Models of change: the impact of ‘designerly thinking’ on people’s lives and the environment: seminar 1 ... modelling and intelligence


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MODELS OF CHANGE

The impact of ‘designerly thinking’ on people’s lives and the environment

Seminar 1 … Modelling and Intelligence

Design: Occasional Paper No 3

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BACKGROUND

This is the first publication relating to a seminar series being led by Ken Baynes, who is a Visiting Professor in the Department of Design and Technology at Loughborough University. Consequently these seminars will be organised through Loughborough’s Design Education Research Group (DERG). The titles of these seminars are:

- Modelling and Intelligence
- Modelling and the Industrial Revolution
- Modelling and Design
- Modelling and Society
- Modelling and the Future

The role of modelling in designing has been a key research interest of the DERG since its establishment, but it has never been more important as Ken Baynes's introduction to the seminar series makes clear. It is easy to say that designing is to do with creating preferred futures, but much harder to explain and understand how that can be achieved.

The first of these seminars will take place at the Design and Technology Association’s International Research Conference at Loughborough on Tuesday 30 June. It is hoped that the second will take place at the 1st International Visual Methods Conference at the University of Leeds in September, the third in the Department of Design and Technology at Loughborough in association with the visit of the Quick on the Draw Exhibition, and the fourth seminar at Goldsmiths University, London. An Orange Series publication will be available for free download about a month before each seminar via the DERG website, where details of venues and associated audio files and PowerPoint presentations will also be posted (http://www.lboro.ac.uk/departments/cd/research/groups/ed/index.htm)

There is no denying that current initiatives relating to STEM are important, but many commentators have noted the absence of ‘design’ in much of the emerging thinking. It is truly vital that the significance of such omissions is understood and that the role of modelling in designing, and hence in shaping the future is fully appreciated. Ken Baynes and his colleagues at the Design Education Unit at the Royal College of Art (eg Bruce Archer and Phil Roberts) took part in what can viewed as parallel debates in the 1970s. Time and circumstances have moved on and it is not the same debate, but we need a similar outcome. Design and designing need to be recognised for what they are and the vital roles that they play. Some commentators trace the origins of design and technology to those debates in the 1970s, and it is time both to revisit and renew the fundamental ideas and concepts that provide its foundations.

It has been both a pleasure and privilege to help bring Ken’s writing and ideas into the public domain.

Eddie Norman
Loughborough
May 2009
ACKNOWLEDGMENTS

It has been a pleasure to work on this book reflecting, as it does, a lifetime’s interest in the nature of creative thought. I am particularly grateful to Loughborough University for giving me the opportunity to complete the project. I owe a special debt to my colleagues in the Department of Design and Technology. Professor Phil Roberts and I have many times debated the issues that are central to this book and I have to thank him for his continuing intellectual stimulus – also for his direct contributions and indispensable ‘critical friend’ response to my first drafts. Dr Eddie Norman has been instrumental in bringing the book to print and giving it life on the Internet and through a number of international seminars. This approach will create instant feedback and it is exciting to think that many other contributions will speedily be brought to bear on what I believe is a very important subject. Without Eddie’s help it just would not have happened.

Over the years, Eileen Adams of the Campaign for Drawing and Roger Standen of the Design Dimension Educational trust have helped me develop the ideas on which this book is based.

My greatest thanks go to my wife Krysia Brochocka. She is both intellectual colleague and practical supporter. She has encouraged me at every turn and whenever the going got rough insisted that the job needed to be finished! Her readings and suggestions have been invaluable.

Ken Baynes
Burley-on-the-Hill
April 2009
ILLUSTRATIONS

A number of the illustrations in this publication come from QUICK ON THE DRAW, an exhibition about the everyday uses of drawing. The show was organised by Brochocka Baynes in conjunction with the City Art centre, Edinburgh; the Harley Galllery, Welbeck; and Croydon Clocktower. It was shown in addition at Loughborough University in Autumn 2009 where it was accompanied by seminars and events about the significance of modelling and the value of drawing as a modelling medium. Other illustrations come from items in Professor Baynes’ collection and the work of staff and students in the Department of Design and Technology at Loughborough. Many thanks to Xenia Danos for her work in photographing many of the items from QUICK ON THE DRAW.
INTRODUCTION

Unlike other animals, human beings do not survive only by adapting to their environment, they also change their environment. Not only do they change the natural environment, they also create a human environment. This human environment is a complex of ideas, institutions, knowledge, communications, systems, things and places. It is dynamic. Human culture is itself constantly changing. Each generation of people are part of a process by which they are subtly different from the generation before and will, in turn, have children who are subtly different from them.

People’s impact on the planet has been substantial and, in the last two hundred years, has become potentially dangerous. Using the human environment as their base, people have begun to deplete and damage the natural environment. Over much of the earth’s surface the evidence of human activity overshadows the natural world. The ravenous appetite of industrialization is directly responsible for destroying plants and animals and depleting and polluting the land, the oceans, and even (through global warming) the atmosphere.

Of course, human beings have not set out to damage their home planet. The paradox is that the negative impact on the natural world comes from some of the most creative and intellectually daring of people’s activities. Science, technology and design have interacted with the driving force of free market economics to shape contemporary culture. In many fields of enquiry, the human mind finds itself exploring ideas and worlds of meaning that would, quite literally, have been unthinkable a hundred or even fifty years ago.

Evolutionary biologists have tried to identify the circumstances and capabilities that have led homo sapiens to occupy such a dominant position. They focus on our ‘general purpose intelligence’. It is this that allows us not only to learn from experience but also to react in new ways to new situations. However, humans do more than react. They are curious and speculative. They are constantly trying to construct a framework of meaning to explain the world and their place in it. They make artefacts not only to achieve practical goals but also, in the form of art, to embody and express meaning. They often try to preserve the status quo but equally they may want to try something new, almost for its own sake. This desire to open up new possibilities goes beyond any narrow interpretation of problem solving. Problems are indeed solved but there is also a search for new horizons. Ironically, the search for new horizons may produce new problems so that a part of the dynamic of ‘progress’ is the emergence of unforeseen and unwanted side effects.

Since the industrial revolution, material culture has hugely expanded in scope, far outstripping our grasp of the intellectual, economic, technological and social forces at play. It almost seems that our genius for making new things is out of control. We often find that the results of technological and design activity are not what we thought they would be. The ramification and multiplication of things has results far beyond everyday practicality. The organisation of the world of things implies matching changes in the
organisation of the world of people. For example, new communications technologies reach into lived experience and affect how people view themselves and how they relate to one another. It turns out that changes in technology impinge on spiritual and aesthetic values as much as they do on work or shopping or travel.

In view of its importance in the contemporary world, the mental capacity involved in shaping the environment has been surprisingly little studied. Compared with the significance attributed to language, it is allocated an inferior position. However, the argument advanced in this seminar series is that the very survival of human civilization depends precisely on our developing a better understanding of this aspect of ourselves.

Cognitive science now recognizes that the mind engages with the world through the medium of mental models. These represent or stand for external reality as presented through the senses. They are neurological constructs which can be manipulated neurologically. Memory uses models of past experience. This enables us to learn from our actions, to store knowledge and to have a sense of continuity with our ancestors. Even more remarkably, the mind can also model things which do not exist. These can be fantasies but equally they can be plans for the future – proposals for things, events or institutions which might one day be brought into existence.

Designing is one of a number of ‘intentional activities’ through which humans shape the future. The particular arena for design is material culture in all its complexity. Material culture is not simply ‘practical’, it is the result of beliefs and desires, ideals and values as much as functional necessity. A useful way of looking at material culture is to say that there are always two aspects to ‘function’ : function in the sense of physical performance; and function in the sense of carrying cultural and other human values or messages. The two are inseparable. Performance and values interact with each other to create an environment which attempts to achieve the purposes of human beings.

Although the focus of professional design activity is material culture, this does not mean that it is solely concerned with shaping the future of ‘things’. The contents of material culture take their significance from the human activities which they support and enable. Design activity is essentially concerned with human behaviour and human potential far beyond the obvious boundaries of ‘things’, reaching out into the wider field of intentional activity in general. Material culture is a dynamic and changing arena which is as much about what people do and want as the physical world they inhabit. In fact, it links the two.

Although design activity is a universal aspect of human societies, its character varies dramatically between one culture and another. The way designing is carried out, who does the design work and who controls what is done, depends on the beliefs, values, resources, political organization and technological know-how of a particular culture. Living in a democratic society dominated by the market economy gives us a view of design which is very different from that which prevailed in medieval times. Beliefs, values and
economic priorities have a powerful influence. Contrast, for example, the prominence of social buildings (hospitals, town halls, water works, libraries) in the nineteenth and twentieth centuries with the cathedrals, monasteries and castles of the thirteenth century. Design effort goes where society wants it to go, or where power directs it.

In pre-industrial societies, it is often difficult to distinguish designing from making. The maker or craftsperson was also the designer and more often than not he or she was reproducing something made before. Skill in making developed and refined what was made and demand sometimes led to incremental improvements in details of the product. However, there was not specialist design activity. Rather it was design activity fully embedded in craftsmanship.

Design activity, practiced as a specialism, emerged as society grew more complex and embarked on ambitious attempts to shape and control the environment. Inevitably, those in power were in control. Early design specialists included architects for temples, memorials and palaces; experts on water and irrigation; and military engineers. It is clear that these prototype ‘professionals’ made use of modelling techniques: they were often depicted with drawings or physical models and it is clear from what they designed that they made effective use of basic mathematical modelling.

For example, the emergence of a cadre of naval architects in the Tudor period reflected the growing competition for trade with distant lands and the matching developments in naval warfare. Contemporary illustrations show these new professionals at work using drawings and mathematics as modelling tools, first to explore the design of innovative ships and then to control their production. The same period saw a dramatic development in map-making and the graphic design of maps. These maps were needed not only by mariners but also by merchants and politicians who were looking across the seas for wealth and power. They provided a picture or model of a wider world and were a key to gaining power over it. They could be used to show conquests and to record the rights of new ownership.

In classical times, the Roman architect Vitruvius had already written on the importance of models in architecture and engineering. His work, in turn, influenced Renaissance designers. By the eighteenth century the stage had been set for the explosion of design activity that marked the Industrial Revolution. Throughout this time, the key modelling media were drawings and numbers. In the new graphic forms of technical, engineering and architectural drawing, the two came together to create a very flexible, well-understood medium for developing and communicating proposals for future designs.

The value of modelling in relation to design was clearly recognized in Britain, France and North America in the nineteenth century, though the term ‘modelling’ was not used. Skill in sketching, measured drawing, technical drawing and model making were an essential part of the training of architects, engineers and industrial designers as well as soldiers, surveyors, cartographers and many others. Skilled artisans were expected to be able to
make informative sketches. Publishing technical illustrations to convey ideas and proposals became widespread.

It was less widely understood that drawing was not simply a way of conveying information but also a tool of the imagination. There was a clear picture of designers – particularly engineers – as people who shaped the future. How they did it, what mental processes they used, and what tools they used to do the job was not much considered. Skills in the key modelling media were taught but there was little theory to explain why they were effective or how a designer should go about the job of designing.

The twentieth century saw the emergence of much polemic on design and its role in society. Some of this had a theoretical flavour and there was a re-evaluation of design activity from radical social perspectives. The best known venue for these developments was the Bauhaus in Weimar, Germany. This institution proved extremely influential and suggested that rational and systematic approaches to design and designing would prove appropriate in an industrial, mass democracy. In fact, the Bauhaus was building on attitudes to design already visible in the work of nineteenth century engineers who believed that form should follow function and that rational and scientific principles should be paramount. Design theorists in the 1920s and 30s certainly suggested what designers should think about and where they should direct their energies. However, in spite of the growing interest in psychoanalysis, there was little speculation about the way the designer’s mind worked or what, if any, special capacities it had.

The Second World War gave a further decisive boost to science and rational management. It was believed – rightly- that the War had to an important extent been a struggle between scientific elites for technological supremacy. The command of superior technology gave victory. At the same time, the conflict gave birth to the computer, a modelling tool which in a remarkably short time has come to dominate every area of life and every area of design activity from animated films to aeronautics.

It was quickly recognised that design, even in architecture, engineering and industrial design, was in practice a rather chaotic process, lacking systematic rigour and a viable theoretical base. The 1960s saw new interest in the management of design, the psychology of design and the systematisation of design into a bureaucratic process. Much of this was driven by the Cold War and the Space Race but it was also a response to the demand for large and complex design teams to work together on social housing, hospitals, schools, new technological equipment, motorways and airports. The nature of the post-War economy needed designers to form teams and become a part of management.

One result of this was a new interest in design methods. The proposition was that if designers used the appropriate methods throughout the course of a particular piece of design work, the resulting design would be fit for its purpose. It soon became clear that this was optimistic. However, what also became clear was that designers relied on a distinctive mode of thought which
could be identified and fitted into emerging theories of intelligence. Very recently exciting developments in neuroscience have begun to shed light on the status of the brain as a living, biological electro-chemical system with extraordinary powers of ‘mind’, particularly learning and imagination. Evolutionary biologists are now able to interpret the capacity and nature of the human brain as an outcome of the evolutionary niche occupied by humankind. Disciplines such as semiotics and epistemology have begun to explain how it is that words and images convey human meaning and can inspire human action. Educational psychologists place the development of mind in the context of each child's unique genetic heritage and the singular experience of being born and growing up in a particular environment.

The aim here is to utilise some of these insights to explain more precisely how it is that designers can in fact design. I hope one effect will be to remove some of the mystique from design activity and to show that it is a common or ‘normal’ aspect of ordinary human behaviour.

Is this important? I argue that it could hardly be more important. In the light of the environmental challenges facing society, it is essential that we gain a better insight into what might be called ‘designerly thinking’.

It could be said that the ability to use models as a way of shaping the future – designerly thinking – is one of the most dangerous of all human characteristics! It is the use of mental and externalised models in conjunction with our adaptable ‘general purpose’ intelligence that has allowed us to achieve dominance over the whole of the natural world. Specialist design modelling, when associated with science, technology and the market economy has led to an extraordinary expansion of the made world. This has been driven by economic growth but has also created economic growth. Design has had the key role of bringing technology to market, creating and helping to sell a stream of innovative products and services. Taken almost for granted in the ‘developed’ world, they are totally inaccessible to very large segments of the world’s population. It remains far from certain that these taken for granted products and services could ever be extended to the whole of the world’s population without causing catastrophic environmental collapse.

The challenge is that the widespread use of ‘designerly thinking’ has, over a period of two hundred years, changed the material circumstances of many people’s lives and revolutionized the cultural climate in which they live. It has now become urgently necessary that society should better understand how this mental capacity ‘works’ and how it can be focused on imagining the existence of an alternative lifestyle capable of being sustained into the future.
MODELLING AND INTELLIGENCE

It is useful to put the discussion of design and modelling into a wider framework. In recent years, the concept of modelling has begun to be important in the analysis of intelligence and the search for a 'missing link' between the brain as a physical neurological system and the experience of consciousness. It has to be said that only the most general linkages have been established: consciousness remains a puzzle both philosophically and scientifically. Nonetheless, neuroscience, cognitive science, psychology and evolutionary biology have all thrown some fresh light on the nature and origins of the human mind and its use of modelling as a basis of thought.

Looked at in a design perspective, the focus is on the way in which the nature of mind has enabled people to create material culture. What has perhaps been underestimated in the past is the dynamic relationship between the human mind and the made world. One way of looking at the made world is that it is an extension of mind. It not only results from mental processes but in itself embodies and reflects back the meanings implicit in those processes. It is easy enough to see that humans had to be able to form mental models of the future before they could construct a made world: it is less easy to pinpoint the effect of that made world on intelligence and to recognise its status not only as an 'artefact' but as a powerful externalized model. The made world is the product of intelligence and action but it also encourages and fosters intelligence and action. It is this synergy between mind and environment that makes designing important and the results of design significant far beyond their utilitarian impact.

In discussing modelling and intelligence this seminar takes an essentially materialist view of consciousness. It assumes that Descartes was indeed wrong in suggesting a dualism between body and something other called 'mind'. In short, there is no ghost in the machine, no little person or homunculus that is 'us' sitting in the mind and overseeing its operations, self-consciously separate and apart from the electro-chemical processes of the biological brain.

This materialist interpretation of mind is relatively new. Even in the first part of the twentieth century, many of the insights of psychiatry (particularly psychoanalysis) somehow saw the person’s individual psyche as over and above neurological functions. It was Gilbert Ryle’s The Concept of Mind, published in 1949 that launched a decisive attack on dualism. His views echoed Wittgenstein’s lectures given in Cambridge from 1929 onwards but not more widely known until the publication of Philosophical Investigations in 1953.

Wittgenstein said that consciousness is misconceived if it is ‘compared with a self-scanning mechanism in the brain’. Ryle examined the will, imagination, intellect and emotion, rejecting dualism and stating that to be conscious, to
have a sense of self, is not a by-product of the physical mind but is, in fact, the physical mind in action.

It has to be said that the majority of historical (and many contemporary) images and models to be illustrated and discussed later in this series were made by people with a very different set of philosophical assumptions about mind and body. Many will have believed in dualism; many in the existence of an immortal soul and many will have felt the influence of metaphysical ideas and spiritual longings as a lived reality. It was an essential part of their consciousness. Many great designers have felt inspired by divine powers external to themselves: others have seen it as their role to discover God’s underlying plan for the Universe and to emulate its qualities in their work. In this they reflected Newton’s view of science and applied it to, for example, architecture. Some have seen God as the heavenly designer, at the most profound level the inspiration for their own role in the world. Others have elevated nature to be the heavenly source book, taking their aesthetic from its structures, forms, patterns and textures.

Taking a materialistic approach to mind is not intended to detract from the spiritual content of many great works of design or to pretend that the meaning of culture and individual experience can be explained simply in utilitarian terms. However, it does seem to be an appropriate stance for the present book. Here we are analysing not the philosophical meaning and quality of designed things, or the existential world of human beings, but the aspect of mind which makes it possible to design things and to do it in such a way that they contribute to the imaginative and emotional life of individuals and societies. The aim is to speculate and analyse at the level of the mediums used for thinking and speculating rather than the content of thinking and speculating, though, as we shall see the two levels are intimately connected.

A book which influenced my own approach to this area of investigation was Jane Abercrombie’s *The Anatomy of Judgement*. Published in 1960, the cover design carried a perceptual puzzle which clearly showed the direction the book intended to take.

![Fig 1.1 Cover motif from Jane Abercrombie’s book](image)
Including the second ‘of’, not normally perceived by the viewer, said something interesting about the nature of visual judgement and acuity.

It was no coincidence that Jane Abercrombie spent much of her life in teaching designers. She was reader in Architectural Education at the Bartlett School of Architecture, University College, London until her retirement in 1975. The origins of her book were in a course she taught at the college. It consisted of eight ‘discussions’ with small groups of young architectural students. The hypothesis was ‘that we may learn to make better judgements if we can become aware of some of the factors that influence their formation’. In other words, we should think about thinking as well as simply thinking. She wrote: ‘The main difference between this and traditional methods of teaching is the amount of attention that is paid to the process of observing or thinking, as distinct from the results’.

Part One of what is a short book had the evocative title: *The Relation Between the Inside and Outside Worlds*. This takes us to the heart of what is challenging in any attempt to understand the cognitive processes involved in designing.

What is inside the mind is essentially and qualitatively different from what is outside it. A thought is not a thing – it is in the physical sense a network of electro-chemical signals – yet a thing can be thought using the network. The same is true of a person’s face. A person’s face is not a thought and yet a face can be thought of. In fact, one important centre in the brain is entirely devoted to recognising and interpreting faces. Equally a thought is not the same as a sound wave and a sound wave does not of itself resemble music. So thought is not music, yet a composer can ‘think music’ – enjoy it, perform it and even compose it in the mind. Here we are concerned with the processes and symbol systems that enable designers to ‘think design’ – appreciate it, discuss it and visualize it in the mind.

What makes this possible (and the limitations it imposes on our ability to think) is the concept of ‘model’. This is ‘model’ in the sense used by mathematicians and scientists: essentially something that stands for something else.

In fact, what is ‘out there’ is only ever open to us in model form. A powerful way to understand human perception is to say that it is sense data rendered into decodable models by the neural networks in the brain. These sensory models can be actively explored and used by the person involved. In cybernetic terms we might say that the feedback loop is almost instantaneous. It is rather as if, in relation to what is ‘out there’, we are scripting and shooting our own film – modelling it in fact – physically inside our heads.
THE VARIETY OF MODELS

In ordinary talk we usually use the word ‘model’ to mean a small scale replica. A model railway is a miniature representation of something very much larger. We can hold a 2mm scale locomotive (1:148) in one hand: the real thing would be twice as high as a person. Model soldiers are tiny replicas of fully grown men. It is typical of models this of kind that they are the result of skilled, often amateur, craftsmanship and that the touchstone by which they are judged is their fidelity to the original. Modellers are fussy people who care about the way things are made and the way they look. They will know if the locomotive has the wrong number of rivets or the soldier the wrong number of buttons on his jacket.

Most models of this kind are made just for the sake of building them. They are a project to be achieved. The goal can only be reached by the exercise of skill and craftsmanship. Constructing them is an end in itself. However, many are made also to be ‘operated’ or - better - to be played with. Adult play is constrained; it is serious and goal directed. For example, the model railway may represent an actual place at a particular moment in the past. Care will then be taken to ensure that the trains are authentic. They may be operated strictly according to the original timetable. Model soldiers can be used to re-enact real historic battles or to play out ‘what if’ scenarios. What if the Prussians had been later arriving at Waterloo? What if a particular skirmish had seen different tactics?

In being ‘realistic’ such models share something in common with waxworks. A waxwork is a sculpture but one where the intention has been narrowed down to an extraordinary degree. The aim is to give the illusion of looking at a living person. The waxwork, however, is very far from being ‘the same as’ a living person. It cannot walk or talk. It doesn't feel like a living person. It cannot make love or engage in philosophical speculation. It is just a clever illusion. Yet the waxwork is fascinating in itself. Looking at it, we are surprised (and charmed) by the fact that such fidelity to appearance can be achieved.

Waxworks and scale models have been developed to capture very particular aspects of ‘reality’ (more properly of our experience of the world.) They allow us to focus on it and engage with it in a particular way. They do not – and cannot – contain the whole of our experience. They capture something about our experience that we desire to encapsulate, to come to grips with, to re-live, to understand, to be in control of.

Looked at in this way, the common usage of the word ‘model’ turns out to be closely related to the more specialist use of the word in relation to design and intelligence. Here too models are used for a purpose.

The term ‘model' is commonly used by scientists, mathematicians, technologists and designers to mean: something that stands for something else. In general, models are powerful because they isolate an aspect of reality and allow us to represent, interpret, manipulate or control it. Models have predictive power because, to use computing language, they can be ‘run'
(played with) to simulate what will happen if proposed changes are carried out. They are indispensable for design activity because they allow designers to develop their designs and understand their likely effect before they are put into practice.

Cognitive psychologists recognise a close link between models and perception. The theory is that the mind itself works by constructing multi-layered models of the world. The linguistic process of labelling and manipulating reality through the symbolic sound system of natural language can be understood as a modelling system but it is ‘imaging’ or ‘visualising’ that has special relevance for design capability. Imagining has its roots in the act of perception but what can be imagined is also shaped by the predisposition of the human mind to see, hear touch and taste the world in a particular way. Sensory input is limited to what we are physically able to receive and the mind is physically limited by its neurological structure. We can only use models that have life and meaning breathed into them by perception and understanding. This means that the models available to us are determined on the one hand by inherited deep structures in the mind and on the other hand by the content of our personal experience and culture.

All models are an abstraction from the chaos of information presented by the complexity of the real world. This is their value. It is this quality that enables us to use models to isolate variables, describe them accurately and analyse their significance. Different kinds of model have been developed to do different kinds of job – in essence, to describe and manipulate different aspects of experience.

A useful way of describing the nature of different kinds of models is to divide them into three groups: iconic; symbolic; and analogue.

ICONIC. These are models that work by looking like (or sounding or tasting or feeling like) a selected aspect of existing or proposed reality. Waxworks and toys come into this category but so does much visual art and many of the models used by designers to develop and explain their proposals.

SYMBOLIC. These are the models that work by using an abstract code to symbolize aspects of existing or proposed reality. A letter of the alphabet, standing for a spoken sound, comes into this category.

ANALOGUE. These are the models that work by means of diagrams or codes that stand for but do not look like a selected aspect of existing or proposed reality. A flow diagram comes into this category.

Many – possibly most – models combine elements of more than one of these categories. A modern map, for example, is strictly speaking an analogue but retains a recognisable iconic element and makes use of agreed symbolic icons.

The common factor is that a model is something that our minds can use to stand for something else. As such it is fundamental to thought. Models
make thought possible but they also channel and constrain what can be thought. Modelling is thus a central part of what makes human beings human. The ability to deploy symbolic communication systems is an essential feature of human intelligence. It makes abstract speculation possible. This is not only a matter of ‘rational’ thinking. Abstract, symbolic thought also makes it possible for us to experience and evaluate our own direct experience, personal relationships and emotional responses.

All abstract thought – probably all communication – depends on the existence of models in this sense of something which stands for something else. Words are symbolic models of the various things they signify. Words in general do not resemble what they stand for although there is a delightful category of language which is mimicry as well as symbolism. Pop (when spoken) does resemble the sound of a balloon bursting. In a fascinating book The Book of Babel, Nigel Lewis, has suggested that many more words have hidden in them various kinds of aural or visual resemblance. However, these ancient roots of meaning have tended to vanish and become obsolete as language has changed.

It appears that, at a deep level, there is a strong aesthetic resemblance between the qualities to be found in different modelling media. We can speak, for example, of colour in music and rhythm in a visual image. Some people experience the phenomenon of synaesthesia where an input form one sense results in a sensation related to another. Sound and vision are commonly associated but colour may result in taste sensations and so on. We are all to some extent synaesthetic. Try this engaging experiment. Look at the two shapes in Fig 1.2. Which is called Kiki and which is called Buba? Look over the page for the answer. Almost 100 per cent of people respond in the same way linking sound, shape and letter form. These semantic interpenetrations have a profound influence on the models we use and the way we use them.
It is clear that practitioners in many fields are able to manipulate and to a
degree actually sense and experience in the mind ideas, images, sounds and
feelings that are not immediately present in the environment. This involves
memory of experience but can also extend to handling ideas about the future.
It seems that humans can use models derived from all their senses and even
deal with possibilities that are completely imaginary.

In *Music and Imagination* (1979), Aaron Copland has several extended
passages discussing what might be called ‘hearing in the mind’s ear’. Here he
is describing the nature of composing:

‘The worst reproach you can make against a composer is to tell him that
what he has written is “paper music”. On the other hand one of the
quickest ways to recognise talent in youthful composer is to note the
natural effectiveness as sound of even the most casual combinations of
different tone colours. It is a true sign of inborn musicality. The way music
sounds, or the sonorous image, as I call it, is nothing more than an
auditory concept that floats in the mind of the executant or composer; a
pre-thinking of the exact nature of the tones to be produced.’

What Copland makes clear here is that what is acting as a model is not a
written symbol for a note but a sound in the mind – what he nicely calls an
‘auditory concept’.

Some human modelling systems exist in more than one medium at the same
time. Language can be expressed in sound or writing. Interestingly these two
media do not give identical results, each has its effect on the capability of the
modelling system. Spoken language is typically informal, strongly supported
by the use of the body and face as supplementary means of communication.
Written language is much more bound by conventional rules. Spoken
language before broadcasting and film was transient, it had to be written down
to be passed on and remembered- though in oral cultures the capacity of
storytellers to retell old stories actually seems to have been extraordinary.
Writing struggles when it attempts to capture and reproduce the nuances of
speech. Children being read to are experiencing the written word being talked
back into sound. A good reader will reintroduce at least some of the richness
of speech back into the narrative. In a drama, what was written is now re-lived
in the full animation of face to face talk and action. But, to add something
more to the equation, it is now also observed by an audience who (usually) do
not directly participate but are thoroughly involved in the action.

Think about a song. A song is a really complex mixture of media existing as
words, musical notation and a performance involving singer, musicians and
listeners. A song is an enlightening example because songs can exist on
paper, in performance, as a recording but also in our memories. The ability of
a crowd to sing a familiar song, words and tune having been stored in many
memories, might well make us tingle with excitement, not only at the music,
but also at the sophisticated mental operation taking place.
When lecturing on the idea of cognitive modelling in the 70s and 80s, I and my colleague Bruce Archer, used to ask an audience to engage in two rather different cognitive games, both of which put them in touch with the sense-based models stored in their memories.

GAME ONE

I asked everyone in the audience to carry out the following exercise in the mind, closing the eyes if this would help.

- Visualise a cup and saucer
- There is a spoon on the saucer

I would then ask members of the audience to describe their cup and saucer:

‘It’s an old blue one that I’ve got at home’
‘Pure white, very elegant with fluted sides’
‘Just like the ones in the canteen’
‘It’s an old chipped mug, I left out the saucer’
What about the spoon?

‘Bent and a bit mucky’
‘Silver with a monogram on the handle
‘An apostle spoon, like my Aunty had’

I then asked them to pick up the spoon and balance it across the open top of the cup. Which way up was the spoon? Did it fall in? Almost everyone could answer these questions!

In a similar way, sportspeople can review a past game in the mind and plan a strategy for the future.

Very many designers report their ability to ‘see in the mind’s eye’ and are able to manipulate images and plans in their heads. Mechanical engineers can (for example) visualise and operate an imagined complex gear-train without drawing or making a physical model of it. As an exhibition designer, I seem to have no difficulty in taking an imaginary walk around an exhibition that I am working on and visualising it as it will be.

Cognitive science acknowledges the existence and importance of such visual images. It is now known that when people think in imagined images the visual brain is activated in something the same way as in seeing. The imagined image is different in character to the ‘seen’ image, but it is powerful in itself and immediately accessible in the mental life of most people.
GAME TWO

I asked the audience to cast their minds back to childhood. Could they remember a place that they either liked very much or found frightening and unpleasant? Please would they write a short description of the place (or draw it) and record some key words to describe its emotional character.

Amongst frequent remembered places were:
- The beach and seaside in summer (always a popular spot)
- A hiding place—under the stairs or behind a sofa (this could be pleasant or unpleasant to different people)
- A grassy bank to roll down
- The dentists’ waiting room
- Playing in the park, frequently the experience of coming down the slide

As it turned out, the memories were not solely visual. Other recalled and partly re-experienced sensations included:
- Wet sand between the toes
- ‘Hot sun on my back’
- The smell of wellies and wax under the stairs
- The lack of air in the dentist’s waiting room, a sense of not being able to breathe
- The sound of a distant train’s whistle as it is approached a level crossing
- ‘The tickly dog’s hairs up my nose’

Most individual and surprising was a headteacher who remembered the pleasure she felt at four years old when she shared her dog’s cosy basket. She also gave a wonderfully evocative description of the daily stopping train arriving and departing across the dead flat prairie in a small Canadian farming town.

The memories were very accessible. We used the modelling media of words and marks to share them with each other.

In a rather different kind of activity, I asked the audience to imagine the room we were in – most commonly a very ordinary seminar space with buff coloured walls – if it were to be painted purple. Most people could do this, generally expressing shock or horror at the likely result. Some people found it quite hard to actually ‘see’ the change in the mind’s eye even if they were quite sure they wouldn’t like it!

In a similar way, most members of an audience could suggest improvements to the space we were in and visualize them and explain them without recourse to drawing or plans. However, when they were allowed to make a drawing or a plan they reported that it helped to make their imaginings more concrete – often leading to changes and further improvements – and, not surprisingly, referring to these models made it easier for them to explain their ideas to the rest of us.
These games highlighted the mental capacity we all share to model the world in the mind, recall the models and to imagine models of alternative futures.

Numbers are one of the most powerful modelling systems devised by humans. In our Arabic system of notation the figures do not resemble what they stand for. This, once again, is their virtue. It does not matter if it is 5 boats or 5 people that are being counted: we do not have to draw five little boats to show what we mean. The system is truly abstract. Different cultures produced different modelling systems for numbers but in the West mathematics has been able to develop a universal modelling repertoire no only for calculation and measurement but for philosophical and scientific speculation as well. As the quantifiable aspects of design activity have increased, so has the designer's reliance on mathematical models.

It is from maths – and particularly computer science – that we have taken on board the idea that a model can be 'run' or played with. That is, it can stand for what it stands for in a dynamic way, showing how it is but also how it might be in the future or how it probably was in the past. In this particular form, it is a modern idea depending partly – but not entirely – on high capacity computing. However, predicting the future consequences of present ideas and actions is fundamental to human beings, not least in design.

In their book on the social applications of mathematics Davis and Hersh (1988), reproduce this very simple diagram of the use of mathematical models:
As drawn, the diagram does not emphasise one important fact – human beings construct models so that they can take action in and on the world (and each other). The model could usefully be further annotated.

The interaction between mental model and the external world is powerful, particularly when it can also be externalised and 'run'. Generally these models have a positive role in giving humans an ability to predict and to initiate change. However, models can also play a negative role. They can inhibit actions and lead to prejudice and ignorance.

Two examples

Different cultures use different kinds of models and the models used reflect the priorities that tradition has previously established. Historically, China was a highly innovative culture and made many technological advances. However, the codes of Chinese mark-making and representation did not make it particularly easy to depict machines with moving parts. When illustrations of Western steam powered machines arrived in China it was hard to illustrate them not only because the technology was unknown but also because the graphic modelling systems available were unsuitable.

In the 1970s geographers, Peter Gould and Rodney White (1974) made a revealing study of people’s ‘mental maps’.

The mental maps presented in their book were models not of the physical reality of places but of the stereotypes about places that we all carry around in our minds. They showed, for example, that in the late 60s, British school leavers had a very favourable picture of their own immediate area but that their appreciation quickly diminished with distance. There were striking
exceptions to this rule. Devon and Cornwall emerged as universally appreciated, there was a ‘dome’ of appreciation over the Lake District but ‘sink holes’ of disapproval for London and the West Midlands! In general, there was a steady downward gradient in appreciation as one moved north from the highly ranked South Coast.

A ‘mental map’ modelling people’s understanding of a place. Los Angeles perceived through the eyes of upper middle class whites in Westwood. In their book Gould and White contrast this wide ranging model of the city with the constricted model understood by people in poor neighbourhood.

What the study of these (and other) mental maps showed was that people’s models of places, even in their own country, are built from very little personal experience and a great deal of generally stereotypical material from the media and conversations with their peers. These models represented a kind of popular mythology about geography. Yet, unreliable as they are, these personally meaningful models are used in decision making: about holidays, where to live and where to work, for example.

It seems clear that many ill-founded, half understood and misinterpreted models – largely absorbed in childhood, often in formal education – continue to influence adult behaviour. Frequently these are reinforced by fundamentalist religious beliefs or secular ideology giving rise to racism and prejudice. Today such models can be magnified by the media and, as became clear in the course of the twentieth century, are capable of stepping out from the mind to wreak havoc in the ‘real’ world.

A further remarkable phenomenon goes beyond the formation of models that are misguided into models which are entirely imaginary. We can all envisage fictional and fantastic worlds in which things happen that would be impossible in a world ruled by the laws of physics. These imaginative models have profoundly enriched human consciousness and culture and clearly feed-back longings and aspirations into the ‘real’ world. They have significance in terms of making meaning but, perhaps as a spin off, they have also contributed towards imaginative endeavour involved in designing.

THE EVOLUTIONARY CONTEXT

One of the most significant recent developments in cognitive science is the attempt to explain the nature of the human mind (and so of ‘human nature’) by placing it in the context of evolution. Steven Pinker’s explanation of How the Mind Works (Pinker, 1997) brings together two key ideas: that mental activity is, in part, a form of computation and that the evolved brain that gives rise to human thought and culture has been decisively shaped by natural selection.

Biologists speak of human beings as occupying the ‘cognitive niche’ in evolution. Pinker describes Homo sapiens sapiens (us) as an ‘unprecedented animal, with many zoologically unique or extreme traits’. The key point is that ‘humans achieve their goals by complex chains of behaviour, assembled on
the spot and tailored to the situation’. People can react inventively and engage in radically different behaviours ‘on the spot’. They plan their behaviour ‘using cognitive models of the causal structure of the world’.

In the animal world, humans are unique in combining a number of characteristics:

- Using cognitive models of the causal structure of the world;
- Learning the models during each individual lifetime, with a long ‘learning phase’ in childhood;
- Communicating the models through language and other externalised modelling media (including images);
- Using language and other modelling media to accumulate, store, and communicate knowledge within a group and over generations.

These characteristics have proved extraordinarily effective. Since the beginning of modern humans they have enabled *Homo sapiens sapiens* to develop a proactive relationship with the natural environmental and other animals. Humans:

- Make and depend on many types of tools, using them to extend and supplement human skill;
- Exchange goods, obligations and ideas over long distances and long periods of time;
- Organise food production: transport, process and store food to give continuity of supply;
- Divide labour between the genders and between specialists and social groups;
- Form large structured communities with territorial boundaries which sometimes co-operate with each other but which also engage in warfare;
- Use fire and other energy sources to extend their own physical powers;
- Create complex social, cultural and sexual customs with rules and ‘laws’ to support them;
- Create mental artefacts such as art, music, religion, philosophy and science to give meaning to their existence.

Many animals display extraordinary powers. Navigation by migrating birds for example. Dam building beavers. The social organisation of ants. But these are highly specialised attributes, closely fitting the animal involved to one highly defined niche in the pattern of evolution. Humans are unique in displaying more general kinds of intelligence. It is interesting to speculate on the evolutionary value and necessity of having general intelligence, problem solving ability and cognitive models of the causal structure of the world.

Pinker cites Tooby and De Vore (1987) who have studied the origins of human psychology in the context of evolution and the emergence of ‘modern’ men and women. They identify ‘surprise attack’ as the key element in making early humans effective. Humans learnt to use novel, goal orientated courses of action to outwit the defences of other animals. They could do this ‘on the
day’ by using their resource of stored knowledge whereas other animals could only change their behaviour over an evolutionary timescale.

Pinker (1997) writes:

‘The manipulations [used by people] can be novel because human knowledge is not just couched in concrete instructions like “How to catch a rabbit”. Humans always analyse the world using intuitive theories [models] of objects, forces, paths, places, manners, states, substances, hidden biochemical essences, and, for other animals and people, beliefs and desires. People compose new knowledge and plans by mentally playing out combinational interactions between these laws in their mind’s eye.’

‘We can add that, because of their social organisation, they can share plans and work together to achieve common goals for the benefit of all.’

At first hearing, it might not appear that the life of hunter-gatherers was a particularly good context for the development of intelligence. But anthropologists who have lived with surviving groups of hunter-gatherers record that these people have an extraordinary insight into their immediate world and remarkable cognitive skills in predicting the movements of animals, the impact of the weather and seasonal change, all within an acute geographic sense of the lands which they inhabit. Their mental world encompasses concepts of time and distance, the elements, cause and effect. They use language, make tools and create images. They know about the annual migration of animals and their habits and understand the life histories of many plants.

Since Homo sapiens sapiens is unique, it is reasonable to wonder about the particular circumstances that may have led to this evolutionary development. Why did the cognitive niche suddenly get filled? The answer at this stage remains speculative but is fascinating in relation to the development of modelling and design.

Biologists identify four major elements that may have been crucial. Each by itself would not have done the trick but taken together they could have provided a dynamic for developing human intelligence in a particular direction.

The four elements could have been:

- Stereoscopic and colour vision
- Group living
- Finely controlled and structured hands
- Hunting

All these were present as potential in the primate ancestors of Homo sapiens sapiens. Primates are visual animals. Stereoscopic vision allowed nocturnal primates to move among the tree tops. Colour vision came with day-time living and the search for brightly coloured fruit. Pinker (1977) describes the cognitive significance of binocular, colour vision in this way:
‘Depth perception defines a three-dimensional space filled with movable solid objects. Colour makes objects pop out from their backgrounds, and gives us a sensation that corresponds to the stuff the object is made of, distinct from our perception of the shape of the stuff.’

‘Within acute vision lie the roots of important abstract concepts, dividing a ‘what’ system (for objects’ location and their shapes and compositions) from a ‘where’ system (for objects’ location and motion).’

‘Even [today’s] scientists, when they try to grasp abstract mathematical relationships, plot them in graphs that show them as two – and three dimensional shapes. Our capacity for abstracted thought has co-opted the co-ordinate system and the inventory of objects made available by a well-developed visual system.’

The emergence of stereoscopic, colour vision is also essential for design intelligence. Designers need to see objects ‘pop out’ vividly from their background and to be able to distinguish between ‘stuff’ and the ‘shape of stuff’. They need to appreciate the distinction between ‘what’ and ‘where’. The spatial nature of design is well captured in Pinker’s discussion.

Group living was the medium through which a comprehensive made environment was made socially possible. As the made environment became more embracing it became not only utilitarian but also a reflector of symbolic ideas and values. Places were designed for the worship of gods and as memorials for the dead. Art emerged as a medium for sharing social goals and as a magical way of influencing the natural world. The made world was in a dynamic relationship with mind, stimulating and reflecting its modelling ability.

Finely structured hands were a key instrument in carrying out design ideas and in advancing technology. Developing tools was, again, not simply instrumental. Tools reinforced human’s self-image as beings who could act on the environment. The experience of skilled tool-makers was a way into new inventions. There developed a synergy between mind and hand that to this day contributes to the sensibility and capability of designers. The results of tool-use built up the store of models in the mind. These models were ready for application in new situations and such is the flexibility of human intelligence that they could be applied in novel ways and adapted to resolve new problems.

Hunting provided a venue in which to develop hand-eye skills, novel technologies and group interactions. Mental models of animal behaviour and physical geography were essential to success. The speed and agility of the hunter was mental as well as physical. The hunt was so vivid that it provided spiritual and artistic energy for the creation of images and rituals.

A further trend running through these evolutionary dynamics was memory and education. Memory was of course a repository of models and these were both
personal and communal. But early societies embarked on the initial step of externalising and sharing these memories in the form of ritual buildings and objects, stories and myths, 'maps' and images. Young humans learnt not only practical knowledge from adults but the meanings shared by their particular group which in turn built up social cohesion and identity.

**DRAWING AND MODELLING**

From an evolutionary perspective stereoscopic, colour vision appears a decisive factor in the emergence of design ability. However, mental operations conducted 'in the mind's eye' are distinct again from operations prompted by made images. Even though all three activate the same areas of the brain, the effect in our consciousness is different. Imagining looking at something is not the same experience as looking at a drawing of something or as looking at the thing itself. Fortunately we are acutely aware of the differences. Clearly it would be very dangerous if we did not have this awareness. It will have been important for our survival to be able to distinguish between imaginings, made images, and direct sensory input from the environment.

Design ability makes use of a subtle interplay between sensory input, imagination and made images or models. What exactly do modelling systems enable us to do? It is particularly enlightening to re-interpret drawing as a form of modelling. Seen in the context of modelling, drawing emerges as a cognitive phenomenon of great power and significance.

In our culture drawing is strongly identified with art. Its value is thought to be representation, and skill in representational drawing is given an almost magical significance. It is not seen as a useful, everyday tool, potentially accessible to the majority of people. Rather it is a rare gift given only to a few. These deeply held views embody a number of wrong assumptions:

- Drawing is the preserve of art – no it isn't. Art is only one of the activities (a very important one) that makes use of drawing. Science, design, technology and many others also make use of drawing.
- Drawing is about making a representation – no it isn’t. Contemporary art rejects the proposition that the overwhelming job of art is to represent what is ‘out there’ and, when drawing serves the needs of other fields, realistic representation of appearance is often not the main criterion.
- Skill in drawing determines the value of what is drawn – no it doesn’t. A high level of skill may be an attractive thing but in many fields useful drawings may be produced with only adequate skill.
- Being able to draw is a gift: it cannot be learnt. For everyday uses, it is not a ‘gift’ and it can be learnt. It is indeed not possible for everyone to learn to be a great artist but in many historical periods particular drawing skills have been taught and – more important – successfully learnt. The nineteenth century engineer, for example, had to learn the conventions of engineering drawing and was strongly advised to learn how to sketch and keep an ‘ideas’ sketchbook. Both goals were regularly achieved. For the Victorian engineer drawing became an accessible, ordinary tool.
So we are missing something important about the nature and potential of drawing. The key is not to interpret drawing narrowly as ‘just’ a means of representation but broadly as a means of modelling and communicating. In drawing the task is to make marks that have meaning, just as in speaking the task is to make sounds that have meaning. Representing what is ‘out there’ in an illusionist way is far from being the only or even the most important use of mark-marking. Deliberately made marks date back to the earliest fragments of material culture that have come down to us. Significantly, archaeologists regard meaningful marks as one of the first of evidences of abstract thought and therefore of distinctively human intelligence. This early mark-making is not exclusively representational: it has in it the seeds of art, writing, and mathematical notation.

We should be wary of interpreting early mark making in ways related to our own very different culture. For example, ‘picture maps’ made native Australians aren’t maps and they aren’t pictures. Although we can enjoy them, we probably have insurmountable difficulty in understanding what they really are and in appreciating the vision and intelligence that have gone into creating them. They appear to be models of the land and spirits of ancestors, animals and dreams, documents of ownership and history. They serve as an aide-memoire for story-tellers and a repository of memories for the community. They are given their intended meaning by the Aboriginal context in which they were made, one which has no exact counterpart today.

Contemporary Islamic calligraphers do not regard their re-imaging of the words or name of God primarily as calligraphy. The mark-making is in itself an act of piety and a medium through which to serve God. The aesthetic quality of work is given in homage. Again, the work takes its real meaning from the context in which it is made and used.

In a similar way, it is quite hard now to recapture the intellectual ferment and excitement that must have greeted the discovery and use of perspective during the Renaissance. The opening up of pictorial space was much more than a technical device to make realism possible, it fitted in with and made visible and tangible the deepest concerns of humanism. Just as much as an Aboriginal ‘map’, perspective too made particular intellectual and emotional sense in the context of the time and place where it was developed.

What this suggests is that marks, like languages, provide a flexible system for making meaning: one that can respond to the changing patterns of culture. What marks can ‘say’, the meanings they can model, are not confined to a single moment in human history. Mark-making appears so far to have proved valuable in every human society but it has not always been used for the same purpose.

In what ways is it useful?
This question brings us to consider some of the key epistemological questions about drawing and mark-making and, by extension, modelling. What kinds of meaning can drawings explore and how do drawings mean what they mean? As a modelling system, what is drawing capable of modelling? What thoughts does it enable us to think? What actions does it enable us to take?

It is helpful to think of a drawing as a space in which meaning can be created by a process of mark-making. Using just chalk and a blackboard, I can create an arena in which we could share ideas or stories, create imaginary worlds, work through algebraic equations, sketch out a map, make plans for the future that we could agree to carry out later on.

The conceptual power of mark-making can be demonstrated without much conventional drawing skill.

- First consider the frame of the activity not so much as a ‘window on reality’ but as a space in which ideas, emotions, speculations and, of course, observations might be deployed.
- If we make a single line across the space we immediately open up alternative worlds of meaning (Fig 1.5).

It could be a horizon line separating the earth from the sky.

We can use this to make a picture or construct a diagram (Fig 1.6).

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Fig 1.5 Conceptual power of mark-making: By drawing a single line across a ‘frame’ we open up possibilities for modelling and representation.
It could be a point on which to place a human figure: very small for insignificance, very large for dominance. Qualitative judgements and philosophical speculations can begin to enter the picture.

It could be part of a reflection on or demonstration of aesthetic principles and ideas. For example, if the division is made according to the Golden Section what further proportional rules or insights could flow from it?

There are very many other possibilities. This is a stimulating game to play, extending our appreciation of the capacity of marks to create meaning and speculating about the power of models in human thought.

Fig 1.6 Making pictures and diagrams, models of ideas, observations, numbers and perceptions
Similar games of speculation could be played with other capacities of mark-making (Figs 1.7 – 1.9).

- Enclosure
- Direction of movement
- Surface

The space could see the emergence (Figs 1.10-1.12) of representational qualities.

- Form (3 dimensions)
- Space
- Atmosphere
It can deal with appearance and emotion and it can invite participation.

Fig 1.13 – 1.15 Potential of mark-making to model appearance, emotion and expression, and an extraordinary range of other concepts
When we took the co-ordinates of Cartesian space and put them behind our window (Fig 1.11) we began looking into the Renaissance world of perspective and apparent realism. In this space, it became possible to explore 3D space as well as 3D form, environments with atmosphere and weather in them, the appearance of people, plants and animals. There is a great increase in our ability to model intangibles such as character and emotion (Figs 1.13-1.14).

Nobody has explored the semantic capacity of mark-making as brilliantly and thoroughly as Paul Klee in his *Pedagogical Sketchbooks*. Anything like the little modelling exercise I have just been through owes a great deal to his beguiling concept – open equally to children and philosophers – of ‘taking a line for a walk’. But much more than this: throughout his work Klee explored and demonstrated both the communicative power of marks and the internal aesthetic logic which defines them and makes them work.

Even in an apparently representational drawing, the marks themselves are of course abstract. The artist may give them powerful expressive and psychological meanings through medium, manual dexterity and insight, but the marks bear scant resemblance to what they represent.

A close up detail of a great European drawing immediately reveals the extraordinary difference between the ‘abstractness’ of the marks and the representational meaning that may be read from them.

Rembrandt’s sensuous images of sexual encounter are conveyed through marks which do not at first sight have a sensual quality. On the other hand, Constable’s bold wash drawings do sometimes seem to have captured a connection between the wetness of the drawing and the wetness of the weather. But even here, the marks left by the brush are boldly abstract and not in any superficial sense directly descriptive.

Generally this abstract quality of marks is concealed by the fact that we easily read the conventions of Western drawing as though we are ‘looking into’ a real space filled with real objects. We imbue these very sparse marks and scratches with qualities of light, colour, form, texture and space. We give them meanings which, in their own way, are a leap of imaginative reconstruction to match the artists’ own imaginative reconstruction, developed in our brains by practice and the conventions of our culture.

Perhaps we should not be so surprised by this. Vision is not a camera. Vision is a highly selective interaction with sensory data, limited firstly by the mechanical structure of the eye and far more importantly by the biological electro-chemical activity in the brain which unfolds to us as conscious vision. This is a continuous picture story interpreting reality and it is available to us so long as our eyes are open. But we do have to develop vision as baby in order to have this faculty.

It is significant that people who are blind from birth because of a mechanical defect – cataracts for example – cannot see immediately their physical
condition is corrected and in fact can never see perfectly. The experience of a French surgeon, Moreau, is reported by Semir Zeck in his enlightening book *Inner Vision*. Moreau operated on an 8-year old boy: it took the boy many months of training to be able to recognize a few objects and his ability to learn about the visual world, including visual memory, was still missing two years after the operation:

'It is only with the more recent discoveries that our concept of vision as a process has progressed. We now view it as an active process in which the brain, in its quest for knowledge about the visual world, discards, selects and, by comparing the selected information to its stored record, generates the visual image in the brain, a process remarkably similar to what an artist does.'

Actually the brain has specialised processing centres that appear to work precisely in response to those aesthetic qualities that art and design have always treated as crucial: form, colour and motion.

The fact that the brain is engaged in a continuous search helps to explain the usefulness of marks as models. Marks are already a selection and a distillation. It is their virtue (and indeed necessity) that they do not model the whole of ‘reality’. They focus instead on particular qualities or features, highlighting them and making them available for further analysis and manipulation.

**THE ORIGINS OF DRAWING**

Further insights into the cognitive significance of mark-making as modelling can be gained by studying young children’s drawings. Here again, the Western cultural context can be unhelpful. Young children’s drawings are not representational in the sense of pictorial realism. They can seem rather peculiar, even quaint. Although we can usually ‘read’ them people often ask ‘Why on earth do children draw like that?’

We do not seem to be similarly puzzled by first words. We easily accept the idea that babies make all sorts of sounds, gurgles and half-formed words as a precursor to language. Parents realise that their children are experimenting with making sounds and words. They recognise it as a satisfying and rewarding activity – they join in and encourage it. This language play is a game but also a powerful medium for learning.

At Loughborough University, I recently took part in some research with young children designed to explore their drawings as a modelling medium. What our research suggests is that there is nothing peculiar about the form taken by young children’s drawings. They make excellent sense in the setting of the stage of each child’s cognitive development.

The research was made possible by the use of a softboard (exactly like a classroom whiteboard) linked to a computer, VDU and printer. A laser grid over the surface of the softboard tracks the location of pens as a drawing is
done and produces a remarkably accurate reproduction of the result on the VDU. The complete process is captured by the computer in real time.

The drawing can then be manipulated in various ways:

- The process of mark-making can be re-run in real time
- The process can be stopped and reviewed at any point
- The drawing can be stored safely while parts are erased and different end-states produced
- Printouts can be made at any stage

The device reveals the process of drawing in ways that were impossible even in the immediate past. I worked with two colleagues: my wife, Krysia Brockocka, and Michael Quantrill. We carried out a series of ‘drawing workshops’ with children aged 3-6 from Radmoor Nursery School, Loughborough, in Spring 2002.

On each of the three days of the workshops we worked with three groups of 5 to 6 children who were accompanied by their teacher and sometimes also a helper or parent. The children were selected by the school to represent a variety of abilities and backgrounds. On the third day the children were selected from those who had already attended. They were children who showed a particular interest in drawing on the softboard.

Activity on the softboard was led by Krysia who is experienced in working with the age group. Krysia encouraged conversations with each child. At the end of a session the drawing was re-run (sometimes more than once) and discussed with the child. Finally, the three adults compared notes.

In introducing drawing on the softboard, Krysia began by asking each child to choose a coloured pen and to draw a series of familiar things. For example, sun or house or car. She did not insist on the completion of the series. Some children dutifully (and with enjoyment) completed all the drawings. Others did not.

Then every child was asked to draw what they wanted. Some children completed two or three of these free drawings. One child refused to do any more drawing. All the children who returned ‘by invitation’ on the third day did drawings of whatever they wanted. The children proved remarkably fluent in talking about and explaining their drawings.

All the drawing work was ‘from imagination’ or memory. There was no observational drawing.

The work done by the children was recorded in considerable detail. A small number of accounts will give a flavour of the activities.

First, here is Joseph (aged 3) working with Krysia as she encourages him to draw such ‘standard’ images as a sun, a person, a house.
JOSEPH

- Joseph chooses to draw the sun and makes it carefully.
- A path leads to the house and there are paths round the house.
- A pussy cat. What colour? Red in this drawing but Joseph says “our cat at home is black and white”.
- A person. The person is a green line and a ‘head’ on top. What kind of person? A funny person.
- The tree is also rather like a person.
- Buzz Lightyear from Toy Story is rather like a tree.
- A moon in the sky with a descending moon beam. It is also rather like a tree.
- A big space is rubbed clear for the car. It is the red car at Granny’s house.
- Now a road which makes Joseph laugh. The line traces a route and joins up to its beginning. Is this a journey?
- Finally a ‘nothing’. We do not know what it is. Joseph appears to have made it that way on purpose.

Joseph’s drawing (Fig 1.16) gives a vivid insight into the status of children’s mark-making at the point when scribble is abandoned in favour of marks to which a meaning may be attached. It is evidently possible for young children to attribute meaning to a drawing with little iconic content. On the other hand, the line with a mark or marks at the top is a powerful and useful symbol with some iconic content. The top squiggly spiral in Joseph’s work can be used as the head of a person, an animal or a tree. The icon itself gave Joseph the poetic idea of a ‘moon in the sky with a moonbeam’.

Fig 1.16 Partially completed state of Joseph’s drawing
GEORGINA

Figure 1.17 records a very different set of images by Georgina who was aged 5. They show:

A sun
A bird
A favourite toy cooker
A small car
Mummy

In this drawing Georgina is using the familiar young child’s schema to depict a varied range of things – people, places, vehicles, animals.

Next came two examples of extended mark-making sequences in which the children are drawing ‘whatever you like’.

Fig 1.17 Nearly completed state of Georgina’s drawing
LAUREN

Lauren is four years old. She is shy but fully engaged in the drawings. She talks all the way through. Her teddy is the key character. Hearts are another key theme. Lauren has them on her T-shirt and at home she has love hearts ‘but some got broken’.

- Lauren is not keen to begin. Krysia talks to her about teddy.
- The conversation with Krysia continues during the drawing and probably influences what appears. The conversation is a trigger. ‘He likes honey’. ‘He’s got big strong teeth’. ‘He’s got claws’.
- Teddy emerges as a typical early drawing of a person – legs attached to the head. But Lauren adds ‘teddy details’ – claws and a bow.
- Krysia asks ‘where will Lauren be in this picture?’
- Lauren draws Lauren in very quickly. She is much bigger than teddy. Her blonde hair is put in very vigorously.

In her drawing, Lauren uses the emerging schema for a person to depict Teddy and herself. She ‘customises’ the schema by adding specified details. There is a strong emotional meaning in depicting Teddy and the relationship with herself.

SEAN

Sean, aged 4½, becomes very engaged in the drawing he does on the softboard. Of all the children, his drawing activity is the most extended.

After the initial activity, he is keen to return a second day and again becomes totally absorbed.

He looks at the softboard rather that the VDU screen but is delighted to watch the drawing re-run.

He is remarkably articulate, talking about the drawing as he carries it out. The meanings he attributes to particular marks remain constant. When we review the drawings together the story is exactly as it was originally.

Sean’s work, (Fig 1.18), demonstrates most clearly the ‘multi-purposes’ and layered meanings that can be found in children’s early drawing. Each drawing became the arena for an exploration of a series of linked ideas or themes. It would be quite wrong to say that Sean’s drawings are ‘illustrations’. In a number of cases the next step in the drawing was clearly triggered by the mark-making in the previous sequence. This is not exactly serendipity. It is more akin the way children tease out a logic of language related to sounds and rhymes as well as their literal meaning.
• Draws a window
• Puts in numerals: 4 5 7 (reversed) triggered by Krysia’s question ‘How old are you?’
• It is an attic window. Right at the top of the house
• Sean constructs a grid within the window pattern. Does not want to stop doing this
• The black parts are a crane with ‘A string coming down’
• Flowers grow at the bottom of the crane
• Green is a boat
• Letters appear in the windows, now a bird
• A snake is going into the crane: there is a man in the crane
• The snake is the crane driver’s pet
• Sean makes a pavement to go all the way round the picture

At the core of this drawing appears to be an exploration of grid or window shapes. The construction of the grid within the window pattern was clearly very satisfying. Grids helped to make the crane. The pavement holding the whole picture together was a strong culmination to the work.

Fig 1.18 Drawing 3 Nearly completed state of Sean’s drawing
The drawing is neither 2D nor 3D. It seems to combine elements of map-making with pictorial representations. The scales of the various parts of the drawing are not consistent. There was a strong sense of a story unfolding while the work was being done.

Working with the softboard enabled us to glimpse the emergence of the fundamental cognitive insight that enables children to give meaning to marks.

The majority of children (but not all) begin drawing by ‘scribbling’. The softboard was used for scribble by a number of the children (see drawing Fig 1.19). To us it seemed clear that even scribble is more than exuberant motor activity. Decisions are being made all the time about where to put the next marks. There is a rhythm to the work: a sequence of fast and furious scribbling will be suspended while a carefully drawn line is taken for a walk. Within the whole activity there may be periods of absorbed attention to detail: whorls and spirals are drawn; dots may be used; colours are changed and contrasted. These changes of pace and marking are themselves meaningful in the child’s intellectual and aesthetic development.

Fig 1.19 A typical scribble on the softboard
The pleasure taken in simply using the medium extends to exploring the potential of the medium. The potential is not only to cover an area and fill a space (though this is exciting and emotionally powerfully in itself); it is also to make shapes and fields of colour or marks that contrast and interact with each other. A world of experiment and discovery is made evident in the arena of the drawing.

In contrast to energetic scribbling, we also saw carefully and deliberately carried out experiments with line (see Fig 1.20). The single line is immediately evocative. It is a route, a journey. It is a personal mark. It could be a snake. Has it got a beginning and end? Where the line crosses over on itself and encloses an area within boundary lines, a ‘something’ is created where there was previously nothing. This something could be a face or a pond or the sun. These possibilities emerge within the activity of mark-making and, it seemed to us, must be one of the satisfactions that make drawing so attractive to young children.

Fig 1.20 A line experiment
Once the child begins to understand that a mark can be used to stand for something else, the idea is used with astonishing flexibility. It does not depend in any way on a close correspondence between the appearance of the mark and the appearance of what it stands for. The same mark can stand for many different things.

Take the hooked line shown in Fig 1.21. This mark is an easy gestural trace to make. Small hands can produce it very readily. This particular mark was made by Joseph. Look back at Fig 1.16 to see how Joseph has elaborated it into:

- A person. The person is a green line with a ‘head’ on top (the hook)
- A tree
- Buzz Lightyear from Toy Story
- A moon in the sky with a descending moon beam

Joseph has used whorls and carefully controlled scribbles to extend the power of the hooked line to stand for a number of different things, some remembered, some imaginary, some from the media. Marks provide Joseph with a powerful resource for making meaning and modelling ideas.

As researchers, we were deeply impressed by the drawings. This was not because of their quality as ‘pictures’ (though some are very engaging and aesthetically interesting) but because of the richness and subtlety of the intellectual and emotional arenas that the drawing activity made accessible to the children.

Young children’s drawings are seldom valued by adults for their cognitive content. To us, however, it was precisely the cognitive element that was so evident. Drawings and drawing activity stimulate and support children’s imaginations, enabling them to play roles, tell stories and create imaginary places.

What working with the softboard revealed was that these early drawings are far more complex – and intellectually valuable – than generally supposed. It appears that they are not simply a first step in a ladder of development that leads to representation. Instead they are multi-functional. These early drawings show not just the ‘origins of drawing’ but the origins of a fascinatingly wide range of concepts, ideas and insights. This has perhaps not been evident before because it is not necessarily evident in the finished drawings. It becomes evident through conversations with children about their drawings. Seeing their drawings ‘replayed’ helped children to talk about them.
and so explain what was happening in the ‘intellectual space’ created by the process of drawing.

Early children’s drawings display the origins of a whole range of adult attainments where marks are used to explore, model or communicate meaning:

- written language
- mathematical notation
- maps and plans
- signs and symbols

As well as the more familiar

- recording observations
- expressing feelings and ideas
- recovering memories

This wide-ranging scope suggests that mark-making is fundamental to every child’s development across the board. From a cognitive perspective it is clear that children use their mark-making not only for making pictures but as a springboard for:

- emergent writing
- emergent calculating
- emergent understanding of space and shape
- emergent designing
- emergent sequencing and ordering

In short, they employ mark-making as a flexible and fluent medium for modelling meanings of many different kinds.

This seminar has attempted to show that mental models are fundamental to human intelligence: that they are, in fact, a key medium for thought and action. Externalized models – drawings and other physical media – enable people to share with each other. They also have a dynamic relationship with mental models. Externalized models enable us to show our thoughts to ourselves, to make ‘ideas visible’. Making thought visible has proved to be a powerful way of developing further thoughts. The ‘dialogue’ in the mind between internal and external models provides a working space for creativity.

The creative use of mental and physical models has helped to push forward the boundaries of science and technology and to establish great traditions in architecture and planning. Some of the most influential models in these fields have achieved an iconic status and have entered the popular imagination. Here are two examples which many readers will be able to recall and ‘see’ in their own minds’ eye. First, Charles Darwin’s tentative sketch of the family tree of evolution bearing the evocative words ‘I think’. This was the model he refined and extended over the years and which underpinned all his work and
which today underpins the biological sciences. Second, Leonardo da Vinci’s
drawing of the Vitruvian Man, standing with arms outstretched and enclosed
by a square and a circle. This model of human scale and proportion has had
a decisive effect on architectural design, particularly via Andrea Palladio
whose own four volume book provided models for classical architecture,
public and domestic all over the western world.

In the complex contemporary world, almost every trade and profession makes
use of specialist modelling systems which are carefully tailored to the
requirements of that particular activity. Most of these are quite hard for non-
specialists to use or understand and acquiring fluency is an important part of
specialist training. The computer – itself a modelling machine – has hugely
multiplied both the use and diversity of the models in play. Digital modelling
affects every aspect of life from the frontiers of science to the fantasy worlds
of computer games and ‘second lives’. Computer models have begun to
change the way people think and the way they behave.

The following pages show a range of models developed for specific purposes.
Some are highly practical, even mundane. Others are speculative, some are
concerned with the future. Taken together they demonstrate something of the
ubiquity of modelling devices in human thought and activity. They show that
modelling is essential to communication and – more importantly – is
instrumental in human beings’ ability to take action in and on the world.
Figs 1.22 - 1.24  Forms and Patterns used in boat building

Pre-industrial manufacturing did not usually need to separate designer from maker. The model for what needed to be made was found in what had been made before. Here traditional fishing boats are built in an open-air boat yard in Turkey. Each new boat is based on the previous vessel. However, full-size templates and other measuring and marking out devices are used as models to help control the manufacturing process.

Photos by Krysia Brochocka
In ordinary language we use the word ‘model’ to mean a replica – often to a small scale. Such models deal only with one aspect of ‘reality’: appearance.

1.25 Waxwork. Leslie Carron modelled by Tussauds in the 1960’s. (Photo: Peter Jones)

1.26 Model Locomotive. A 4-6-0 Royal Scot, modelled to ‘O’ guage. It achieves remarkable fidelity to the appearance of the steam original though in fact to a scale of 1:76 and powered by an electric motor. (Photo: Peter Jones)

1.27 Model Cavalryman – modelled in accurate detail in a suitably dramatic pose. (Photo: Peter Jones)
Fig 1.28. Maps are a very familiar form of model. However, they come in a wide variety of forms. Each map often mix analogue and iconic elements in a pictorial way. This map of Constantinople, dating from 1420, combines a plan with purely iconic elements. Note how the waters of the Bosphorus are shown by a wavy line convention that is both analogue and iconic,
Fig 1.29 The familiar conventions of modern cartography allow for the landscape to be modelled in considerable detail to a small scale on paper or screen. This is a footpath map of part of Berkshire by Berenice Pedgley.
Fig 1.30 We are able to understand very simplified models of geographical systems such as railway networks.
Fig 1.31 Maps and plans in sketch form are used by designers to model initial ideas and to make them ‘visible’. Emerging ideas for a future landscape by landscape architect, John De Jardine.
Fig 1.32 Models of business situations or organisations are used as an important part of management, particularly in planning for the future. This ‘business map’ is by consultant Andrew Maskell.
Fig 1.33 ‘Back of the envelope’ sketches are widely used by tradesmen to model installations or give instructions to colleagues. Page from a logbook kept by Terry Garislandt, an electrical and electronic engineer, when working for the Ford motor company.
Fig 1.34 Sketch modelling a central heating system by plumber Brian Brookes.
Fig 1.35 ‘How to clean a window’ notebook giving instruction to an apprentice by window cleaner, Steve Saxby.
Fig 1.36 Human culture has evolved partly by the development of new ways of modelling. For example, anatomists had to 'invent' anatomical drawing as a way of exploring, capturing and communicating the results of their new science. Their work had cultural as well as scientific repercussions: anatomical images, models and photographs have profoundly changed or image of ourselves.

Anatomical illustration by the French anatomist, Jacques Gautier D'Agoty. (Photo: Peter Jones)
Fig 1.37 Modelling and mathematics affect every aspect of contemporary life, particularly though the medium of the computer which is itself a modelling machine. In relation to design, mathematical modelling has made it possible for designers to visualize and build forms that would have been impossible even fifty years ago.

Digital drawing for the City Palace Tower, a new building now under construction in Moscow to designs by British architects, RMJM.
Fig 1.38 – 1.40 Models are used to give instructions in many different fields.

Fig 1.38 A traditional dress pattern from the 1950s.
Fig 1.39 Dance steps from a dance magazine.
Fig 1.40 Diagrams showing the key points in a rally route taken from a motoring magazine.
Fig 1.41 Many of our conceptions of the world depend on and are expressed through models. It is one of the roles of education to foster the development of more sophisticated, more 'eloquent' models. This drawing by Joe, aged 4½, shows a model of the world that creates his own world of people and family in the familiar globe of the earth (Courtesy of Yvonne Allison)
REFERENCES


