Models of change: the impact of ‘designerly thinking’ on people’s lives and the environment: seminar 2 . . . modelling and design

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MODELS OF CHANGE

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

Seminar 2 … Modelling and Design

Design: Occasional Paper No 4

Ken Baynes
Department of Design and Technology
Loughborough University of Technology
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 took 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 be 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
August 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
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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 Gallery, 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 and integrating them into this volume.
MODELLING AND DESIGN

Industrialisation hugely expanded the role and scope of design activity. The range of products increased exponentially. Engineers and architects conceived of new types of buildings and structures incorporating materials and technical principles that were completely novel. Towards the end of the Nineteenth century there began an explosion of communications technologies and related products culminating in the digital revolution and the consequent development of virtual worlds. All these products, places and images needed to be designed. Not surprisingly, the Twentieth century saw an unparalleled multiplication of the modelling techniques used in design activity.

At first, the emergence of the new range of design specialisms and the related range of modelling media went largely unremarked. The 1920s and 30s saw the first attempts to identify ‘design’ as a distinct discipline and these efforts gathered pace in the 1950s and 60s. Even then, the idea that ‘modelling’ was a key aspect of design intelligence and design activity was not widely acknowledged outside academic circles. How designers thought, how they got and developed ideas seemed an esoteric area of enquiry not particularly relevant to the actual practice of design. Designers just did the job using a largely unexamined range of intellectual skills and related modelling media.

In this Seminar, the aim is to focus attention on modelling as a crucial activity in design practice and to identify how designers think using mental or cognitive models and how they communicate using externalized modelling media. What should emerge is a clearer picture of the methods used, what they have in common, and the dramatic impact they can have on practice, culture and society. The development of new models, relevant to the modern world, has in fact been one of the major creative contributions of designers in various fields during the Twentieth century. A further argument, to be explored in the final Seminar, is that our survival in the Twenty-first century will depend on our ability to invent, share and use new and more relevant models. In other words, the development of effective modelling media is a work in progress.

By the start of the Twentieth century engineering and architecture had already achieved flexible, widely used and well understood externalized modelling media. There also existed considerable evidence – much of it anecdotal, however – of the ability of architects and engineers to manipulate existing and proposed reality in ‘the mind’s eye’. They evidently thought not only in words and numbers but also in space, materials, functions and relationships. Prior experience and relevant models in these fields could be found recorded in textbooks, formulas and drawings.

However, the repertoire of models now used by designers had its origins in many other fields including traditional crafts, printing, textiles and fashion, advertising and photography. There were also important contributions from such new areas as work study and ergonomics. They contributed graphical ways of modelling how things would perform as well as how they would be
made and how they would look. Market Research developed tools for simulating choice and modelling lifestyle options, often being able to put new products into a larger setting of ideas about class and identity. Digital technology has served to enhance these modelling media and to offer dramatically increased realism. Its computing power has made it possible to ‘run’ alternatives to see how they would function and to capture and understand complex inter-relationships in time and space.

PERSONAL EXPERIENCE

I entered the design field by the art school route. In my first experiences of designing I used models but neither I nor my tutors recognised them for what they were. As it happened, my early career involved using modelling media from three strongly contrasting sources. However, they were typical of the diversity of influences on design practice at the time. I worked first in an area where practice was virtually unchanged since medieval time; then in an area which was fully industrialized in the Nineteenth century; and finally in an area where work study, ergonomics and ‘scientific’ methods were being used in the service of public policy.

A personal account will help to give the flavour of three very different modelling phenomena.

In 1950, at the age of sixteen, I went to study at Bideford School of Art in north Devon. It was here that I first met up with a modelling system typical of many found in art, craft and design. Remarkably, for such a small centre – there were only 15 or so full-time students – the school was one of the few that offered stained glass as a subject. I had very little idea about stained glass. I did not know how a window was constructed or how it was painted but I was very keen to find out and did so in the time-honoured craft way: by doing it alongside a skilled practitioner.

Stained glass is a wonderful medium. When it was first developed in the Twelfth and Thirteenth centuries its impact must have been stunning. The great cathedrals became immersive environments with the windows creating shimmering, changing patterns of light. But in 1950, stained glass was still overshadowed by a dowdy, sentimental Victorian tradition. It was about to break free. Not only would contemporary painters make windows, but post-war commissions would inspire a new generation of young artists specialising in the medium.

Stained glass entails mastering a relatively complex craft. Compared to painting, the means of production is inflexible. The screen of glass, when complete, has to withstand wind and weather. It is a utilitarian functional element within the façade of a building as well as a means of expressing ideas and emotions and telling stories. The stages in making a window are well established and have changed very little since stained glass began.
Although I did not hear it described in this way at the time, a stained glass artist uses a modelling system in conceiving and producing a window. The models are closely related to the craft processes that are entailed in making a new window.

A stained glass screen or window consists of many separate pieces of glass held in place by H shaped lengths of lead. The glass is held by the jaws of the lead and the lengths of lead are soldered together by soldering over the joins. To control and organise this procedure the artist must divide the work into stages, and each stage has to prepare the way for the next. Just as in painting, the work will change and evolve as the artist works directly in the medium. However, freedom is constrained simply by the fact that the huge jig-saw of glass pieces has eventually to be joined together by the leads. This means that the size and shape of the pieces in the jig-saw need to be fixed fairly early in the procedure.

The following are typical steps in the process highlighting the model used.

1  **A sketch design.** Usually to a small scale and in realistic colours, this will be used by the designer to clarify ideas. If the window is a commission the sketch will also be used for discussions with the client. The sketch will become the basis for the commission and so the contract between designer and client.

   The sketch design itself is likely to reflect and echo the designer’s ‘work in progress’. The medium for this continuing exploration of images and ideas may be found in sketch books, drawings or even paintings. Individual artists might use collage, rubbings, photographs and many other ways of ‘limbering up’ ready for an actual commission.

   The sketch design itself can pass through a large number of stages and undergo fundamental transformations. There may be an element of chance in the procedures use. Often the designer is attempting to set up a process from which the right answer will emerge. A part of the designer’s skill is to recognise when it does!

2  **A full-size design.** Traditionally called a ‘cartoon’ this model is a drawing that is a master or template for the finished work. When stained glass began these may have been on parchment or whitewashed tables. In 1950 the conventions used strongly reflected Victorian ideas and values. The cartoon was done in black and brown; black for the leadwork and brown for the painting to be done on the glass.

   Victorian windows were essentially coloured illustrations and the brown drawing on the cartoons would be copied very exactly by the glass-painter in a semi-industrial means of production.
By the late 1950s this tradition was breaking down. The painting on the glass would be much more free and much less pre-planned. Designers wanted to be able to respond directly to the qualities of the glass. This began to be reflected in the cartoons. Sometimes they were simply photographic enlargements of the sketch design, emphasising textures and chance marking as well as the original small drawing. On other occasions they could be complete reinterpretations of the sketch in a larger scale. These big drawings were works in themselves.

Changes in the format of the ‘cartoon’ accurately reflected changes in what stained glass designers wanted to do, how they wanted to work, and the expectations of their clients.

3 The cut-line. Whatever form the cartoon took, the cut-line had to remain more or less the same because of its function. The cut-line is a full-sized model of the jig-saw of glass that will make up the window. It represents, by a narrow black line, the necessary space between each piece of glass. The space is actually the size of the cross-piece of the H shaped leads.

The cut-line is used as a guide for cutting out each piece of glass.

In contemporary practice, each piece is fixed temporarily to a large plate glass window. As the jig-saw of pieces builds-up, the designer can see the coloured mosaic of transparent glass take shape. Decisions are made about colour and shape by considering this mosaic which, of course, is remarkably like the finished window. During this part of the work, the cut-line may have to be modified in the light of working with the actual materials.

In Victorian times, each piece of glass would have been placed over the cartoon to be painted. This may still be done, or a free, direct method will be used, painting directly on the pieces of the mosaic while they are in position on the plate glass sheet.

The paint used in stained glass is an enamel. In many windows, the colour comes solely from the pigment in the glass, the painting being dark brown used as line or tone. Some glass is coloured on one side only and hydrofluoric acid can be used to etch this away to give transparent and coloured parts on a single piece. Silver stain can be used to give yellow or gold. The paint and stain have to be fired in a kiln to fix them. The paint may be built up in layers with a firing required to fix each layer. So each piece of the mosaic that makes up the window may have been subject to several craft processes before it is finished.

During cutting, painting, etching and firing the window is constantly changing and evolving. The designer is responding directly to the glass, to the impact of each new development in colour selection or painting. Glass changes subtly when it is fired so adding a whole lot of
newly-fired pieces to the rest can set up a chain reaction of modifications and new ideas.

The designer may also find it necessary to break away from the window as present on the plate glass screen and try out ideas in other media. It may be necessary to make new drawings to see if they could improve on the original proposition in the cartoon. It is quicker and easier to change the cartoon than it is to change the actual glass. The cartoon then acts as a model for actual changes that might or might not be made. It allows them to become more visible and their implications more evident and so more easily judged. Quite possibly the cartoon will begin to resemble a collage as new fragments are developed and pasted into place. It may become a record of the decisions the designer made as the window evolved and developed. It is a working tool for ideas and also a part of the means to implement them.

A more radical weighing up of possibilities will take place if the designer decides that it is worthwhile making up an alternative idea in actual glass. These physical models in the real materials can be tried out in place and a decision reached.

Some work may be necessary right away from the glass in the studio, making a journey in search of just the right imagery. Sketch book, notebook and camera could all be used to gather up useful material or to explore a new line of thought. Strictly speaking, there is no limit to the sources that might be relevant to a particular situation.

In the final stage of making the window the cut-line is used again. The window is assembled on it lying flat on a work table. Each piece of glass is carefully surrounded by lead of an appropriate size. Glazier’s big headed nails hold the whole construction temporarily in place. Then the leads are soldered on each side and the spaces between lead and glass filled with a black sticky putty, the recipe for which has not varied for centuries.

It is easy to appreciate that it would actually be impossible to bring a stained glass window into existence without some such repertoire of modelling devices. The designer requires a medium for a continuing encounter with the evolving work. Designer and client require a shared model of the design so that they know what is proposed and can agree on it. The designer needs the full-size design and the cut-line to organise the process of building the window. The range of models used fulfils essential roles in the designers’ personal artistic development, the social and economic context and acceptance of the work and its development and production.

In discussing designers’ use of models, we shall constantly return to a framework of this kind. The models used in producing a stained glass window are relatively few in number. By contrast, the complex products of contemporary technology require a huge range of models to be deployed to bring them into being. For example, many thousands of drawings, calculations, patterns and prototypes are needed in the conception, design,
development and production of an aircraft. Nonetheless many of the models used in designing an aircraft fulfil the same underlying functions and purposes as those involved in producing a stained glass window. There prove to be very many factors common to designing and making any material thing. The enterprise is to conceive and produce an end result but – essentially – also to be able to know in advance what the end result will be. Models make this possible.

In 1960 I was appointed editor of Ark, the Royal College of Art’s magazine. This was to change the direction of my interests, towards media involving words and pictures or words and things. From editing Ark, I went to Zürich as assistant Editor of Graphis. Although graphic design deals in a medium that is, on the face of it, totally different from stained glass, there still exists a recognisable affinity between the two procedures. Both involve the use of established modelling systems that relate very closely to the production processes involved.

The printing industry in 1960 bore no resemblance to the same industry today. The computer had not yet come in even as a word processor, let alone as a design tool allowing the designer to produce complete camera-ready artwork for the printer and to go to a fully digital process without an intervening stage on film. Most setting was done in hot metal (Monotype or Linotype) even where the pages were to be printed by lithography, a process involving photographing a print-out of the type before plate-making. Some use was made of setting by a photographic process but this was principally employed for headlines, titles and unusual typefaces. The process and models used were essentially those relevant to letterpress printing and would have been familiar to generations of publishers and printers going back to the origins of printing with moveable type.

Everyone involved in printing and publishing at that time shared proposals, ideas and controlled production through an established set of models:

Type specifications  
Sample settings  
Page roughs or thumb-nails  
Sample page layouts  
Illustration roughs  
Dummies  
Marked-up copy  
Galley proofs  
Finished art work or paste-up  
Page proofs

Each major publisher and printer had a book of house rules which were in essence the instructions - or model - for punctuation, spelling, grammar and layout for printed material produced by ‘the house’. The rules brought together the literary, visual and physical aspects of a book, giving them coherence and a unity of style.
The measuring systems used in the printing industry were time-honoured and esoteric, varying between Britain, Europe and the United States. Paper sizes, type sizes and the conventions of page layout were determined by the limitations imposed by having to print from raised metal letters cast onto a metal body and locked up into heavy metal frames.

Within this rigid framework, however, it was possible for the typographer to specify very accurately what was required. Although rough page layouts and sketches were often used, it was, in principle, possible for typographers to specify every detail of a page layout in words and numbers alone, knowing that the pages seen 'in the mind’s eye' of the designer would be reproduced in the mind’s eye of the compositor and so onto the printed page. This was an extraordinary example of the ability of one thing to stand for another – in this case words and numbers standing for the spatial disposition of a page and the visual appearance of text on it. Table 1 summarises some of the elements that a typographer could specify using only the technical modelling language of the trade.

Learning the repertoire of typographic codes and contrasting them with the various drawings and patterns used in stained glass design was the first thing that really made me think about the nature of the different media which designers use to generate and communicate their ideas. Although the functions of a full-size stained glass design and a type specification were clearly similar, in that they both reflected their designer’s purpose, they looked extraordinarily different from each other. One was a big picture, supplemented by the cut-line. The other was in an esoteric technical language of specialist words and measurements, usually supplemented by a drawn page layout. The small-scale coloured stained glass design actually resembled the finished window in many respects (but the cut-line did not). On the other hand, the type mark-up bore little resemblance to the printed book (but the drawn page layout did). Here was an intriguing puzzle. Unthinkingly, I had always assumed that to be useful an idea or a plan for something had in some visual way to resemble it. Clearly, it did not.
**TABLE 1**

**Type mark-up**

What a type designer could specify using traditional forms of type mark-up

- The size of the type
- The type to be used
- How long each line of type should be
- What space there should be between the letters within a word and between words
- What space there should be between lines
- What space there should be between paragraphs
- How big the page is to be
- How the page should be divided into columns
- The size of the margins around the type and between columns of type
- How illustrations will be positioned on the page
- Position of page numbers

- The type and size of type to be used for titles and headings –
  - Chapter or section titles
  - Sub-headings within text
- The style to be used for
  - Book or other titles in text
  - Captions to illustrations
  - Quotations from other authors
  - Footnotes, references

Each of these can also be specified in detail as to: type to be used; size of type; lengths of line; letter, word and line spacing. Also the positioning on the page of captions and footnotes.
TRADITIONAL TYPE SPECIFICATION

It was possible for a designer using traditional ‘hot metal’ type to give a complete specification for a typographic layout using the specialist typographer’s ‘code of type’ as the modelling medium. This code was built around the physical reality of letterpress printing – raised metal letters locked into a frame were used to make the impression on the printed page. Shown here are pages from a Swiss manual, published in 1949, comparing the names and measurements used in different countries: Germany, France, Britain and the United States. They were all different!

Fig 2.1 The parts of a piece of metal type
<table>
<thead>
<tr>
<th>Type Sizes</th>
<th>Didot pt</th>
<th>Didot sizes</th>
<th>French</th>
<th>Didot sizes</th>
<th>German and Swiss</th>
<th>Italian</th>
<th>Dutch</th>
<th>English pt</th>
</tr>
</thead>
<tbody>
<tr>
<td>English sizes</td>
<td>6-point</td>
<td>H</td>
<td>corps 6</td>
<td>H</td>
<td>Nonpareille</td>
<td>corpo 6</td>
<td>corpo 6</td>
<td>6.42</td>
</tr>
<tr>
<td>American sizes</td>
<td>8-point</td>
<td>H</td>
<td>corps 8</td>
<td>H</td>
<td>Petit</td>
<td>corpo 8</td>
<td>corpo 8</td>
<td>8.56</td>
</tr>
<tr>
<td>Didot pt</td>
<td>10-point</td>
<td>H</td>
<td>corps 9</td>
<td>H</td>
<td>Borges</td>
<td>corpo 9</td>
<td>corpo 9</td>
<td>9.63</td>
</tr>
<tr>
<td>Corpse 5</td>
<td>11-point</td>
<td>H</td>
<td>corps 10</td>
<td>H</td>
<td>Garmond</td>
<td>corpo 10</td>
<td>corpo 10</td>
<td>10.69</td>
</tr>
<tr>
<td>Corpse 6</td>
<td>12-point</td>
<td>H</td>
<td>corps 12</td>
<td>H</td>
<td>Cicero</td>
<td>corpo 12</td>
<td>corpo 12</td>
<td>12.64</td>
</tr>
<tr>
<td>Corpse 7</td>
<td>14-point</td>
<td>H</td>
<td>corps 14</td>
<td>H</td>
<td>Mittel</td>
<td>corpo 14</td>
<td>corpo 14</td>
<td>14.98</td>
</tr>
<tr>
<td>Corpse 8</td>
<td>16-point</td>
<td>H</td>
<td>corps 16</td>
<td>H</td>
<td>Tertia</td>
<td>corpo 16</td>
<td>corpo 16</td>
<td>17.12</td>
</tr>
<tr>
<td>Corpse 9</td>
<td>24-point</td>
<td>H</td>
<td>corps 20</td>
<td>H</td>
<td>Text</td>
<td>corpo 20</td>
<td>corpo 20</td>
<td>21.39</td>
</tr>
<tr>
<td>Corpse 10</td>
<td>30-point</td>
<td>H</td>
<td>corps 24</td>
<td>H</td>
<td>Zwiebies</td>
<td>corpo 24</td>
<td>corpo 24</td>
<td>25.68</td>
</tr>
<tr>
<td>Corpse 11</td>
<td>36-point</td>
<td>H</td>
<td>corps 28</td>
<td>H</td>
<td>Doppelmittel</td>
<td>corpo 28</td>
<td>corpo 28</td>
<td>29.96</td>
</tr>
<tr>
<td>Corpse 12</td>
<td>42-point</td>
<td>H</td>
<td>corps 36</td>
<td>H</td>
<td>Dervi cero</td>
<td>corpo 36</td>
<td>corpo 36</td>
<td>38.52</td>
</tr>
<tr>
<td>Corpse 13</td>
<td>48-point</td>
<td>H</td>
<td>corps 48</td>
<td>H</td>
<td>Vienciero</td>
<td>corpo 48</td>
<td>corpo 48</td>
<td>51.35</td>
</tr>
</tbody>
</table>

Fig 2.2 Comparisons between the different ways of measuring type used in Britain, America and Europe
Fig 2.3 and 2.4  Comparison between some of the different technical languages used in typography in Britain, American and Europe
Beginning in the late 1960s, I was exceptionally fortunate to be able to pursue a personal quest for better understanding of ‘designerly thinking’, first through my design work and then through academic research and teaching. As it turned out, my own interest in the topic chimed in with a wider move to develop viable theoretical models of design and design activity. The motivation for this was political and economic.

My own early involvement was in the field of design for health. From 1966 to 1977 I was a design consultant to King Edward’s Hospital Fund for London (now simply the King’s Fund). This far-sighted charity was concerned to improve management practice in all areas of the health service. It did this through courses, research, conferences and publishing. It was thought that better design management, more transparent design practices and teamwork linking designers with users would produce better hospital buildings and equipment. More than that, it would lead to a long-lasting relationship between designers and users that would enable users to make better use of their physical resources.

The King’s Fund was engaged in a number of product development and architectural design projects that pioneered the application of new design methods and approaches to design management. They were concerned with the integration of design teams consisting of specialists from diverse fields – architecture, engineering, medicine and nursing, for example. The publications department disseminated some of the results of the Ministry of Health’s exemplary project to design and build the new Greenwich District Hospital. Almost incidentally this proved a forum for the use of new ways of designing and the use of an extraordinary range of modelling techniques including many different kinds of drawing, gaming, and the construction of full-size mock-ups and prototype constructions.

My involvement in these publications gave me considerable food for thought. It struck me that there was a very close relationship between the graphic (or numerical or physical) ‘content’ of each model and the thoughts they enabled the designers to think. Further, some were easy to share with laypersons whether or not they had previous knowledge of design activity while others appeared esoteric and hard to interpret. Many of these hard to interpret modelling forms were, however, specially useful to the designer. They were often of two very different kinds. Not surprisingly technical drawings were hard for non-specialists. They simply contained too much information and were, of course, drafted in a set of codes and conventions that had to be learnt. But quick and simple conceptual sketches could also be difficult to understand and easy to misinterpret. Clearly there was much to find out about the potential of models – and their limitations.

There proved to be remarkably little information available on the value of different kinds of model. Some kinds of drawings and physical models were conventional and had developed over a surprisingly long period of time. Their effectiveness was on the whole taken for granted. Their limitations were unexamined and could of course arise because the users were unfamiliar with them. By contrast, many designers used quite individual ways of modelling –
Fig 2.5 Greenwich District Hospital was intended not only as an exemplary design but also as a vehicle for new approaches to design management. Several publications recounted the development of the project. They included many diagrams and other modelling tools. This diagram was made to explain the potential of alternative handling methods.
The opportunity to do this came in a rather unexpected way. Almost simultaneously I was invited to do some teaching in the Teaching Training Department at Hornsey College of Art in North London and, through the King’s Fund, became involved in a project to develop a new specification for a hospital bed. The bed project was based in the Design Research Department of the Royal College of Art under the leadership of Bruce Archer.

The aim at Hornsey was to give a fresh emphasis to art education in schools, recognising the importance of design, architecture, fashion and mass media alongside painting, sculpture and the traditional ‘art school’ crafts such as pottery, textiles and the other areas of applied art.

The aim of the bed project was not only to develop a national specification for a health service bed but also to use a ‘real’ design project to throw light on the nature of design and designing. This was the distinctive approach of Archer’s Department and it meant that he and his colleagues were one of the few research groups in the world whose brief included examining the cognitive processes involved in designing. As it happened this linked very powerfully with the work of Hornsey: if teachers were to help children learn about design, they (the teachers) needed to understand better what they (the children) needed to know and be able to do.

The developments at Hornsey were part of a larger national ‘design education movement’ intended to establish design as an element in the curriculum in British secondary schools (later extended to primary schools). It stretched over several school subjects: art and design; craft, design and technology; and home economics. Bruce Archer soon became involved in this movement and set about the task of providing it with a viable theoretical framework. He effectively plugged the work in schools into his higher education network. The linkage proved to be remarkably fruitful.

Bruce Archer’s lasting contribution was both to provide a taxonomy for design as a field and subject and to identify ‘cognitive modelling’ as the mental process that made designing possible. He declared that models (drawings, plans, 3D models etc) were the essential ‘medium’ used in design. He saw cognitive modelling as the language of design, analogous to the natural language that was the essential medium of the Humanities and to notation (or number) that was the essential medium of Science.

The modelling media used in these health projects demonstrated the hybrid nature of design media in the 70s. Many of the professionals working on the buildings or products for the NHS were from an architectural or engineering background. The media used, however, had roots also in work study, ergonomics and market research – even fine art. The same complexity continues into the Twenty-first century, now reinforced and expanded by the use of the computer and computer generated imagery (CGI).
THE KING’S FUND BED

This NHS project was very carefully planned and its aim was quite subtle. Although Bruce Archer assembled a multi-disciplinary team at the Royal College of Art and they did indeed design a prototype new standard hospital bed, the real purpose of the exercise was to produce a general specification that might be met in a variety of ways. The specification would be a kind of ‘gold standard’ against which to measure and evaluate rival design proposals.

The prototype bed was, of course, a physical model that embodied and made tangible the requirements of the specification. By contrast the publication containing the specification was entirely expressed in words and numbers. It was not supposed to pre-judge any issues about the best way to achieve the specification. However, it was, in its own way, as much a model for the bed as was the prototype bed. The book set out to appear as cool and rational as possible: the type design was intended to ‘model’ the assumptions behind the project. To view the prototype bed alongside pages from the specification remains enlightening even today. The two ‘models’ are each useful in their own domain. The actual prototype can be used and through its use some of the underlying assumptions of the specification can be put to the test. On the other hand, it doesn’t immediately convey the details of the specification and it certainly begs (but perhaps prejudges) the question: ‘how else could you achieve these results?’

The project was also effective in throwing light on the nature of design activity and modelling systems. It highlighted the potential value – and some of the problems – entailed in design by multi-disciplinary teams and the types of model they could use to support collaboration.

In developing the hospital bed specification the first task for the Design Research Unit was to analyse the problem and gather information. The results were embodied in a statement of the user’s needs which was used as a performance specification for the first prototype design. The steps towards the production of the specification were logical and exhaustive, and described the design problem in a number of different ways – for example, by the purposes of the bed and by the known constraints on its development.
<table>
<thead>
<tr>
<th>Activity</th>
<th>Critical factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bed as focus of nursing:</td>
<td>Height adjustment, high height, leg and foot clearances, width, length, obvious mode of operation, obvious state of adjustment, smooth perimeter, tucking-in surfaces, stable immobilisation, access to immobilisation device</td>
</tr>
<tr>
<td>Light and heavy handling of patient and bedclothes</td>
<td></td>
</tr>
<tr>
<td>Bed as examination table:</td>
<td>Height adjustment, high height, length, obvious mode of operation, all round access, stability, sitting support, backrest support, neutrality</td>
</tr>
<tr>
<td>Attendant's head and hands in close proximity, small movements, close lighting</td>
<td></td>
</tr>
<tr>
<td>Bed as treatment table (without apparatus):</td>
<td>Height adjustment, high height, leg and foot clearances, width, length, obvious mode of operation, all round access, stability, tilt, retention of mattress, sitting support, stable immobilisation</td>
</tr>
<tr>
<td>Light and heavy handling of patient, special postures, use of medicaments, exercise, activity of any part of patient's body</td>
<td></td>
</tr>
<tr>
<td>Bed as workbench (with apparatus):</td>
<td>Height adjustment, high height, leg and foot clearance, length, obvious mode of operation, all round access, stability, tilt, retention of mattress, drainage, fitting of ancillaries, mattress and base structure, sitting support</td>
</tr>
<tr>
<td>Light and heavy handling of patient, light and heavy use of mechanical components, close work, close lighting, wet procedures</td>
<td></td>
</tr>
<tr>
<td>Bed as focus of emergency:</td>
<td>Height adjustment, high height, leg and foot clearance, obvious mode of operation, obvious state of adjustment, all round access, stability, tilt, stable immobilisation, access to immobilisation device, retention of mattress, drainage, fitting of ancillaries, mattress and base structure, smooth perimeter, neutrality</td>
</tr>
<tr>
<td>Haste. Light and heavy handling of patient, bedclothes, other equipment. Often more than one person attending. Changes in location or orientation of bed. Confined space, simultaneous procedures</td>
<td></td>
</tr>
<tr>
<td>Bed as place for sleep:</td>
<td>Width, length, stability, retention of mattress, mattress &amp; base, sitting support, backrest support, structural transmission of noise</td>
</tr>
<tr>
<td>Side, supine and prone lying. Often supine with upper body slightly raised. Light sleep, restlessness, disorientation</td>
<td></td>
</tr>
</tbody>
</table>

Fig 2.6 A page from a report produced by the Design Research Unit summarizing the critical factors in the design as they relate to the activities which take place in and around a hospital bed
### Design factors extracted and ranked

<table>
<thead>
<tr>
<th>Critical factor in layout</th>
<th>relevant to:</th>
</tr>
</thead>
</table>
| **Stability**            | Bed as examination table  
                          Bed as treatment table  
                          Bed as workbench  
                          Bed as focus of emergency  
                          Bed as place for sleep  
                          Bed as place for eating and drinking  
                          Bed as place for excretion  
                          Bed as place for daily toilet  
                          Bed as daybed or chair  
                          Bed as focus of ambulation  
                          Bed as (un)loading surface |
| **Height adjustment**    | Bed as focus of nursing  
                          Bed as examination table  
                          Bed as treatment table  
                          Bed as workbench  
                          Bed as focus for emergency  
                          Bed as place for excretion  
                          Bed as place for daily toilet  
                          Bed as focus of ambulation  
                          Bed as (un)loading surface |
| **Obvious mode of operation** | Bed as focus of nursing  
                         Bed as examination table  
                         Bed as treatment table  
                         Bed as workbench  
                         Bed as focus for emergency  
                         Bed as focus of ambulation  
                         Bed as trolley  
                         Bed as (un)loading surface  
                         Bed as obstruction to other activities  
                         Bed as thing to be cleaned, maintained or stored |
| **Retention of mattress** | Bed as treatment table  
                          Bed as workbench  
                          Bed as focus for emergency  
                          Bed as place for sleep  
                          Bed as place for eating and drinking  
                          Bed as place for daily toilet  
                          Bed as daybed or chair  
                          Bed as (un)loading surface |
| **Sitting support**      | Bed as examination table  
                          Bed as treatment table  
                          Bed as workbench  
                          Bed as place for sleep  
                          Bed as place for eating and drinking  
                          Bed as place for daily toilet  
                          Bed as daybed or chair |

Fig 2.7 A later page from the same report, this time showing the critical design factors extracted and related to the activities which make them important.
Fig 2.8 A page from the initial performance specification

Fig 2.9 In the final version of the specification, published in 1967, the requirements are supported by detailed Appendices. A page from the Appendices is shown here.
Fig 2.10

In order to fully test the validity of the specification, designers and engineers at the Unit produced a working prototype for use by nurses in a ‘real’ situation. The development of the prototype was the result of team work involving Ken Agnew, industrial designer; Peter Slann, aeronautical engineer; Ed Walden, mechanical draughtsman; Tony Driver, sheet metal craftsman; and Gordon Cork, welder. They took the specification as created by nurses, ergonomists, research librarians and others and turned it into a physical object. Interaction with the physical object – the working bed – helped to further refine the specifications. Contemporary bed design continues to be influenced by this pioneering work.
The production of prototypes allowed the specification to be exposed to the views and experience of users-to-be. In these circumstances the prototype was itself acting as a model – albeit a highly realistic and complete one.
DESIGN AND DESIGN METHODS

Experience in the Second World War gave a decisive boost to science, and ‘rational’ management. In this context, design looked to be a rather chaotic process. There emerged in the 50s and 60s a strong desire to codify and systematize design in the hope of more reliable design results. One outcome 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 apparent that designers needed to use (and in practice did use) a variety of ‘methods’. It also emerged that different kinds of modelling were appropriate to the different stages of a design project and that each method depended on the use of a relevant modelling medium.

It is debatable how far practising designers were influenced by the exploration of design methods. However, the concept was seized on by managers for the very good reason that it appeared to make the process of designing more transparent, more rational and more scientific. The hope was, of course, that the results of design activity would be more predictable. The ultimate goal would be to be able to feed the requirements for a design in at one end of the design process and be sure that the use of the right design methods would ensure the emergence of the correct answer, perfectly fulfilling the requirements.

A side effect of the ‘design methods movement’ was to raise questions about the mental processes used by designers. Some ‘methods’ or ‘exercises’ such as ‘brainstorming’ were an attempt to provide an arena for innovative ideas; others such as ‘synectics’ tried to provide designers with a reliable method for bringing together disparate sources to provide the impetus for a new design. Implicit in all these methods was some proposition about the nature of what we might usefully call ‘designerly thinking’. However, it was far from clear just what this was.

Already in the 1960s there was enthusiasm for models of ‘the design process’ and the recognition that different stages in the activity (rather than the singular ‘process’) required different kinds of thinking (and modelling). One useful distinction was between divergent and convergent thinking. In the divergent stage of design activity the designer tried to be open to every possible idea or proposal; in the convergent stage the aim was to narrow down to a practical and realisable design proposition. Linking the two was a phase of ‘transformation’, a potentially creative manipulation of the possibilities to focus on the outlines of a possible solution. Sketching and other kinds of free drawing were modelling media identified with the divergent and transformation stages, technical drawings, prototypes and mathematical calculations with the convergent stage. This was a crude way of looking at it but it was an important step in the attempt to understand how designers designed.
CHOOSEING DESIGN METHODS

1. Decide which of the inputs in the chart is already known to you.

2. Select, from the outputs, the category of information that you require next.

3. Methods appropriate to your problem appear in the cells where the selected input rows and output column cross, e.g. method 5-3 AIDA is in input row 4 and in output column 6. Methods are listed below in order of their appearance in the book.

1. PREFabricated Strategies (Convergence)
   1.1 Systematic Search (The Decision Theory Approach)
   1.2 Value Analysis
   1.3 Systems Engineering
   1.4 Man-Machine System Designing
   1.5 Boundary Searching
   1.6 Page’s Cumulative Strategy
   1.7 CASA (Collaborative Strategy for Adaptable Architecture)

4. Methods Of Searching For Ideas (Divergence And Transformation)
   4-1 Brainstorming
   4-2 Synectics
   4-3 Removing Mental Blocks
   4-4 Morphological Charts

2. STRATEGY CONTROL METHODS
   2.1 Strategy Switching
   2.2 Matchett’s Fundamental Design Method (FDM)

5. Methods Of Exploring Problem Structure (Transformation)
   5.1 Interaction Matrix
   5.2 Interaction Net
   5.3 AIDA (Analysis of Interconnected Decision Areas)
   5.4 System Transformation
   5.5 Innovation by Boundary Shifting
   5.6 Functional Innovation
   5.7 Alexander’s Method of Determining Components
   5.8 Classification of Design Information

3. Methods Of Exploring Design Situations (Divergence)
   3.1 Stating Objectives
   3.2 Literature Searching
   3.3 Searching for Visual Inconsistencies
   3.4 Interviewing Users
   3.5 Questionnaires
   3.6 Investigating User Behaviour
   3.7 Systemic Testing
   3.8 Selecting Scales of Measurement
   3.9 Data Logging and Data Reduction

6. Methods Of Evaluation (Convergence)
   6.1 Check lists
   6.2 Selecting Criteria
   6.3 Ranking and Weighting
   6.4 Specification Writing
   6.5 Quirk’s Reliability Index
A key publication in 1970 was *Design Methods: Seeds Of Human Futures* by J Christopher Jones. It set out a menu of then current design methods, relating them to the stages of development of typical design projects. Significantly it recognised Divergence, Convergence and Transformation (now dignified with capital letters) as categories of design activity. Many of the methods described depended on the manipulation or ‘running’ of models for their success.

A large number of the methods recorded by Jones remain in current use and some are taught in design and business schools.
Studies of how designers actually worked in practice did not appear to conform to any of the theoretical models of the design process then current. Although designers did appear to use divergent and convergent thought processes and there was (almost by definition) a journey from divergent to convergent, it certainly did not proceed in a linear way. Several new theories emerged. It began to look as though many designers actually started with the solution (!) or at least with a strong personal conviction about the direction to follow. They certainly did not use any formal procedures to stimulate divergent thought – on the contrary, they appeared to draw on their accumulated store of professional expertise to leap to a design idea that held out the promise of meeting the requirements. They then worked over a relatively long period to ‘fill in’ the details and realise the design. It was soon clear that different designers worked in different ways and that procedures in distinct fields of design also differed.

A further unexpected factor was the importance of precedent or ‘prior art’ in all fields. Material culture is a huge storehouse of design ideas and knowledge the content of which is shared between designers, clients and users. It is part of the general culture of any society. Making deliberate use of the storehouse, reflecting it or reacting to it, enabled some designers to develop their ideas quickly and helped them to reflect shared meanings and symbols in the resulting designs. It turned out that many designers had developed their enthusiasm for the made things as a result of places, products or images that had excited them in childhood. They were thoroughly immersed in material culture, not only as rational professionals but as thoroughgoing enthusiasts. In a profound sense, precedent, what had been done before, provided a model for the future. In this the designer could appear similar to the craftsman but whereas the craftsman might refine and develop an existing model, the designer used knowledge of earlier designs to help shape something new.

Making models of ‘prior art’, usually in the form of drawings or mathematical formula, historically made up of a large part of the theoretical content of the various design disciplines. Student designers or apprentices were always expected to study and master these precedents during their training.

It was easy for the new breed of design theorist to overlook the significance of this. They worked from the belief that the aim of design activity was essentially to produce something entirely novel. In many fields this was simply not the case. In typographic design, for example, each book or magazine has to be designed afresh but its value is not to be found in its novelty but in its ability to communicate. Effective communication will often depend on using well-understood codes and conventions. Novelty might actually be counter-productive. In a similar way, familiar building styles – including modernism – are an essential element in people’s ability to ‘read’ the meanings of buildings. Knowledge of prior art has a key role in people’s appreciation of design and its cultural significance.

In European architecture there was, after the Renaissance an extraordinary continuity in style, proportions and detailing which was itself based on a ‘rediscovery’ of Classical Greek and Roman precedent. The tradition was
passed on in published works and also of course through the direct teaching of apprentices and students. Architects often made their own collections of drawings and observations, usually interspersed with sketches of design ideas and explorations of form and proportion. Georgian and Regency architecture was supported and transmitted through the medium of pattern books which provided complete designs – models – for various house types and other buildings which would either be copied or modified in detail. (see Fig 2.14).

In the Twentieth century the influence of architectural precedents was extended to include vernacular architecture, building forms from other cultures and an interest in borrowing models based on work buildings (barns, for example) for domestic architecture. Suburbia became a playground for details torn out of context to provide a semblance of variety and individuality. This approach continues and is supported by the media which transmits models of house design far more widely and more effectively than pattern books ever did.

Fig 2.14 Page from a pattern book for a ‘classical’ London home. In many parts of the Capital, fine streets still exist that were constructed by spec builders using pattern books.

‘Second-Rate House’ by M A Nicholson from Peter Nicholson’s New Practical Builder
In the second half of the Twentieth century the significance of precedent in architecture changed dramatically. Modernism argued for a complete break with the past, championing the use of new materials and new technologies to serve a new kind of (industrial) society. In response, precedent was re-defined in sociological and psychological terms. The value of ‘prior art’ was not any longer to provide models of culturally correct style and proportions but to represent the wisdom and experience of generations of designers, tradesmen and clients. The focus shifted from grand designs to vernacular buildings, drawing on cultures from all over the world. A remarkable contribution to this movement was made by Christopher Alexander and his team at the Centre for Architectural Structure at Berkley, California. In *A Pattern Language*, (1977), (one of three related publications) the patterns found in human settlements and structures are analysed, described and modelled. The intention was to provide a kit of parts for environmental design but also, by revealing the components of the successful patterns of human settlements, to enable non-specialists to engage in design activity.

*A Pattern Language* contains many evocative photographs and texts which describe and link together the various elements but the key to the whole venture is found in hundreds of small sketch drawings which reveal the essence of the designs being exemplified (Fig 2.15). These drawings are, of course, iconic models and they are very efficient in conveying the essence of architectural ideas. They deal with such qualities as space, relationships, forms and structures in the context of human requirements such as privacy, identity and shelter. It is hard to imagine a more effective means of representation and communication for such ideas, which are essentially non-linguistic.

In the applied arts (one precursor of industrial design) craft methods continued longer than in architecture. However, by the end of the Eighteenth century, the field was supported by its own range of pattern books. By the time the British design schools were established in 1838, the main training medium was copying ‘prior art’ as the basis for future designs. Students were encouraged to work directly in museums but there were also useful publications surveying and reproducing examples of decorative and applied art from all over the world. The most comprehensive – a masterpiece of its kind – was Owen Jones’ *Grammar of Ornament*, published in 1856 and influential for many years afterwards.

The situation in engineering design was rather different. Engineering could only become a distinct discipline when it was able to make reliable predictions about the future performance of structures, vehicles, devices and machines. Much relevant knowledge was embodied in prior art. Before, say, the Sixteenth century in Europe very complex structures – cathedral vaults, for example – were built without a supporting theoretical basis. They were achieved by the gradual refinement of precedent, pushing towards the limits of what could be done. The builders made much use of full-size setting out, form work and patterns. Success depended on the accumulated know-how and experience of these architect/builders who passed on the stonemason’s art.
Fig 2.15 Illustrations from *A Pattern Language* by Christopher Alexander
Engineering succeeded by turning this practical know-how into engineering science. To do this, it was necessary to apply physics and chemistry to the practical business of shaping new things. Engineers developed mathematical models, formulas, diagrams and graphical representations to reveal and predict performance. Until the advent of the computer, these were supported by hand-drafted drawings which ranged from simple ‘ideas’ sketches through to elaborate working drawings intended to control the production process. Computerisation has made it possible to bring mathematical and iconic forms of modelling closer together.

Engineering had its equivalent of the architectural pattern books. The tradition began in the Renaissance and developed into drawings of collections of mechanical movements or constructional details. Collections of physical models were also assembled and used to teach young engineers. Significantly these were called such things as ‘mechanical alphabets’ or ‘mechanical grammars’, echoing the idea of these models being in some sense similar to language. At this time, all engineers received a thorough practical training entailing direct contact with constructions or machines as well as the theories that explained why they performed as they did.

Fig 2.16 Cabinet of models of mechanisms in the Academie des Sciences, Paris, 1711. Engraved by Sebastien Leclerc (1637-1714)

Engineering developed a number of specialist symbol systems many of which, such as electrical circuit diagrams, are today quite widely understood. The notion that an abstract collection of symbols, bearing no direct visual resemblance to the system or function they represent, can be used as a tool for designing or communicating is a remarkable expression of human ingenuity. It appears to be one of a number of useful modelling techniques which the design professions have given to general culture.

In the 1970s, the divergent/convergent dilemma was partly resolved by the insight that design activity was an ‘iterative’ process. That is to say it repeated
an apparently similar set of cognitive processes all through the design work. Put simply, designers operate rather like TV camera men, taking a long-shot of the whole project then moving to a close-up or three quarter view before returning to a long shot. They do this many times during the development of a design. There was clearly a coherent interaction between the close ups and the long shots, the dynamic between them ensuring that the parts and the whole of a design developed in harmony.

If there was a general move from divergent to convergent in the course of developing a design proposal, the journey was achieved through a long series of feed-back loops, each perhaps being divergent/convergent. More recently it has been recognized that the feed-back loops may contain activities of many different types and that it will not do to see them simply as iterations of the same operations. If these feedback loops are represented as an interaction between model and ‘real world’ there is a striking resemblance with the mathematical analysis diagram shown in Seminar 1.

Fig 2.17 to 2.19 explore this idea. Fig 2.20 applies the feedback model to part of a typical architectural design project.

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![Diagram](image)

Fig 2.17 Basic feedback loop in design activity
Fig 2.18 Feedback loops in design activity, showing how the loops depend on the use of the appropriate models for their effectiveness.

If the model in the design model box is inappropriate, the apparent design results will not be valid. The choice of model and the insight with which it is used or ‘run’ by the designer will determine the quality of the result and its eventual impact on the real world through the resulting designs.

Fig 2.19 These design feedback loops bear a striking resemblance to the Mathematical analysis diagram in Seminar 1.
Fig 2.20 Feedback loops as part of a typical architectural design project. Progress in the design development results from using, running and drawing conclusions from the appropriate modelling medium.
It is rare to find detailed records of the feedback loops in action. Partly this is because the paperwork and physical and other models used in a design project are seldom kept. An exception to this rule is the design for a polymer guitar developed by Owain Pedgley while in the Department of Design and Technology at Loughborough University. For his PhD, Dr Pedgley not only kept all his design drawings but also noted their function and how they related both to other forms of design modelling and to the project as a whole. It was evident that the feedback from the drawings (models in our sense) did indeed move the work forward.

Dr Pedgley identified five main ways in which the drawings were ‘embedded’ in his design activity:

- **Explaining things to colleagues**
  ‘Nearly all of these drawings were prepared in advance of meetings so as to illustrate key points to other people’.

- **Mementos of ideas coming from existing products**
  ‘These served as sketched and written reminders of the features of existing products’.

- **Restating design ideas and archiving information**
  ‘Drawings within this category assisted project co-ordination, especially after extended breaks way. They restated established design ideas, recorded out-of-hours designing, clarified emerging design criteria and served as a space for recording the findings of information searches’.

- **Recording ideas and decisions taken at meetings**
  ‘The drawings here were made to prevent loss of information from meetings, act as a formal record and to refer back to as a resource at a late date’.

- **Generating and developing product designs**
  ‘The main use of drawing was as a medium through which product designs were conceived and took shape, and by which ideas entertained the mind became externally represented’.

In the QUICK ON THE DRAW exhibition (2008), we were able to show 22 of these sheets of drawings and to accompany them with extracts from Dr Pedgley’s ‘diary of designing’. Taken together they give a vivid insight into the interaction between the drawings and the progress of the design activity.

In Figs 2.21 – 2.28 we show a selection of the sheets with the diary extracts.
COOL ACOUSTICS
Drawn models used in the design development of a prototype polymer guitar

THE PROJECT

Cool Acoustics began as part of Owain’s PhD work. In the intervening years it has grown to become a larger research project focusing on acoustic guitar innovation. There are today two key members of the team in addition to Owain:

Dr Eddie Norman, Senior Lecturer, Department of Design and Technology, Loughborough University.
Rob Armstrong, Luthier, Coventry.

The debate is no longer whether polymers are suitable or any good for guitars, but rather in what way they can be effectively integrated into mainstream instrument production.

The original motivation was to create an affordable and desirable beginners acoustic guitar of consistently high quality. The way to do this was to use polymer (plastics) in place of wood. Not only do polymers give very good sound quality at low cost, they open up radical approaches to instrument design, construction and finishing. The Cool Acoustics team have succeeded in developing non-wood guitars that sound and play just like wood!

Owain’s original design work was intended not only to develop an effective polymer guitar prototype but also to throw light on the way designer’s work. Just how do designer’s innovate? Owain kept all his drawings and a diary explaining why each drawing was made and how it helped in his designing. Here we show a small selection of 8 Drawings with their explanatory diary entries.
"Talked to Eddie about GRP [glass reinforced plastic] lay-up, since I've not done it before! Have illustrated the basic stages for doing this as a reminder to myself and to be used in design discussions in upcoming days, particularly for gathering comments on how to produce surface textures. I have added notes on vac-forming (using the different types of mould in the GRP process) because I have re-read that the Forex-EPC [special polymer sheet] is suited to vac-forming, despite my earlier workshop trials. So - I am leaving the vac-forming route open, and might well contact a manufacturing company soon to look into making use of it."

Purpose: Explaining things to colleagues

[29.01.98, Project Day 108/227, Diary Entry 229/312, Source: DS51]
"Commentary on DS55. This is an important design sheet to me - I have set out how I think the mass-manufactured guitar will be constructed, for the purposes of talking to Eddie [Norman] and Dick [Heath], so that I can then go on to: (a) make firm recommendations and justifications for the manufacturing route of each component; (b) go ahead and complete the presentation CAD [computer aided design] model, knowing exactly how components will be assembled. I have already had a meeting with Eddie to discuss the ideas on the design sheet - his suggestions are noted on the tracing sheet. We agreed at this meeting that it wouldn't be necessary to provide exact dimensions for the components involved, but rather to communicate the proposed materials, production and assembly details in a joint graphical/text way. After all, final dimensions have not been decided upon… they would be meaningless at this stage."

Purpose: Explaining things to colleagues

[27.04.98, Project Day 143/227, Diary Entry 293/312, Source: DS55]
"Some of the 'checklist' of tech. features on DS3 have been sparked off mentally from previous encounters with 'guitar design' work, others pertain to more 'general' considerations which are appropriate to any product I may be designing."

Purpose: Mementos of ideas coming from existing products

[22.05.96, Project Day 5/227, Diary Entry 11/312, Source: DS03]
"This was clearing up, in my mind, how the build-up of components for the final design was going. I was thinking whilst drawing these that I would need to produce CAD [computer aided design] models of each."

Purpose: Restating design ideas and archiving information

[07.01.98, Project Day 95/227, Diary Entry 195/312, Source: DS43]
"Design sketches of prototype 3 manufacture, for me to visualise what Rob Armstrong was explaining to me. I'll find it easier to make use of this information in the near future when it's in illustration rather than memory."

Purpose: Recording ideas and decisions taken at meetings

[21.01.98, Project Day 103/227, Diary Entry 212/312, Source: LB1:49]

"Strengthening ribs on 3D view (experience). Fixing points for moulds (knowledge)."

Purpose: Generating and developing product designs

[17.10.96, Project Day 19/227, Diary Entry 55/312, Source: DS23]
"All the while whilst on DS45 I knew that I would be working with 8mm depth polycarbonate and that the bridge would be machined using CNC [computer numerically controlled] methods because of the intricate/precise curves required. When working on the right-most drawing (marked 'X') I had in my mind an image of a block being machined to produce the shape I wanted - using the Department's Workshop 1 machines. I found myself 'extending profile lines' as if they were paths for the milling cutters to follow. I also imagined the milling machine producing the overall edge shape, 1mm or so a time. I concluded that the whole component could be produced on the CNC machines, save a few operations which cannot be performed in 2.5-D machining."

Purpose: Generating and developing product designs

[22.01.98, Project Day 104/227, Diary Entry 214/312, Source: DS45]
"When I placed the shell against my table (reasonably dark wood) it confirmed in my mind (and what I'd drawn on DS51) that I'd like the neck and head to be manufactured from very light coloured wood. It looked too dingy and furniture-like with the darker wood."

Purpose: Generating and developing product designs

[15.07.98, Project Day 173/227, Diary Entry 306/312, Source: DS51]
PROBLEM SOLVING AND PROBLEM RESOLVING

Thinking on design and particularly design education in the 1970s and 80s was influenced by the intellectual currents of the period. This was a time of intense speculation about the nature of human creativity and the factors that had allowed humans to spread their material culture throughout the globe. Flexibility was seen as a unique element, commonly, but nevertheless somewhat naively, referred to as ‘problem solving’. Not surprisingly, design activity was, at a high level of generality, quickly identified as a type of problem solving.

However, the idea demanded further refinement before it began to have explanatory or illuminative power. The main puzzle was that although design activity certainly seemed to address and even solve some economic, social and manufacturing problems, it did not come up with a single unique or ‘best’ solution. For example, attempts to solve the problem ‘a space for family living’ result not in a single ‘perfect’ house design but in a multitude of responses representing, in fact, different balances of the priorities inherent in the requirement: ‘a space for family living’. Moreover, the design ‘solutions’ proposed and built in different cultures and in response to different economic and technological resources differed dramatically. The same could be said for everything designed and made by human beings.

What emerged was that ‘problems’ were not exactly what designers worked on. Problems are defined but design situations are better understood as ‘ill-defined states of affairs’ – ones, which have a range of viable solutions rather than a single perfect outcome. They have usefully been tagged ‘wicked problems’.

Characteristically in the case of wicked problems, the problem definition is incomplete and the problem definition may have to change as work proceeds. Design activity includes not only solving the problem but also re-defining the problem in the light of emerging solutions. In short, creative thought is applied to re-working the problem as well as solving it. Resolving it would be a better word to use.

Bruce Archer and Phil Roberts put the situation particularly clearly in a paper written for the Design Education Unit at the Royal College of Art in 1979.

‘…(Design) is a problem-centred activity, but it is distinguishable from some other sorts of problem-solving activity by the fact that it is chiefly concerned with ‘ill-defined problems’. In this context, the term ‘problems’ refers to the presently existing state of affairs; it does not refer to the statement of requirements which a (possible) thing or system is expected to meet. Nor does the term ‘solution’ refer to the design arrived at. (…) Design problems are described as ‘ill-defined’ because there is no way of arriving at a provision description merely by the reduction, transformation or optimisation of the data in the requirement specification. By the same token, it is rarely possible to determine whether or not the finished design is ‘the correct’, ‘the only’ or ‘a necessary’ answer to the requirements. It must usually be possible, of
course, to establish whether or not it is a ‘proper’ answer. Where such doubts do not exist, the problem is not ‘ill-defined’ and might therefore have been resolvable by scientific or mathematical methods rather than designerly methods.’ (Archer and Roberts, 1979)

This proved to be a very helpful interpretation which managed to bring together theories of design with the observed practices of designers. It has been widely influential, though design continues to be loosely described as ‘problem solving’ without the necessary further analysis. Linking the idea of problem solving back to the iterative feed-back, zoom-in, zoom-out picture of design activity, it became clear that some of the iterations might involve the designer in problem solving where the result could be quantified (through the use of mathematical models, for example) others would involve the designer in ill-defined problems. Design activity included tackling both defined and ill-defined problems.

A more radical step would have been to recognise that design activity in fact encompasses a number of very different mental and physical processes including the solution of conventional problems, resolving ‘wicked problems’, visualisation and speculating, handling tools and materials, studying ‘prior art’, management and persuasion – and a host more should they prove to be relevant to the particular project in hand. At the highest philosophical level it became clear that design activity was as much about opening up new possibilities and creating new ‘meanings’ in the human environment as it was about solving problems defined in advance.

The 70s saw great interest in attempts to define design and to characterize or model design activity. An extraordinarily varied range of definitions was proposed ranging from the severely practical to the extravagant and philosophical. It began to seem as though design might be expanded to include almost every human activity.

Roberts suggested a different way of tackling the problem of defining design by replacing the question ‘what is design?’ by the question ‘when is design?’ If we consider this question, we can respond, ‘A design problem consists in a state of affairs, in which we feel some unease of discrepancy or incompatibility’. The ‘problem statement’ consists in a description of that state, and it will be, inevitably, an approximate or tentative description. Improving the situation consists in resolving the mis-match as shown by Roberts in the diagrams below.
The notion can be developed thus
If a 'problem' = 

(Condition of discrepancy or incompatibility or tension)

The condition described as its resolution =
an acceptable degree of closure of the gap

Fig 2.29

A further important point is that in almost every situation, resolving the problem is only a temporary resting place in a continuing series of overlapping problem states some of which may in fact develop directly, and even as a result of, the resolution of a previous problem state. So design activity will generally lead on eventually to more design activity, thus:

Fig 2.30
### TABLE 1

**DEFINITIONS OF DESIGN COLLECTED IN *DESIGN METHODS* (1970) BY J CHRISTOPHER JONES**

- Finding the right physical components of a physical structure (Alexander, 1963)
- A goal-directed problem-solving activity (Archer, 1965)
- Decision making, in the face of uncertainty, with high penalties for error (Asimow, 1962)
- Simulating what we want to make (or do) before we make (or do) it as many times as may be necessary to feel confident in the final result (Booker, 1964)
- The conditioning factor for those parts of the product which come into contact with people (Farr, 1966)
- Engineering design is the use of scientific principles, technical information and imagination in the definition of a mechanical structure, machine or system to perform pre-specified functions with the maximum economy and efficiency (Fielden, 1963)
- Relating product with situation to give satisfaction (Gregory, 1966a)
- The performing of a very complicated act of faith (Jones, 1966a)
- The optimum solution to the sum of the true needs of a particular set of circumstances (Matchett, 1968)
- The imaginative jump from present facts to future possibilities (Page, 1966)
- A creative activity – it involves bringing into being something new and useful
TABLE 2

DEFINITIONS OF DESIGN PROPOSED IN THE ROYAL COLLEGE OF ART DESIGN IN GENERAL EDUCATION REPORT, 1976

The term DESIGN can be used in an academic or very general sense to describe one of the broad division of human concerns, competence and knowledge:

Design is the field of human experience, skill, understanding and imagination that is concerned with the conception and realisation of new things and events and particularly with man’s appreciation and adaptation of his surroundings in the light of his material and spiritual needs. In particular, though not exclusively, it relates with configuration, composition, meaning, value and purpose in man-made phenomena.

The term DESIGN can also be used in a range of more operational and more limited senses, as indicated in the Concise Oxford Dictionary.

design, n. Mental plan; scheme of attack; purpose; end in view: adaptation of means to ends; preliminary sketch for picture etc; delineation, pattern; artistic or literary groundwork, general idea, construction, plot, faculty of evolving these, invention.

design, v.t. & i. Set (thing) apart for person – destine (person, thing) for a service; contrive, plan; purpose, intend; make preliminary sketch of; draw plan of; be a designer, conceive mental plan for, construct the groundwork or plot of.

The term DESIGN AWARENESS can be used to describe the degree to which individuals in a particular society appreciate and take part in design issues:

Design awareness is the consciousness of the issues of the material culture and of the products and the values of planning and making, together with the ability to understand and handle ideas related with them.

The term DESIGN ACTIVITY can be used to define an area of human competence:

Design activity is the exercise of the set of skills useful in planning, making and evaluating.
THE VALUE OF IMAGES

The key importance of models – particularly drawings and diagrams – in the practice of mathematics, engineering and architecture was recognized long before the idea of a related mental process emerged. A fully developed theory of cognitive modelling had to wait until the Twentieth century when psychologists and cognitive scientists began to be able to probe the workings of the mind. However, Eugene S Ferguson, in *Engineering and the Mind’s Eye*, shows that though ‘visual thinking’ traditionally had a low academic status (except in art) a number of engineers were aware of its significance in their own work:

‘In the 1780s Oliver Evans, a Delaware farm boy, invented the automatic flour mill, in which bucket elevators and screw conveyors were coordinated to eliminate the need for manual lifting or carrying of grain or flour. Evans claimed to have first put the system together in his head: ‘The arrangement I so far completed [in my mind] before I began [to build] my mill that I have in my bed viewed the whole operation with much mental anxiety’.

‘Also in the 1780s, James Watt informed his partner, Matthew Boulton of an idea he had for a “straight-line” mechanism (to guide a piston rod in a straight line), which became his favourite invention. “I have started a new hare”, he wrote; “I have got a glimpse of a method of causing the piston-rod to move up and down perpendicularly by only fixing it to a piece of iron on the beam, without chains, or perpendicular guides . . . or other pieces of clumsiness”. Marc Isambard Brunel, the French refugee engineer who, in England just after 1800, designed semi-automatic machines to make pulley blocks for ships in sequential operations, remarked on the ease with which he expressed his ideas in his drawings; he considered drawing techniques to be the true “alphabet of the engineer”.

‘In describing the origin of his steam pile drive, James Nasmyth, a mid-nineteenth-century English engineer, said that the machine “was in my mind’s eye long before I saw it in action”. He explained that he could “build up in the mind mechanical structures and set them to work in imagination, and observe beforehand the various details performing the respective functions, as if they were in absolute material form and action”.

‘Scientists also noticed the significance of visual thinking. Francis Galton, founder of the ‘science’ of eugenics, was a visualizer who contrasted his methods with the majority of scientists who reported that they thought in words. Writing in 1880 Galton guessed that everybody had the ‘visualizing faculty’ but probably lost it by disuse. In fact, however, many distinguished British scientists, including Michael Faraday, Lord Kelvin and James Clerk Maxwell did think fluently in terms of models and mechanical analogies’. (Ferguson, 1992)

Eugene Ferguson records that French scientists were critical of their British counterparts reliance on physical models. Commenting on Oliver Lodge’s book on electromagnetic theory (full of pipes, gears and pulleys in its
explanations) Pierre Duhem, French physicist and historian of science commented: ‘we thought we were entering the tranquil and neatly ordered abode of reason, but we find ourselves in a factory.’

Ferguson shows that, in practice, non-verbal forms of thought are essential to science:

‘Early in the Twentieth century, the prominent American philosopher William James remarked that a favourite topic of discussion among his colleagues was “whether thought is possible without language”. James said that it was perfectly possible, and that different thinkers think in different ways: “With one, visual images predominate, with others tactile”. Historians of science in the late Twentieth century have documented the persistent use of imagery by Ludwig Boltzmann. Albert Einstein said that he rarely thought in words at all; his visual and “muscular” images had to be translated “laboriously” into conventional verbal and mathematical terms.’

‘In the late 1940s Richard Feynman, a brilliant theoretical physicist, enhanced the power of quantum mechanics by inventing “Feynman diagrams”, a visual alternative to a formidable array of equations. Feynman thought that Einstein, in his old age, failed to develop his “unified theory” because he “stopped thinking in concrete physical images and became a manipulator of equations”.

In the 1980s the chemist-philosopher Robert S Root-Bernstein documented the “extracurricular” abilities of more than a hundred prominent scientists of the eighteenth, nineteenth, and twentieth centuries. Most were part-time visual artists, musicians, and poets; a few were composers, writers of fiction, and photographers. Root-Bernstein argues that those visual and artistic proclivities have a distinct bearing on the originality of the scientists. His extensive studies have led him to conclude with certainty that “most eminent scientists agree that nonverbal forms of thought are much more important to their thought than verbal ones”. (Ferguson, 1992)

The focus of these engineers and scientists was on visual thinking – seeing in the minds’ eye. As we have seen in Seminar 1, however, the mind makes models linked to each of its sensory inputs and also creates and manipulates abstract symbol systems such as language and number. However, the concentration on the visual in these disciplines is not surprising. It is the visual (and tactile) modes that are particularly engaged in shaping and interpreting the environment.

For science, the link between the visual world and number appears to be particularly fruitful. For design, the visual (and tactile) seems to be a gateway into other realms of understanding, qualitative and quantitative.
COGNITIVE MODELLING

It was in the 1970s that the first systematic efforts were made to identify a type of cognitive modelling as the essential element in ‘designerly thinking’. It was accepted that design activity might entail many different types of mental process but the bold claim was made that without the ability to build cognitive models of future possibilities, designing would be literally impossible. Bruce Archer was a leading figure in developing this insight into a theoretical framework for design activity, design research and design education. Cognitive science has moved forward since the 1970s and has left some of the claims looking a little vulnerable, but the fundamental argument has stood the test of time and is worth quoting at length:

‘The term “cognition” is intended to embrace all those processes of perception, attention, interpretation, pattern recognition, analysis, memory, understanding and inventiveness that go to make up human consciousness and intelligence. Philosophers of mind and cognitive psychologists tend now to talk of cognition as the mental function of construing sense experience as conceptions, and of relating conceptions with one another. The use of the word “construe” is significant. It is intended to acknowledge the circumstance that the individual conscious being cannot “know” anything of the reality beyond its own skin except by the collection and interpretation of the signals received by its sense organs. These signals are overlaid by all sorts of irrelevance, interference and noise, and distorted on reception by all sorts of errors, illusory juxtapositions and omissions.

‘Moreover, in the neurological sense, the signals are ultimately received as electrochemical impulses scattered over different parts of the grey matter of the brain. There is no screen anywhere in the mind on to which a collected picture is projected. The conception in the mind which is built from these scattered impulses is that of a coherent set of signals betraying the presence of a supposedly equally coherent causal phenomenon beyond the sense organs. Subsequent patterns of signals may reinforce or deny the conception, or permit the useful association of conceptions into greater conceptions. When they are sufficiently integrated these constructions in the mind become a general cognitive model of external reality. Since the cognitive model is all the individual consciousness has as evidence of external reality, then for all practical purposes the cognitive model is seen as if it were the reality. Memory and imagination are those further capacities of mind which are capable of conjuring up models of reality in the absence of causative sense date.

‘There is evidence that the human mind is predisposed to construe sense experience in particular ways, so that conceptions of space, form, object-coherence, colour temperature, sound and so on, are common to all human beings. These could be called categories of perception. There is also evidence that the human mind is predisposed to seek similarities within and between its accumulating conceptions, and to assign these to categories. It is from the labelling of conceptions and categories, and from the labelling of the relations between conceptions and categories that rational thought springs. It
is from the recognition of pattern in and amongst conceptions and in and amongst categories, and from the recognition of pattern amongst the kinds of relations which conceptions and relations have with one another, that “designerly” thought springs. There is a third predisposition of the human mind which lifts it above and beyond that of other sentient beings. This is the predisposition to assign symbols to represent conceptions, categories and relations. The use of symbols permits abstraction in inner thought, and the externalisation of thought for recording or communication purposes.

‘In the course of evolution the left half of the human brain has learned to specialise in the arts of categorisation from which is developed rational sequential thought, and in the use of digital symbol systems to construct language, mathematics and forms of notation. At the same time the right half of the human brain has learned to specialise in pattern recognition, and the use of presentational symbol systems to construct images, diagrams and other spatial forms of representation. Interplay between the two halves of the brain permits the pursuit of thought both to the highest levels of abstraction and to the further reaches of practical planning design.’ (Archer, 1981)

At the end of this passage Archer is moving closer to a more precise analysis of the content of ‘designerly’ thought, recognising that it is simply one of a number of types or modes of cognitive modelling. For a while the term ‘imaging’ seemed to be a useful way of characterizing the designers’ special capacity though it was, of course, shared with others such as painters and sculptors. This is how the distinction was made:

‘The expression “cognitive modelling” is intended to refer to the basic process by which the human mind construes sense experience to build a coherent conception of external reality and constructs further conceptions of memory and imagination. The expression “imaging” is intended to refer to that part of cognitive modelling which construes sense data and constructs representations spatially and presentational, rather than discursively and sequentially.’

Attempts were made to capture the essence of these ideas about modelling in the form of models, particularly insofar as they were important for general education. Two potentially useful models are shown in Figs 2.31 and 2.32.
Fig 2.31 Archer's model for general education, identifying design as a third area in the curriculum. Humanities is seen as essentially dependent on language; science on notation. Design is linked to modelling but this would later be modified to 'imaging', since language and notation are also modelling media. However, this modification is itself open to misinterpretation since the modelling media used in design activity are not solely visual.

Proposed relationships between Humanities, Science and Design
Fig 2.32 DIAGRAM from the 1970s identifying the relationship between imaging and physical models

Basic elements in the relationship between imaging and modelling as represented by Ken Baynes. The diagram needs further development to distinguish more clearly between the mental models used in imaging and the externalized models used to represent cognition in physical or symbolic forms.
The idea of imaging and the existence of other specialized aspects of cognitive modelling chimed in with the growing realization that the mind was quite highly compartmentalized. It was not, as some had supposed, simply an undifferentiated ‘intelligence machine’. General purpose intelligence had also become specialized. The understanding that different parts of the brain definitely carried out specific mental processes came first from studying people whose brains were damaged but only in one area. Such damage could lead not to a general loss of function in these patients but to very precise – and sometimes bizarre – loss of particular functions. The idea of specialization was the foundation for the proposition that there were in fact a number of distinct and identifiable ‘intelligences’. This notion proved to be a useful way of enabling discussion of clusters or federations of activities of mind that might otherwise go unidentified.

THE THEORY OF MULTIPLE INTELLIGENCES

In his book *Frames of Mind*, Howard Gardner (1983) discussed the idea of ‘multiple intelligence’. He described the growing biological evidence for locating certain kinds of thinking and feeling in particular parts of the brain. He noted, for example, that there is a physical developmental process called ‘canalisation’ which has the effect of confirming and crystallising paths of use and custom in and between the different areas of the brain. It is rather as if a highway were to be made wider and its route more fixed directly by the passage and amount of the traffic using it. After a certain point, different for different functions, the route becomes permanent and cannot be changed or replaced.

Gardner argued that all this new biological understanding should result in a change of philosophical approach. In the immediate past, the common view has been that all ‘intelligence’ was really the same thing – a particular style of thinking and reasoning which we apply to widely differing activities. But with the strong physical location of different functions there developed the concept that different kinds of intelligence actually depend on the existence of distinctive kinds of mental processes.

Gardner recognized that there might be differences of opinion as to the most useful way to identify the ‘intelligences’ but to forward the argument he proposed six. For each he recognized a medium (or modelling system) and also named a role that would epitomize that intelligence in action. The intelligences were:

- **LINGUISTIC INTELLIGENCE**
  The Poet. Spoken and written language

- **MUSICAL INTELLIGENCE**
  The Composer. Sound: pitch; rhythm; timbre

- **LOGICAL – MATHEMATICAL INTELLIGENCE**
  The Mathematician. Number and notation underlying both science and logic
• SPATIAL INTELLIGENCE
  The Chess Master. Configuration of the physical world

• BODILY – KINESTHETIC INTELLIGENCE
  Dancers and swimmers. Skilled use of one’s body

• THE PERSONAL INTELLIGENCE
  Access to one’s own ‘feeling life’ and awareness of that of others

Gardner was well aware that these intelligences did not cover the whole of human thought and equally did not exist in watertight compartments. He noted, for example, the strong connection between musical intelligence and logical-mathematical intelligence. The same case can be made for a vital connection between spatial intelligence and number. Linguistic intelligence interacted with the other five offering a medium for explanation and clarification. However, it was strongly presumed that there was some kind of fundamental connection between the different kinds of intelligence and the sensory inputs into the brain on the one hand and the active outputs on the other. In consciousness the intelligences interacted to give the unique experience of being alive and aware.

Clearly spatial intelligence is likely to be specially relevant to designers. Gardner characterized it in this way:

‘Central to spatial intelligence are the capacities to perceive the visual world accurately, to perform transformations and modifications upon one’s initial perceptions, and to be able to re-create aspects of one’s visual experience, even in the absence of relevant physical stimuli. One can be asked to produce forms or simply to manipulate those that have been provided. These abilities are clearly not identical: an individual may be acute, say, in visual perception, while having little ability to draw, imagine, or transform an absent world. Even as musical intelligence consists of rhythmic and pitch abilities which are sometimes dissociated from one another, and as linguistic intelligence consists of syntactic and pragmatic capacities which may also come uncoupled, so, too, spatial intelligence emerges as an amalgam of abilities. All the same, the individual with skills in several of the aforementioned areas is most likely to achieve success in the spatial domain. The fact that practice in one of these areas stimulates development of skills in related ones is another reason that spatial skills can reasonable be considered “of a piece”.

‘A comment is in order concerning the phrase “spatial intelligence”. From some points of view, it would be appropriate to propose the descriptor visual because, in normal human beings, spatial intelligence is closely tied to, and grows most directly out of, one’s observation of the visual world.

‘But just as linguistic intelligence is not wholly dependent upon the auditory-oral channels and can develop in an individual deprived of these modes of communication, so, too, spatial intelligence can develop even in an individual
who is blind and therefore has no direct access to the visual world. Accordingly it seems preferable to speak of spatial intelligence without linking it inextricably to any particular sensory modality.’ (Gardner, 1983)

The key phrase for design activity in this very helpful discussion of spatial intelligence is:

‘to perform transformations and modifications upon one’s initial perceptions, and to be able to re-create aspects of one’s visual experience, even in the absence of the relevant physical stimuli’.

To this we must add Gardiner’s own caveat: we are not concerned solely with the visual but also with other aspects of the physical human milieu and the behaviour of people in that milieu. The designer uses his intelligence to envisage – image – the future and uses models to help in this task. The models are frequently visual, often mathematical but they can in principle take any form that will help to get the job done. In practice, the information needed in a particular piece of design work may be wide-ranging and take many different forms: equally the outputs needed to realise a project may be visual, numerical, or linguistic according to need. See Fig 2.33 for a particular example of this diversity.

Fig 2.33 The information needed in any piece of design work can be very wide ranging and take different forms. Here is a classification of the information that could help to determine the design of seats in a vehicle. It is taken from Christopher Jones’ Design Methods, a book that had an important impact on design theory following its publication in 1970.
DESIGNERLY MODELS

However, there are certain core concerns of the designer which cannot effectively be modelled in language (though some of these may be very effectively modelled in numbers). It is, therefore, not surprising to find that the majority of the modelling media used by designers relate very directly to these non-linguistic aspects of the environment and our experience of

Fig 2.34
The designer has to focus on many aspects of reality that cannot be modelled in language. In this representation of the ‘perfect nippy’ the essence is conveyed by non-verbal means – the image – while words are used to explain the ‘meaning’ of the image. The words could not do the job in the absence of the image, but the words point up the significance of the image and highlight points that might not be obvious without further explanation. (A ‘nippy’ was the name given to waitresses in the once famous teashops run by J.Lyons & Co).
Colour provides a dramatic example. It can only be discussed or evaluated by reference to actual examples or models. Although colours can be translated into notation to describe their wavelengths or as part of a cataloguing system, a particular tone or hue of red can be consciously perceived and appreciated only by reference to itself or to other contrasting or slightly different colours.

Proportion is similarly impossible to perceive consciously except by reference to itself. The example has to be present before us in some form, or we have to have the power to recall it through our spatial memory. The diagrams of the Golden Section and its relatives (Fig 2.35) use language to give instructions on how to construct the figures and their mathematical properties can be rendered into numbers but their actual impact on our senses and consciousness can only come from the things themselves.

Fig 2.35 Proportion cannot be described in words though words are needed to describe how to construct the figures.
A similar point can be made about most anthropometric data, particularly where this involves an attempt to understand the proportional or functional relationships between a person and his or her surroundings.

Person/environment relationships and issues of human proportion cannot be dealt with fully by using words or numbers. Words and numbers serve to interpret and quantify visual/spatial models. Attempts to understand the aesthetic relationships inherent in the human form go back to Vitruvius and Leonardo da Vinci’s interpretation of his theory: the influential figure inscribed within a square and a circle.

Roman architect Vitruvius believed that buildings should conform to the ‘measure of man’, an idea revived with enthusiasm during the Renaissance:

‘Four fingers make one palm, and four palms make one foot, six palms make one cubit, four cubits make once a man’s height and four cubits make a pace, and twenty-four palms make a man’s height, and these measures are in the building.’

By relating body to geometry, Vitruvian Man was born. However, the idealistic proportions portrayed by Leonardo’s Homo Vitruvius were both vertically and horizontally challenged as no one is that perfect. Art historian Kenneth Clark even observed that from the point of view of strict geometry, ‘a gorilla might prove to be more satisfactory than a man’.

Travelling to New York from Le Havre on a cargo boat in 1945, Le Corbusier utilized his time to refine a system of harmonious proportions based on the human figure. He called it Le Modulor:

‘Take a man-with-arm-upraised,’ he writes, ‘2.20 metres in height, put him inside two squares, 1.10 by 1.10 metres each, superimposed on each other; put a third square astride these first two squares….. With this grid for use on the building site, designed to fit the man placed within it…you will obtain a series of measures reconciling ‘human stature and mathematics…’

Neither Vitruvian man nor Le Modulor are easy to see in the mind’s eye. However, when captured in a visual model they take on life and meaning.

Today ergonomics continues the search for good relationships between people and their surroundings.

Fig 3.36 Leonardo’s visualisation of the Vitruvian man
Fig 2.37 Corbusier’s figure of a man related to the proportional system of Le Modulor

Fig 2.38 A contemporary anthropometric digital ‘man’ – SAMMIE – used to model the relationships between people and their environment, particularly vehicles. Developed at Loughborough University in the Design and Technology Department.
Eugene Ferguson takes up the same point from an engineering perspective. ‘Certainly it is very difficult to transmit though the medium of natural language or scientific notation knowledge of certain sorts of dextrous skill or sensory discrimination, or to render into natural language adequate equivalents of, say, musical notation or engineer’s orthographic drawings of mechanisms’. (Ferguson, 1992)

In the design field what kinds of ‘equivalents’ are required? Here is a selection of physical properties and spatial relations that are difficult (or impossible) to convey in natural language:

- COLOUR
- SPACE
- FORM
- MOVEMENT
- STRUCTURE
- DISTANCE
- PROXIMITY
- TEXTURE
- PATTERN
- RELATIONSHIPS
- SCALE
- PROPORTION
- VISUAL RHYTHM

To these essentially visual/spatial properties we could add those to do with sound/noise and, indeed, any properties of the natural or made world that impact on our senses and so out minds and behaviour. For the designer these properties underlie and translate precisely into the specific forms and constructions found in of the made world:

- LANDSCAPES
- ROAD SYSTEMS
- TOWNSCAPES
- VEHICLES
- TOWNS
- CLOTHES
- VILLAGES
- MACHINES
- HOMES
- EQUIPMENT
- PUBLIC BUILDINGS
- ENTERTAINMENT MEDIA
- SHOPS
- GRAPHIC IMAGES
- PRODUCTS

A further list would move from abstraction and physical things to deal with qualities which people might value in their own lives.

- PRIVATE
- METROPOLITAN
- CONVENIENT
- RURAL
- BEAUTIFUL
- HIGH-SPEED
- EXCITING
- GLOBAL
- IDENTITY
- LOCAL
- TRADITION
- GREEN
- MODERN
- RESPONSIVE
- PROGRESSIVE
- COMMUNAL
- COST
- CLEAR
- PURPOSE-BUILT
- SIMPLE
- HOME MADE
- EASY TO USE
It would be easy to construct a matching list of negative qualities – which for some people might also include some of those listed above as positives. Notice how difficult it would be to deal with them completely using natural language alone. It is necessary to be able to say ‘look, it could be like this’ or ‘see, these are the traditional colours’ or ‘I’ll take the lid off the model – then you can try out how easy it would be to change the batteries’.

The range of models used in each field of design has been developed on the one hand to capture what is of the essence in that field and on the other to slot into the particular organization and management structure of the related industry. So in animation and film design the storyboard allows the designer to represent movement, the passage of time and to link these visual qualities with the proposed soundtrack. The storyboard is about storytelling. In landscape design, the range of plans and viewpoints commonly deployed allows the designer to link together wide ‘birds’ eye views’ with intimate ‘ground level’ perspectives showing vistas, focal points and the effect of planting. In any landscape work the landform, drainage runs and routes will need to be modelled. The landscape has to link the large scale of, say, a hillside and lake to the small scale of a person walking or the even smaller scale of pavement and wall details. The landscape designer also needs to model the effect of weather and the passage of daylight and night-time. Landscapes also change over the years and the impact of the seasons is dramatic.

In woven and knitted textiles, on the other hand, designers often work directly with the materials themselves, producing sample weaves and knits in many different colourways. The selection of which colourways to try can be preceded by work in paint of collage or by reference to photographs of people, landscapes or natural materials. In fashion textiles, getting the colours right for the years to come often two or three years in the future) is vitally important. The textile manufacturer will have to be ready when fashion designers begin to develop their collections and fashion changes rapidly. To be behind the game is to go out of business. Designers and manufacturers will invest large sums of money in expert predictions of what colours and styles will be ‘in’. These predictions have to be based on acute awareness of cultural trends and an understanding of the way one phase of fashion design tends to determine – to be the starting point for – the next phase.

In product design small internal mechanical and structural details interact with an external identity which is to do with operating the product but also making a style statement. These require many different means of representation and the use of 3D prototypes of mechanisms, mouldings and appearance models.

In environmental design drawings, scale models, full size mock-ups, computer aided drafting and working drawings are used. Film production designers and directors frequently use storyboards to plan visual story-telling in fine detail. Use of computers has made it easier to plan in advance such elements as lighting and movement.
Fig 2.39 Conceptual sketch for a future landscape design by John de Jardine

Fig 2.40 A view of Croydon city centre as it might look in the future. From the Third City project by Wil Alsop. Alsop produced a detailed structure for the future Croydon. This extraordinary aerial view is a fine example of the way digital imaging can show us a picture of something that does not yet exist.
Fig 2.43

Although textile designers make much use of drawings and full-size coloured masters, they also frequently work directly in materials gaining inspiration from collections and collages and developing ‘samples’ using the actual materials. Here the author is examining a collection of sample carpet weaves produced as part of designing a new range.
Figs 2.44 to 2.48  Drawings and other models used in the development of a pyrotechnic spectacle by World Famous. Full Circle was first seen in Falkirk and has since been shown in London and Turin. The story line of the show follows the unfolding of the seasons marked out and symbolized by synthesized and live music, gouts of flame, smoke, changing lights, a blazing symbolic tree and extraordinary pyrotechnics.

FULL CIRCLE credits

A collaboration between The World Famous (directed by Mike Roberts) and the Slovenian band Terrafolk. Full Circle is an IN SITU show. IN SITU is a European network for artistic creation in public areas financed with the support of the European Commission. Full Circle was commissioned by the Big in Falkirk Festival and IN SITU and co-commissioned by Without Walls.

Fig 2.44  Initial design sketches by Mandy Dike
Fig 2.45 Technical drawings for the pods by Graeme Gilmour
Fig 2.46 3-D visualizations of the pods. Computer generated images by Graeme Gilmour

Fig 2.47 Lighting plan by Phil Supple
Fig 2.48 Firework designs by Maria Hingerty
Fig 2.49 Design for a theatre costume by Lez Brotherston
In some areas it is possible to build and test a prototype or small production run before proceeding to full production. The prototype then becomes yet another model in the sequence of models used to develop the initial idea. In many industrial products a number of refinements and changes will be made during the lifetime of a design, frequently in response to comments – often complaints – from users. In these circumstances the initial design/and production run become themselves models for further modified versions with sequences of design work running in parallel with the marketing and use of the product.

However, in many fields – exhibition design, for example – the product is a true ‘one-off’. The designer does not have the luxury of being able to learn from experience with a prototype or first production run, though he or she does of course build up a very useful body of experience and knowledge of precedent and prior art.

We have already noted the theory that design activity moves from divergence, through transformation to convergence. We have seen also that in practice the situation is more complex, often running through a sequence of divergence – transformation – convergence loops and on occasion even starting with a favourite resolution already in mind. What is certain, however, is that the process has to move towards convergence, to the resolution that is the motivation for design activity.

Resolution means gaining greater and greater specificity in the design. In the end everything that is required has to be specified (including human behaviour and systems) and this will usually mean moving towards models which, unlike many of the models used earlier, are unambiguous. They will have to quantify what is quantifiable and they will have to embody a complete description or representation of the proposed design. What is more, they will have to be in a form that others can interpret and act upon.

Over the years, these ‘production models’ have assumed great complexity. Thousands of drawings, today usually produced using a CAD programme, may be necessary for a vehicle or a large building. Physical prototypes and models will also be required and there exists in manufacturing industry a culture of skilled tradesmen – pattern makers and the like – whose job it is to stand between the designed model embodied in drawings and specifications and the production process. They will feed back comments and suggestions to the designers. Similarly in building a one-off structure changes will be suggested by skilled tradesmen. Here again models are used – sketches, prototypes, mock-ups – to clarify what the problem or query is and to enable its resolution to take place.
Figs 2.50-2.51 PRODUCTION MODELS

Historical and contemporary examples of models that link the designer with the maker through the medium of patterns, tools or templates.

2.50
Traditional metalworking required for translation of drawings for metal castings into wooden masters which were used in the moulds. This work required highly skilled pattern makers who would frequently modify the design in the light of their experience.
Photograph by Peter Jones

2.51
A sail-maker translates the design to full size by marking out in a sail loft
Photograph by Krysia Brochocka
THE DIGITAL REVOLUTION

Many of the designers’ models and modelling systems discussed in this seminar have been affected by the revolution in digital imaging and calculating. Some models – engineering drawings, maps and plans – have more or less been translated directly into digital equivalents. Others – perspective drawings, for example – have become very much easier to produce. Some have been made functionally redundant, particularly in graphics where design and production have become a single, unified process. The link between computer aided draughting and rapid prototyping has closed the gap between drawing and 3-D modelling and brought prototyping into the iterative sequences of designing.

The use of the computer has opened up new areas of creativity and exploration and dramatically extended the scope and nature of modelling. Examples include:

- The ability to create on-screen models that can be ‘run’ and explored in real time.
- Greater freedom to make changes in design proposals because the program will follow the changes through into revised drawings or directly into the digitally controlled production process.
- The introduction of computer aided manufacture and rapid prototyping systems links computer aided design directly into the production of prototypes which can in turn be fed-back into the production of modified prototypes. This marks the beginning of being able to integrate computer aided design and manufacture with a design process.
- Virtual reality (VR) has the potential to represent proposed products and buildings to a high degree of realism. VR is already used in the design and evaluation of high-value, high-risk products (fighter aircraft, for example) where the cost of failure is very great. VR can also provide a medium for training on a simulation rather than on expensive, vulnerable or potentially dangerous equipment. Learning may take place away from the equipment itself by using a virtual version of it. This can also be used in design work to help evaluate proposals by involving potential users in simulations.
- Digital networking provides many new opportunities for cooperation between designers and design groups even when based in widely separated locations. They can work together on a changing model of proposals that are updated on a day-to-day basis as the design develops. If linked with rapid prototyping this can dramatically speed up the design time involved in an international or other large-scale design project.
- The huge calculating power of digital machines make it more likely that designers will design structures that are mathematically sophisticated or that would have been difficult or even impossible to draw using conventional drafting techniques. In architecture particularly the results of this can be seen in buildings with indeterminate forms and complex spanning and roof structures that seem to flow across space.
• In entertainment computer generated imagery (CGI) has made possible completely new realms of fantasy. Remarkably convincing worlds of impossible acrobatics, incredible monsters and the clash of huge robot armies are commonplace. Computer games bring similar situations and characters into participatory situations. Interestingly, the designs for these fantasies are often originally drawn and visualised using traditional drafting tools. However, motion capture, the use of human ‘avatars’ in creating animation and increasingly creative and intelligent programs may lead to the ‘sketching’ stage also becoming digital.

Digital models will become more and more universal because of their convenience, versatility and high capacity to handle design ideas and proposals. They are also going to be more and more the ‘gatekeepers’ of industrialized production processes (though probably not those still dependent on traditional trade and craft skills). Eventually they will become less standardised than they are now and designers will be able to develop personal and idiosyncratic styles of digital imaging, information retrieval and communication – including with clients and users.

Digital models have some drawbacks which will prove hard to overcome and which may ensure the survival of traditional modelling methods in some fields and for some purposes. The emerging difficulties include:

• When using an expert program, the designer hands a great deal of power over to the program and its authors. On the one hand, the program may enable the imagination and particularly speed the production of manufacturing or construction instructions but it will also, by definition, have built into it fixed but unexamined assumptions and rules.

• Programs may lead to errors and it is important for the designer to spot these before they are multiplied. A problem here is that computer output always looks authoritative. It is too finished and, worse, pretends to be the result of ‘science’. It lacks the tell-tale sketchiness of an exploratory drawing or the rough edges of a 3D lash-up. Many errors get through the net of the designers’ critical faculties until they pose practical problems on the factory floor or building site or even, at a much later stage, for the end user.

• There is a degree of standardisation now visible in many products, buildings and printed images that comes from a powerful mixture of regulatory requirements (built into programs), manufacturing limitations (built into programs) and the use of standard details and layouts (built into programs).

• Many argue that the use of computer programs in design has contributed to the increasing distance between designers (working on screen) and skilled tradesmen (working with ‘real’ materials). The virtual product or building does not easily reveal the sheer cussedness and physical recalcitrance displayed by physical materials, constructions and mechanisms. The designer can become very
remote from the struggle to make and build and feedback from the workplace is not something that most programs accept readily.

- Eugene Ferguson, writing in *Engineering and the Mind’s Eye*, notes that since the 1950s there has been a steady move towards identifying engineering as a science at the expense of both intuitive engineering knowledge and practical know-how. He sees the computer as further widening the divide. In his view, proper communication between designers, tradesmen and operators is essential, and not only for the health of engineering products. It is important for engineers – and all designers – to be well and truly ‘inside’ the things they design. They must be familiar with, speak fluently the language of, partake in the culture of their products in real as well as virtual or model form. Some traditional modelling methods may be superior when it comes to the ‘reality’ test.

The question emerges: will digital models completely replace traditional modelling systems? The answer seems to be: no. However, digital modelling has now become the norm in most industries even when other models are also used. In almost every field it has become the essential link between the designer and the production process. The designer may well continue to use drawings, models or storyboards as a part of the personal creative process and there is now a move to revalue the potential of such media. It is becoming clear that they have a unique position in their ability to energize and externalize the dynamic between interior or mental models and externalized or physical models.

The Seminar ends with an example of an architectural design project where different types of models were deployed skilfully to match the requirements of each stage of the work. Such knowledgeable use of a repertoire of modelling techniques is likely to become typical of professional design practice in the future. See Figs 2.52-2.59.
TO RUSSIA WITH LOVE

Contemporary modelling media in architectural design

Drawings and other models were used in the conception and design of an iconic new building for Moscow, the City Palace Tower.

THE PROJECT
In 2005 RMJM* was invited to propose a design for a unique new building just four miles from Red Square. It will have an important civic function – new Registry Offices for Moscow City Centre – combined with office development, retail area and public space.

The client was looking for a building that would be an impressive new landmark in the Moscow cityscape while also reflecting its very special function as a venue for weddings. The work began in Edinburgh where the first ideas were generated, continued in London where the detailed designs were produced and now continues in Moscow where work on the building has begun. A team of 40 architects were involved. The building will be ready for its first bride and groom in 2010.

The approach to the design work was more than unusual in that it combined architects with an artist, Karen Forbes, in what the team describes as a ‘real partnership’. There was a true merging of views in an exchange of roles and aspirations: ‘the artist becoming architect and the architect becoming artist’.

* RMJM is an international practice with offices in Edinburgh, London, Moscow, Hong and New York amongst other cities. Tony Kettle is Managing Director of RMJM (UK). Philip Nikandrow is Director of RMJM offices in St Petersburg and Moscow. Karen Forbes is Head of Drawing at Edinburgh College of Art.
The job of the architect is to imagine a new building, depict it and then bring it into reality as a concrete three-dimensional object. Drawings have always played a crucial role in this process. The journey from initial sketches through to visualisations, structural, working and contract drawings is marked out by different kinds of drawings. Today many architectural drawings are made using a CAD (computer aided design) program as a creative tool. Realistic simulations of interiors and exteriors can be made using CGI (computer generated imagery). Whether the drawings are done by hand or by digital means, they help to make the future building ‘visible’ and provide the basis for its design development and technical specification.

The City Palace Tower was a development using all these means but with conventional drawing having a special place in the initial stages.

The evolution of the design for the City Palace Tower shows the continuing importance of drawing as a medium for creativity in architecture. A dynamic intellectual and aesthetic thread links the probing lines of the initial sketches directly with the finished designs. Only drawing could have given immediate visual reality to initial insights about the linkage between natural forms, love, gender and the celebration of marriage.

It is clear that the emergence of the building design was an intensely exciting cooperative endeavour. Karen Forbes describes the process:

‘Experiment and complexity are edited down as new possibilities begin to emerge. Each personality brings different characteristics and discoveries to these meetings. All these thoughts are expanded and compressed in hours of sketching and debate’.

‘Drawings are scattered over tables, the energy and determination are real. Enmeshed in the purity of the rotated square, a line in space takes shape. Cut into they sky the helix is faceted into spars of reflective light, drawing the eye upwards and signifying the age old desire to join the earth to the heavens’.

Nevertheless, the use of computer aided design and computer generated imagery were essential in ‘making the concept visible’ in an extraordinarily convincing way. The computer also provided the ideal way to model the buildings complex geometry and to translate it into instructions for fabrication, construction and erection on side.
Fig 2.52
ALLOWING A LANGUAGE OF FORM TO DEVELOP

The question was: what form should the building take? The City Palace Tower clearly needed to be something more than functional. Could the form of the building somehow represent the idea of marriage? The double helix familiar from genetics came to symbolize the idea of union. Drawing proved to be the perfect way to explore this interaction between form and meaning. Sketches could quickly give shape to ideas about natural forms and building structures. The fact that they were quick to do – a kind of shorthand – helped to stimulate creative thinking.
Fig 2.53
THE IDEA FOR THE BUILDING DEVELOPED THROUGH DRAWINGS WHICH SYNTHESIZED THE DIVERSE FORMS

The origins of the final design can be clearly seen in these exploratory sketches. The architects thought of the tower as though it was a drawing! “The organic form of the tower is a beautiful linear drawing in three dimensions.”

Figs 2.54-2.55
THE TOWER IN PLACE

“In Moscow, the City Palace Tower will not only contribute to the architectural dynamic of the city, it will add to its poetic and cultural dimensions.”

Using CGI – computer generated images – it is possible for architects to give extraordinary reality to their proposals for future buildings and environments.

A fine 3-D model was also used to show how the building would appear as a form in space.
Fig 2.55
ELEGANT AND SENSUOUS – A LINEAR DRAWING IN THREE DIMENSIONS

“The formal spiral round the core links back to the chemical structure of DNA as well as the intertwining of two figures. The nature of DNA providing a fused genetic inheritance linking us back to the past and forward into the future:

Digital drawings take the concept forward from the initial sketches into more detail. This process continues as the design of more and more elements in the building are resolved.
Fig 2.57
Figs 2.58 – 2.59
HOW WILL IT BE?

Computer simulations allow the architects to imagine and ‘make visible’ the proposed interiors complete with realistic people and the activities of everyday life. Doing this helps the architects as much as their clients and future users of the building.

Fig 2.58
Fig 2.59
REFERENCES

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Further information about the theoretical work of the Design Education Unit can be found in:
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The QUICK ON THE DRAW exhibition was organized jointly by the City Art Centre, Edinburgh; the Harley Gallery, Welbeck; Croydon Clocktower and Brochocka Baynes, 2008-2009. In addition to Edinburgh, Welbeck and Croydon it was shown in the Design and Technology Department, Loughborough University.