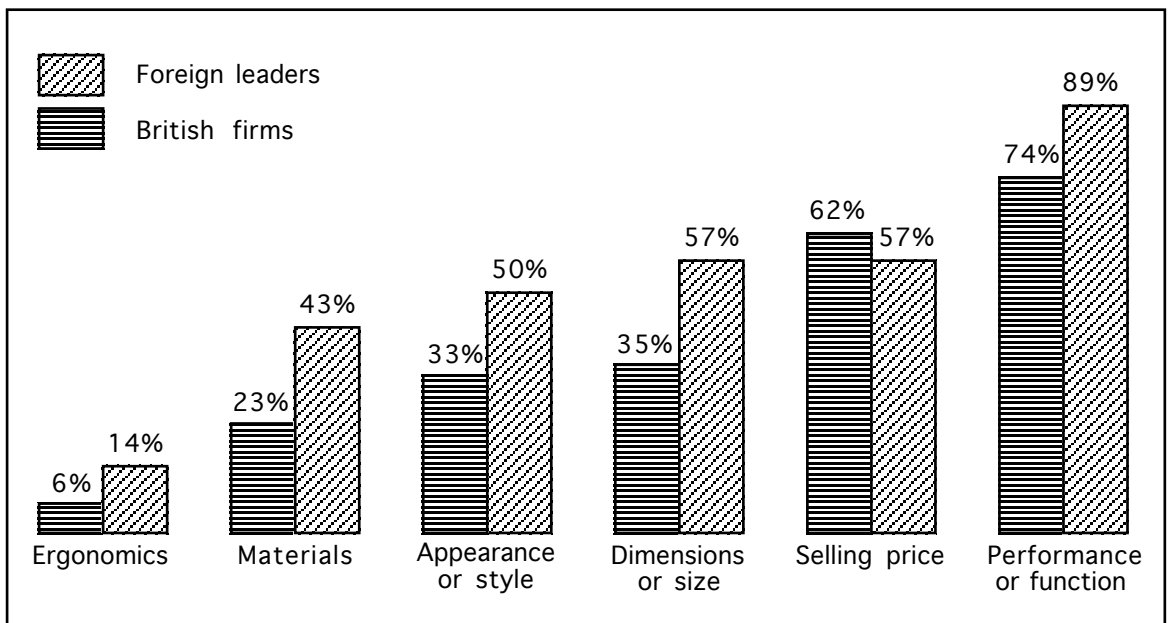


Figure 3

Factors included by management in the product brief

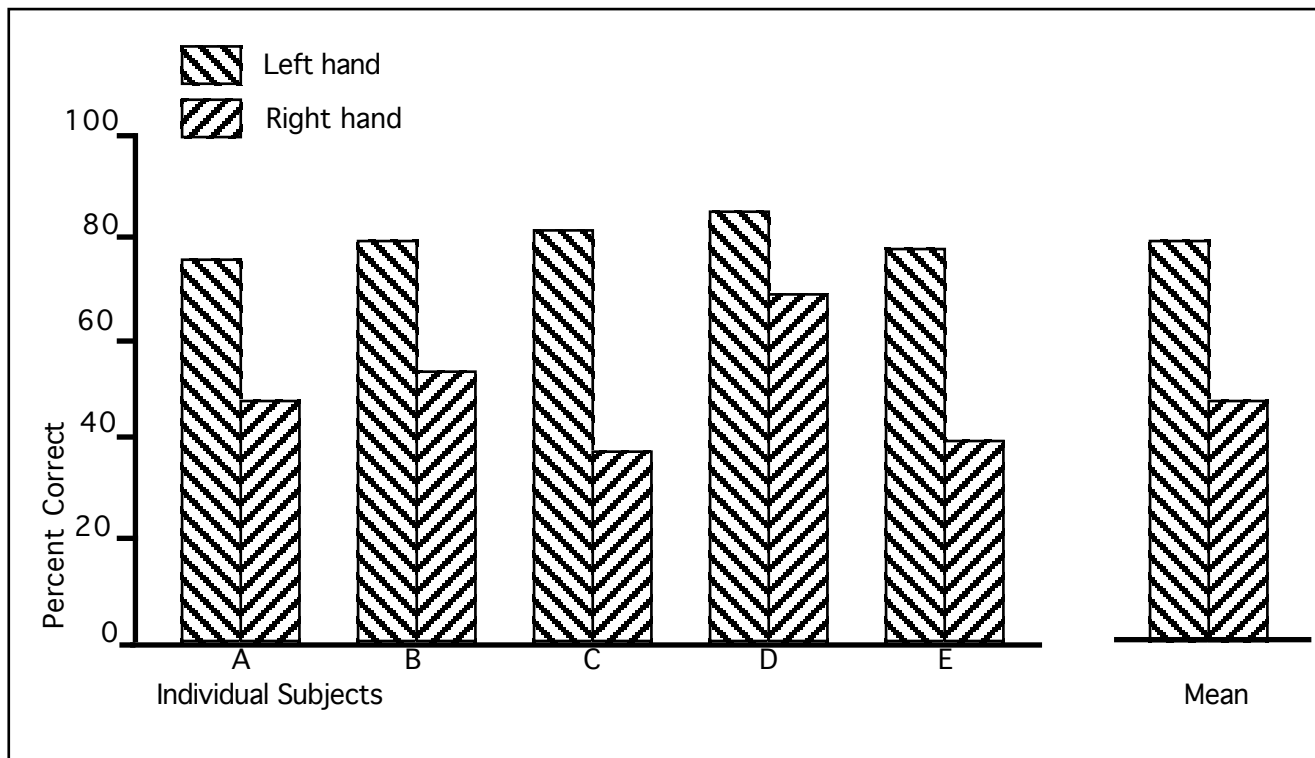


Figure 4

Geometry tests on split-brain subjects: comparison of left- and right-hand performance

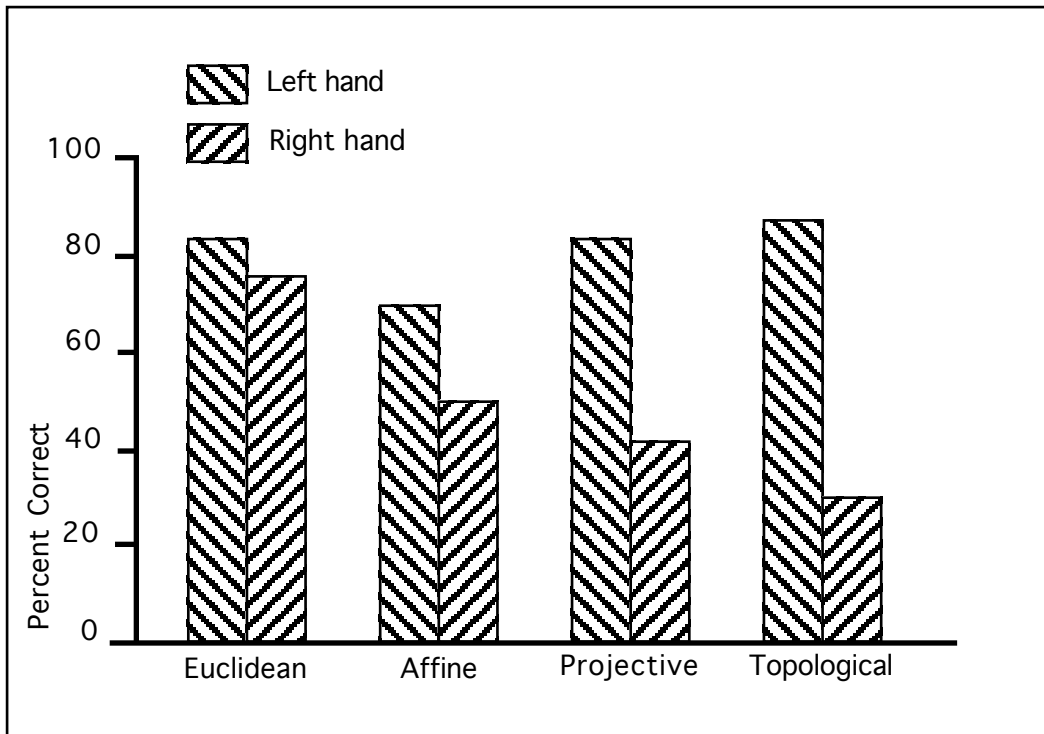


Figure 5

Geometry tests on split-brain subjects: left- and right-hand performance for different geometries

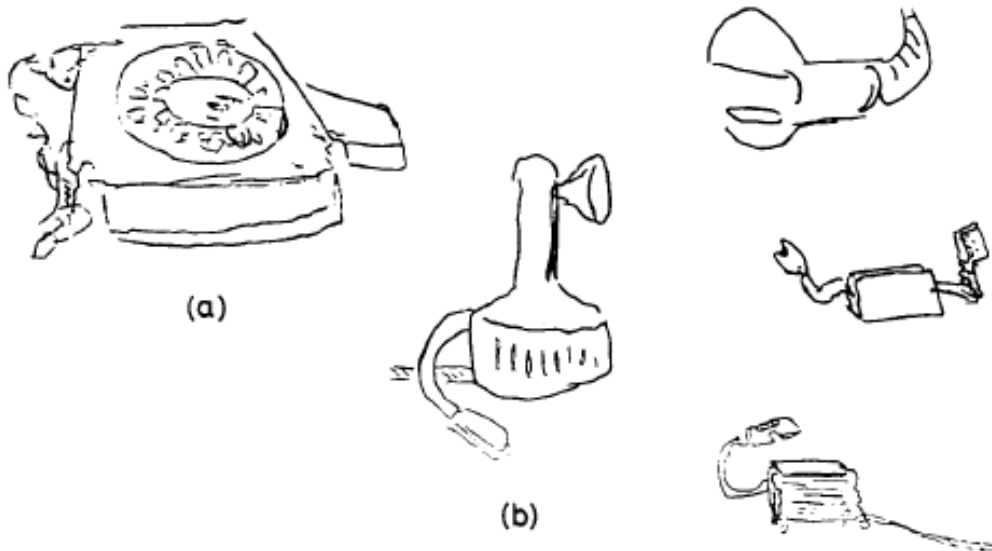


Figure 6

Drawings of a telephone by an ex-artist with right-brain damage
 (a) drawing from a model
 (b) drawing without a model

Distance-learning medium	Type of learning:		
	Knowledge	Values	Skills
Text	✓✓✓	✓✓	✓
Broadcast TV	✓	✓✓✓	✓✓
Video and A/V	✓✓	✓	✓✓✓
Computer	✓✓✓	✓	✓✓

Figure 7

Comparative strengths of distance-learning media for types of learning