Beyond the formal/concrete axis

A study of individual difference in approach to design practice

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Abstract

This thesis examines the nature of individual differences in approach to design practice, concerning a practitioner's relationship with the medium with which they work, and its role in their practice. It does so with a view to developing future digital environments for creative practice.

Most existing computer systems for 3D design and modelling have developed around the 'design-by-drawing' paradigm. Recent advances in digital technologies offer more direct manipulation of models in 3D space through touch, bringing the more immediate ways of working with materials associated with other approaches to design within the realm of digital systems. A previous investigation of an alternative paradigm for future computer systems, the working processes of designer-makers, was undertaken to better understand the role of materials within their processes. This revealed differences in individual approach: some practitioners developed their ideas using sketching, while others chose to work with materials (either to design, or making with the medium), or combined both.

Reporting on initial enquiries concerning such practitioners' preferences for working in two or three dimensions to generate design ideas, this thesis suggests that there are more fundamental differences between individuals in their relationship with the medium in which they work. However there exists little design literature to assist in this regard.

Drawing on literature on creative processes from other disciplines, including writing and computer programming, it proposes that differences exist between individual design practitioners which are more significant than variation arising from each designer's personal style, unique experience, or working context; rather they represent wholly different approaches to design, elements of which relate to the nature and extent of a dialogue between practitioner and medium. A systematic analysis of this literature suggested the formal/concrete axis is an organising principle for differences in approach across disciplines and across a number of levels of practice.

An investigation was undertaken to determine whether similar differences in approach could be observed between 3D design practitioners. Using primarily interview methods, but also set tasks and observation, three empirical studies were conducted to examine in detail the creative practices of students and professional practitioners working with three-dimensional media, both material (silversmithing and jewellery, textiles, sculpture) and digital (3D computer graphics and animation, 3D modelling, 3D immersive digital environments). The results demonstrate that important underlying differences exist between individual design practitioners, concerning their relationship with the medium with which they work, and its role in their practice. This thesis concludes that while elements of these differences in approach can indeed be mapped directly to a formal/concrete axis, others cannot, and proposes avenues for further exploration.

This examination of differences in approach demonstrates an underlying commonality between disciplines including 3D design practice, writing and computer programming as regards how practitioners work, and their relationships with the medium they work in, on or through. It indicates important aspects of working and knowing that are not embedded in the material context of practice, which should be acknowledged by theory, and could be harnessed practically in the development of future digital environments for creative practice.

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Fondly dedicated
to Mum and Dad, who only got to share the beginning of this adventure;
to Campbell, who has been a staunch and loving supporter throughout;
and to Eliza, Hookie, and Bella, who will never read this thesis but have sat on it
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Annotated list of chapters

Prologue: a parable of design xvi

A parable of design, which leads into the realm of this thesis, from a children's novel where contrasting approaches to design used by two main characters play a major role in the story.

1. Introduction 1

Defines the broad parameters within which this research has been conducted; sets the scene for the research; and outlines the shape of the argument.

Defines what the research is and is not concerned with. Describes the type of research which is being conducted, and the methods used. 1

Describes the motivation behind this research: both the immediate concern, the search for a cohesive explanation of the differences between individual design practitioners, in terms of the artefacts they work with in their creative processes; and the broader contextual motivation, how a better understanding of these differences might inform the development of future digital environments for creative practice. 2

Introduces the different elements of the research, and their purpose and role in defining and exploring the territory of the research. 4

2. Digital technologies and design 14

Sets the research within its broader scope of impact: to bring a deeper understanding of the working processes of creative practitioners to the development of future digital environments for creative practice.

Describes the parameters within which this research has been conducted. 14

Describes some of the drawbacks and limitations of existing computer systems for 3D design and modelling, in relation to design processes; and how new modes of creating, visualising and interacting with digital models offer new opportunities for using digital systems in creative practice. (Appendix B introduces a range of the technologies and principles involved, for readers unfamiliar with this area.) 14

Describes selected examples of ways in which these technologies are being, or could be, integrated into the working processes of artists and designers, focusing on approaches to creating and interacting with 2D and 3D artefacts/design representations. 15

Sets these examples within the context of the research undertaken for this thesis, and outlines a number of limitations with this body of research, and directions in which it could be extended. 26

3. Artefacts and the design process 28

Reviews a range of design research literature to identify the roles that artefacts play in a design practitioner's process; to characterise the nature of the relationship between the practitioner and the artefacts they create and work with in their processes; and to identify possible reasons for differences in this relationship.

Briefly discusses the nature and focus of existing research in this area, and describes the different models of the design process which underpin and influence the design of the studies reviewed in this chapter. 28

Describes the different focus and scope of these studies, and the methods by which they have examined design practice. Clarifies the focus of the research being undertaken for this thesis. 31

Reviews a number of studies concerning the use of two-dimensional artefacts, primarily sketching, in design. 32

Reviews studies of three-dimensional artefacts within design, and then examines a small number of studies which have dealt more generally with the use of artefacts in the design process. 43

Summarises the variety of roles that artefacts are held to play within designers' processes, and the characteristics of artefacts that make them useful in design. Discusses aspects of these roles on which the studies agree or diverge. 52

Discusses the findings from this review within the context of this thesis: an examination of diversity in design practice. Briefly discusses possible reasons for some of the limitations of the existing research in this respect. 55

Reviews a small number of case studies of individual designers which make reference to differences in approach relating to the roles of sketching and drawing or working with materials between individuals' practice. 60

Concludes by describing the rationale on which the next stage of research for this thesis is based. 65

4. Difference as a means of enquiry 68

Explains that diversity in design practice is not only the focus of this research, but why and how it has also been used as the primary means of investigation.

Discusses some of the issues that arise in dealing with this diversity, relating to a lack of existing models of individual difference in 'traditional' design research, and the nature of the diversity in design practice with which this research is concerned. Explains why techniques often used to examine design practitioners' processes aren't suitable in this context, and therefore why an alternative approach was chosen. 68

Describes the three main principles that have been used to derive the means of investigation: the comparative framework; the comparison of the individual against the collective; and added insight from comparing phenomena which are similar-but-different. Discusses benefits and drawbacks of this method. 69

Draws comparisons between it and the phenomenographic approach described by Marton and Booth in their book, Learning and Awareness. 74

Describes the variety of ways in which these principles have been implemented in the four main studies of the thesis (one theoretical, three empirical). 75

5. Artefact study 80

Describes an exploratory study of undergraduate Silversmithing & Jewellery students to ascertain, broadly, whether clear differences could be distinguished between students' approaches to and preferences for using 2D or 3D artefacts to generate design ideas; and to identify any other significant observations relating to individual differences which could inform the design of future, more focused, studies.

Explains the design of the study, including the educational context in which it was conducted, and the means of data collection and analysis. 80

Describes the findings from the study, and identifies a number of recurrent themes that could be observed within the data relating to the students' use of and relationships with artefacts. 89

Acknowledges a number of limitations with the analysis that arise from the design of the study and its exploratory nature, and proposes a more rigorous second stage of analysis that could be made in future research. 100

Draws a number of conclusions concerning the nature of the relationship between individual design practitioners and the artefacts and media they use to support their processes. 101

6. Concepts of dialogue in design 104

A comparative review of commentators from design, computer programming/epistemology and writing who propose alternative models of the creative process and the relationship between practitioners and artefacts, or alternative explanations of differences between individuals. The commentators can be distinguished by the nature and extent of dialogue they attribute to the relationship between practitioner and artefacts.

Describes the purpose and nature of the review. 104

Contrasts the different ways in which commentators from various disciplines describe the relationship between practitioners and the medium/artefacts with which they work, and examines the nature of individual differences in approach, if any, discussed by each commentator. 105

Proposes a model of diversity in design practice based on the nature and extent of a dialogue between designer practitioner and medium. 123

7. Comparative study 125

Investigates whether the differences between practitioners identified in these other fields could also be observed in design practice; in particular whether they could be observed in two groups of student 3D design practitioners, one working with digital media, the other working with physical media.

Describes the design of the study, including the aims and objectives, the choice of subjects, and the arrangements for data collection and analysis. 125

Reports on a preliminary analysis of individuals' approaches using a comparative framework derived from the literature, and the decision to change the mode of analysis because of certain limitations with this initial phase. 134

Examines the differences in approach that emerged from an examination of the collective data within each group: firstly, the group working in digital media; secondly, the group working in physical media. Describes the context of 137

practice within which each group is working, and the 'conventional' approach embodied in the way each course is structured.

Describes a comparison made between these emergent dimensions from each group, to determine whether similar differences exist within both groups. Illustrates how a comparison between similar approaches within the two environments, physical and digital, has value in clarifying aspects of approach, and the insights that arise from the differences between the two media. 164

Briefly assesses how well the original conceptual framework derived from the literature explains the differences in approach that can be observed within the groups (discussed further in Chapter 9, ***Discussion***). 170

8. Practitioner interviews 173

An interview study of three 3D practitioners with an established material practice and a substantial body of work in digital practice, which aimed: by drawing comparisons between each practitioner's approach to material and digital practice, to gain insight into key elements of their relationships with the medium they use and the artefacts they create; to determine whether, in support of the principle of comparing material and digital practice which underpins the method chosen for this thesis, a practitioner's approach is consistent across media; to examine differences between individuals; and to gain a professional as opposed to educational perspective on the research.

Briefly expands on the original aim of this study: verifying the basis of comparison between material and digital practice. Describes the design of the investigation. 174

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9. Discussion 204

Examines the findings from the different elements of the research. Draws a number of conclusions about the nature of the relationship between practitioner and medium, and more particularly about differences between individuals in this respect. Proposes a number of areas for further investigation.

Places this research and its findings within their wider critical and practical context. 205

Examines the collective results from all the studies which comprise the research for this thesis, and draws a number of conclusions, describing how they are supported or challenged by the different elements of this research. 211

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- one day workshop study with set exercises

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- 11 final (4th) year B.A.(Hons.) Design in Silversmithing & Jewellery students and 12 final (2nd) year M.Phil. in Advanced 2D/3D Motion Graphics students
- interview study

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- three advanced 3D practitioners with an established material practice and a substantial body of work in digital practice
- interview study

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Prologue: a parable of design

The father said nothing more to the child; they lay in silence through the night, while the wind brought them the smell of the pines to remind them of the Christmas tree where they would never dance again.

Once upon a time, there lived a Mouse and his Child[1].

Perhaps 'lived' is not right. Sentient, yes, but the mouse and his child moved through the world not freely, through the pulse of blood and muscle and bone, but with actions determined by and dependent upon the interaction of springs, cogs, bars and wheels. For the mouse and his child were 'wind-ups', clockwork toys that remain motionless until moved at the whim of their owner; friend or foe. This is not the place to recount their adventures, broken and abandoned to their fate in the world; Mr Hoban does that admirably in his written account of their tale. But his descriptions of their attempts to become self-winding, independent rather than reliant on others, lead us into the realm of this thesis.

Near the end of their adventures, once they have defeated their enemy Manny Rat, regained their home and gathered a family of their own, the mouse and his child finally have time to give attention to the their long held dream: to become self-winding.

'Key times Winding Equals Go,' said the child.
'Go divided by Winding equals Key,' said the father.
'That isn't getting us anywhere,' said the child. 'Let's start again...'

The mouse and his child are attempting to use Muskrat's Much-in-Little to solve their problem, a way of thinking exemplified by an acquaintance from much earlier in their adventures. Muskrat's expertise in 'figuring things out' is well known and, other than their enemy Manny Rat (an expert in clockwork as they have learned to their cost), is the only one who may be able to help them learn how to achieve their dream. When they meet Muskrat, they realise that he has a rather unusual outlook on life.

'You'll have to wind me up,' said the father. 'There's a key in the middle of my back.' Muskrat looked at the key. 'Of course,' he said as he wound it, 'I remember now: Key times Winding equals Go...'

[1] The story and quotations in this section are taken from The Mouse and His Child [Hoban 2000].

'You have a strange way of speaking,' said the mouse father.
'I'm always looking for the Hows and the Whys and the Whats,' said Muskrat. 'That is why I speak as I do. You've heard of Muskrat's Much-in-Little, of course?'
'No,' said the child. 'What is it?'
Muskrat stopped, cleared his throat, ruffled his fur, drew himself up, and said in ringing tones, 'Why times How equals What.' He paused to let the words take effect. 'That's Muskrat's Much-in-Little,' he said. He ruffled his fur again and slapped the ice with his tail. 'Why times How equals What,' he repeated. 'Strikes you all of a heap the first time you hear it, doesn't it? Pretty well covers everything! I'm a little surprised that you haven't heard of it before...'

But when the child tells him of their dream to become self-winding, and asks for his help, Muskrat explains that his mind is now on 'higher' things.

'I'm afraid that's a little out of my line,' said Muskrat. 'Oh, I've tinkered with clockwork now and then, but I have long since gone beyond the limits of mere mechanical invention. That's applied thought, you see, and my real work is in the realm of pure thought. There's nothing quite like the purity of pure thought. It's the cleanest work there is, you might say.'

The workroom where he now does most of his thinking reveals the stark contrast between these activities.

An oilcan and a ball of string lay among mussel shells and the forgotten nibbled ends of roots and stalks beside a small terrestrial pencil-sharpener globe; a BONZO Dog Food can stood filled with salvage from the bottom of the pond: rusty beer-can openers, hairpins, fishhooks, corroded cotter pins, tangles of wire, drowned flashlight batteries, a jackknife with a broken blade, and part of a folding ruler. Near it sprawled improvisations of discoloured pipe cleaners, tobacco tins, old fishing-licence badges, draggled wet- and dry-fly feathers, coils of catgut, jointed lures that bristled with hooks and staring eyes – all the neglected apparatus of past experiments in applied thought...

However, Muskrat is drawn back into applied thought when he inadvertently learns that he now has a reputation as someone who can't 'do' anything, unlike the Beavers. To demonstrate that his capabilities are undiminished, he decides to 'do something': "something big, something resultful – something, in short, that will make both a crash and a splash and show the pond how truly much is meant by Muskrat's Much-in-Little".

'First,' said Muskrat, 'we must define the problem; that's how you begin.'
'Suppose we say, then, that the problem is to fell a tree... Now, who fells trees? Beavers... The teeth of beavers are of the proper size, shape, and sharpness for cutting down trees.... When a beaver gnaws at a tree for a period of time, that tree will fall.' He picked up a withered brown arrowhead stalk and chewed it reflectively. 'So we may now reduce this data to the following much-in-little-... Beaver plus Teeth times Gnaw times Time times Tree equals Treefall,' said Muskrat...
He drew himself up and launched himself anew upon his thought. 'Let us now disassociate the tooth from the beaver,' he said.
'How his mind soars!' exclaimed the fireflies all together, and intensified their light...
'You've got to be able to make those daring leaps or you're nowhere,' said Muskrat.
'Where was I?'
'Disassociate the tooth from the beaver,' said the mouse father.

'Yes,' said Muskrat, 'and consider it simply as any *tooth of the proper kind, or as we might say, Tooth^{K}.'*
'Tooth^{K},' said the mouse child.
'Tooth^{K} times Gnaw,' said the father.
'Tooth^{K} times Gnaw times Time times Tree equals Treefall,' said Muskrat. 'Wait – it's coming to me now!' The fireflies has dimmed a little; now they kindled up again.
'I've got it!' shouted Muskrat.
'What?' said the mouse and his child together.
'X!' said Muskrat, 'X!... It needn't be a tooth at all! Anything of the proper k, *which is to say size, shape and sharpness, will do it.' He limped to the broken piece of slate, hastily rubbed it clean with his paw, wrote $XT=T^{F}$, and sat back, rocking on his haunches. 'X times Tree equals Treefall,' he said huskily and crooned beneath his breath a little song of triumph... 'There's very little to it, I'm sure, once you've got the X, and I'm off to find one now.'*

Muskrat agrees to address the problem of self-winding once the tree has been felled.

'That's not pure thought, you know; that requires some tinkering. I can't consider the Hows and the Whats of your clockwork without taking you apart; and I can't take you apart until we've finished our work here.'

However, the tree felling ends up being crashful and splashful beyond Muskrat's wildest imaginings, due to the unwelcome reappearance and unwarranted interference of Manny Rat at a crucial point in the project. The mouse and his child are swept away in the flood of a broken dam, and have to overcome many more trials before they can address the problem again. We rejoin them, frustrated in their own attempts to apply Much-in-Little to their problem.

Their old rusty motor lay on the platform before them as step by step, wheel by wheel and cog by cog they reasoned their way through the clockwork that had driven them on their journey out into the world. The sunlight faded into dusk, then darkness rose up with its myriad voice below the red glow in the sky. Night passed into silent morning and the dawn; the Dog Star flashed and glimmered. The mouse and his child, beaded with dew, watched the sun come up, and wondered when they should achieve the daring leap of discovery and the X of self-winding.
Another day passed, another night without success, and on the following morning they were no nearer to a solution than they had been when they started.

It is their old enemy Manny Rat, subdued, toothless and (apparently) having learned his lesson, who finally gives them their freedom.

'Spring times Cog...' said the child.
'Times Cog times Wheel, said the father, 'and still no X.'
'Excuse me for saying so,' said Manny Rat, 'but vere are fings vat simply cannot be figured out.'
'Reasoning won't do it all', he said. 'You have to have a feel for fings.' He put down his wire, picked up two motors from the spare-parts can, and hummed abstractedly to himself as he inspected them. 'Going and ungoing,' he murmured, and followed the coils of the steel springs caressingly with his paw. Then he sat down with the motors in his lap, and still humming, retraced the sequence of the gear trains.

'Ungoing into going and back again,' muttered Manny Rat, and tried to sense how energy released by one spring could be made to wind another spring. The hours passed unheeded; twilight came again, and evening. The guardian uncles, relieving one another in regular shifts, had rotated five times through their roster...

'And vis goes here,' said Manny Rat, 'and now we attach vis...' Almost against his will he saw his own paws find the answer that would make the triumph of his enemies complete... He reached for the pliers, and made connecting rods from wire so that he could rearrange the gear trains. Then he saw his paws couple the two motors together and wind one up. As the first buzzing spring uncoiled it clickingly wound up the second one, which, running down, rewound the first.

So it was that the mouse and his child became self winding, that they might unassisted walk the boundaries of the territory they had won from Manny Rat.

1. Introduction

In his account of the Mouse and his Child, and their attempts to become self-winding, Hoban describes two quite different approaches used in trying to achieve this goal. Muskrat's Much-in-Little is characterised by abstract, rational thought applied to an objective analysis of the situation. Manny Rat's approach is intuitive, drawing on concrete and tacit ways of knowing, and grounded in the materials of the situation. While Muskrat's Much-in-Little is a somewhat extreme version of the application of abstract thought (everything is reducible to an equation!), nevertheless Hoban's description of two quite distinct approaches, different at a number of levels, and largely relating to the protagonist's relationship to the material context, reflects the concerns of this thesis.

This thesis proposes that similar diversity can be observed in the approaches that design practitioners use within their working processes. It argues that differences can be observed between individual practitioners which do not arise solely from the personal and situational context within which the practitioner is working, rather that they represent wholly different approaches to design, reflecting different relationships between individual design practitioners and the artefacts and media with which they work within their creative practice.

Initial analysis of the literature suggests that these differences can be characterised as two contrasting approaches lying at each end of the formal/concrete spectrum, with characteristics similar to the approaches of Muskrat and Manny Rat described above. Subsequent investigation argues that, while it is a useful device from which to start examining individual differences in approach to design practice, a distinction along this single axis does not fully describe the variation that can be observed, which implies a more complex interaction between a number of different dimensions of variation. The thesis concludes by proposing avenues for further exploration.

This research concerns the nature of individual differences in approach to design practice. I use the term 'design practitioner' to refer to someone who not only designs, but also makes; it is intended to include those who would describe themselves as 'applied artist', 'maker', 'designer-maker', or 'craftsperson' but also a broader spectrum of those who design and also make, but who might not identify with terms which usually imply a close relationship with physical materials. In this research it is three-dimensional design

practice with which I am most concerned. I use the term 'artefact' to denote the physical manifestations of a designer's processes, including sketches, models, etc.

This thesis constitutes a process of mapping territory, both theoretical and practical, within which further exploration can be focused. It uses methods and instruments designed to elicit information on differences: between individuals, between theoretical positions, and between other phenomena. It examines the same activity in different contexts, and different activities in the same context. It includes reviews of the literature (both contextual and theoretical); a systematic analysis of selected literature to derive a comparative framework as the basis of empirical work; and three empirical studies, mostly interviews, but also set tasks and observation. It also offers a bridge between two research communities which still seem to be largely separate: 'traditional' design research, which focuses largely on design-by-drawing and formal design methods; and research into the working processes of practitioners who not only design but also make.

This chapter begins by describing the motivation behind this research: both the immediate concern, the search for a cohesive explanation of the differences between individual design practitioners, in terms of the artefacts they work with in their creative processes; and the broader contextual motivation, how a better understanding of these differences might inform the development of future digital environments for creative practice. It then introduces the different elements of the research, and their purpose and role in defining and exploring the territory of the research, summarised in its thesis:

> *that individual practitioners experience different relationships with the artefacts they create and work with in their processes, and that elements of these differences can be attributed to the nature and extent of a dialogue between designer and media*

Difference as a focus of enquiry

The motivation for this research arose from the fusion of a number of strands of thought. These emerged both from my own experiences as a student practitioner, and from a previous piece of research - An Investigation into Interaction with Computer Systems for 3D Design and Modelling, in terms of Interface and Process [McLundie 1998] - which was motivated by the apparent lack of use of computer systems within the crafts/applied arts: I had come to study at Glasgow School of Art from a computing science background, and had been aware that while computer systems were used in other areas of design, they were (at that time) conspicuous by their absence in the crafts/applied arts. The overall aim of that research was to investigate the possibilities for incorporating some of the tactile, manipulative aspects of the way designer-makers work with materials, within the context of the design process, into future computer systems for 3D design and modelling. This included a comparison of the ways designer-makers interact with

material within the design process, with the ways existing computer systems for 3D design and modelling allowed the user to interact with the digital 'material' within the design process. A number of designer-makers were interviewed on aspects of their design processes, and the role materials played; subjects included jewellers, silversmiths, ceramicists, a blacksmith, and a glassmaker.

At that time I was looking for characteristics of 'the' designer-maker approach to creative practice: an approach typified by a close relationship with materials. However, my interviews with a range of designer-makers revealed a spectrum of approaches, ranging from design-then-make, to design-through-make, to make-as-design. While some practitioners developed their ideas using sketching, others chose to work with three-dimensional artefacts or used a combination of both. This suggested that the role of materials in different practitioners' processes might not be the same, and required further investigation.

These findings resonated with as yet unarticulated ideas that had arisen from my own experiences. As a student on the B.A.(Hons.) Design course in Silversmithing and Jewellery at Glasgow School of Art, I began to notice differences between my own approach, and that of some others in my class. I had no sensation, as some of the practitioners interviewed in the present research describe, of being able to see images of objects quite clearly in my head, as if they were in front of me. I often found that ideas came more readily when I had materials to work with, rather than through sketching: in many cases it was not until I actually sat down with materials that ideas seemed to flow.

This contrast in approaches can be seen in the following example, where the project brief was to create a piece of jewellery out of a specified amount of gold: one small piece of gold sheet, and a short length of gold wire. (Because of its cost, we were 'lent' the gold for this project, on the basis that it would be returned for melting down and reuse. Each student had to pay for any discrepancy in weight between the gold handed out and the gold handed back. This emphasises the care with which the gold had to be worked; even the filings from sawing the metal were collected for return.) One of my fellow students worked out exactly the dimensions of the material she would have to work with, and designed a pair of earrings within these limitations, which she then made. I took a different approach, inspired by the commonly-quoted belief that if you hammered out a small piece of gold sufficiently thinly, it would cover a football pitch. Using copper to experiment with different ideas, then silver to make a prototype of the final 'design', I developed a bangle with a simple catch, which takes advantage of the length, strength and springiness of metal (particularly gold) when it is mechanically rolled very thinly (Figure 1).

Figure 1: Gold project – presentation drawing of bangle as made from gold sheet (40mm x 15mm x 0.9mm) and wire (100mm x 1.5mm diameter). (M. McLundie)

There also seemed to be quite clear differences between individuals' approaches to producing the body of work for the Degree Show: those who were design-led, and those whose work was driven by, and based around, the exploration of particular techniques and processes. These differences were apparent both in my own group, and in student groups from previous years.

These personal observations also suggested that there may be important differences between individual design practitioners, relating to the artefacts they create and media they use within their creative processes.

The rest of this chapter introduces the different elements of the research, and their purpose and role in defining and exploring the territory of the research. Each section here corresponds to one chapter; a more detailed 'map' of each chapter is given in the Annotated List of Chapters (p. vi).

Digital technologies and design (Chapter 2)

Although my understanding of the creative processes involved has developed since I began the research for this thesis, the broad contextual motivation for this work remains the same: to bring a deeper understanding of the working processes of creative practitioners to the development of future digital environments for creative practice.

The focus of this research is the relationship between an individual designer and the media with which they work; it is not concerned with other ways in which computers might support designers, such as knowledge support systems, or by supporting collaborative working. It is not concerned primarily with ways in which creative practitioners are using existing digital technologies in their material practice, rather on

systems being developed using new technologies specifically to support artists and designers, particularly in the early stages of design.

Many recent developments in digital technologies to support creative practice focus on replicating and extending the ways in which creative practitioners currently work with materials, or in harnessing the potential benefits that can arise from combining the capabilities of computer systems with the traditional skills and working methods of artists and designers. A lot of projects still favour the 'design-by-drawing' paradigm: research into more intuitive methods of creating virtual design representations tends, though not exclusively, to emphasise sketching, or the use of sketch- or gesture-based interfaces to create three-dimensional form; similarly, many research projects which address computer support for conceptual design focus on sketching, even for the creation of three-dimensional virtual objects. Systems that draw on alternative approaches to design often reflect the belief that 'hands-on' access to materials is very important to makers/creative practitioners, and should be replicated when developing new digital environments for design: this thesis challenges and clarifies this viewpoint, by analysing more closely what it is that may be important in the relationship between a practitioner and the medium with which they work.

This thesis demonstrates, through an investigation of diversity in design practice, that this relationship encompasses important aspects of working and knowing that are not embedded in the material context of practice. Systems which focus on simulating ways of working with physical materials through touch may therefore be missing out on other aspects of a practitioner's approach which are at least as important. This does not mean that the ways in which we interact with computer systems cannot be improved; a number of practitioners and students interviewed during this research commented on aspects of the software interface which they found frustrating. But while the goal of designing interfaces to make them more intuitive for creative practitioners (and indeed all users) is commendable, it is not merely a matter of reproducing the ways in which creative practitioners currently work with materials: the role of the medium in one individual's practice may be quite different than in another's; individual practitioners will approach and use a digital medium in different ways; and what one practitioner may find frustrating about working with a medium may be someone else's creative springboard.

Diversity in design practice (Chapter 3)

This research focuses on an individual designer's relationship with the artefacts they create, and how the interaction between the two contributes to, influences or comprises the design process; it is particularly concerned with the diversity that can be observed in

design practice in this respect. It is not concerned with what might be termed 'design processes' (e.g. the patterns of and relationships between analysis, synthesis and evaluation, or divergent and convergent thinking in a practitioner's process), or 'creative cognition', nor does it explicitly examine the role of haptic (tactile, kinaesthetic or proprioceptive) feedback or tacit knowledge in practitioners' processes. Although these aspects may be an element of the individual differences in which I am interested, they are not the territory of this research.

While much research has focused and continues to focus on 'design thinking', there has been a growing interest in the 'external representations' with which designers work. A review of the literature demonstrates that artefacts are considered to play an active role in a designer's process, and that design is viewed as a process of incremental transformation, facilitated through or revealed by engagement with the artefacts a designer works with in their design process. Moreover, artefacts can be seen to play an interactive role, allowing the designer to have a 'dialogue with themselves' about the design situation.

Existing research in this area has been concerned predominantly with two-dimensional artefacts, including drawings, diagrams and sketching. A smaller number of studies have examined the role of three-dimensional or material artefacts within designers' processes, and even fewer are concerned with differences in the way that 2D and 3D artefacts might support designers' processes. In the realm of this thesis, very few studies have investigated differences between individual designers that relate to their use of artefacts within the design process. 'Traditional' design research in this area has focused mainly on design-by-drawing, and on formal design methods, less on other areas of design which do not fit this model. Many studies are broadly concerned with what is to be learnt about "designing as a basic human capacity" [Pedgley 1999], viewing it as a single process to be discovered. Most studies look for consensus, rather than diversity, and the experimental approach used in many is less likely to reveal differences in approach, especially where there are differences which may be most clearly observed in the wider spectrum of practice. However, comparisons within and between a number of case studies of individual designers in the literature revealed quite different personal approaches to design, relating to the roles of sketching and drawing or working with materials between different individuals' practice. These findings strengthen the position of this thesis: that clear differences in approach can be observed between individual designers, which are worthy of further investigation.

This review highlights the importance of placing the relationship between design practitioner and artefact at the core of this research, and of using a method of enquiry which enables individual differences to emerge.

Difference as a means of enquiry (Chapter 4)

A number of factors have therefore prevented much existing research from observing the natural diversity in practice, and the dimensions of its variation. One of the challenges in starting to explore this area was that there appeared to be a number of possible interdependent factors involved in this diversity, at different 'levels' of process. One approach to examining this diversity would be similar to the experimental studies above: constrain the context to look at each of those factors, while eliminating the influence of the others. However in this situation it was not clear at the beginning what factors to constrain, and what the interdependencies might be. The alternative selected for this research was to choose a method which allows the situation to be examined as a whole, and enables an investigation into what some of the interdependencies might be. It uses a comparison of the differences between individual instances as a means of developing a descriptive model of an underlying phenomenon. This method is underpinned by three related principles: the comparative framework; the comparison of the individual against the collective; and the added insight from comparing phenomena which are similar-but-different. It has similarities to the phenomenographic approach described by Marton and Booth [Marton & Booth 1997].

The rest of Chapter 1 illustrates how this approach has allowed the research to move from an initial position of exploration and uncertainty to its thesis:

> *that individual practitioners experience different relationships with the artefacts they create and work with in their processes, and that elements of these differences can be attributed to the nature and extent of a dialogue between designer and media.*

Different dimensions? (Chapter 5)

Earlier in this chapter, I described how the starting point for this research was the differences I had observed within the group of designer-makers during a previous investigation where, while some practitioners developed their ideas using sketching, others chose to work with materials (either to design, or making with the medium), or used a combination of both.

As there was little design literature to assist in this regard, an exploratory study was conducted with four groups of undergraduate Silversmithing and Jewellery students in the form of a one-day workshop focusing on preferences students might have for using different 'types' of artefact for generating design ideas, e.g. drawing as opposed to

materials, two-dimensional as opposed to three-dimensional. This study used the creation and examination of artefacts as its primary means of data generation and analysis. The participants were asked, through a series of short exercises, to use words, mark-making and materials to respond to a selection of words, mark-making outcomes and objects, then to generate design ideas.

Within the limitations of the original analysis of the data, no clear conclusions can be drawn that the primary differences between individuals related to a preference for working in 2D rather than 3D. What became apparent during the study was that striking differences could be observed *within* as opposed to *between* media type. A number of recurrent differences emerged from the collective examination of all the artefacts: regarding the relationship between the student and the source object, a subjective or objective approach towards the object; the extent to which the materials play a background or foreground role in the artefact; and within the design exercises, the extent to which the 'design' is derived by the student and then expressed in the media, or is derived through working with the media.

These findings suggested that design practitioners may well use the same media quite differently; that for some participants, materials seemed to play a much more significant part in *all* their responses than others; that a 'blunt' comparison between 2D and 3D may therefore be of little value; and that in subsequent studies it would be not only necessary but valuable to look beyond these original categories to examine more closely the variety of ways in which individual design practitioners perceive and relate to the artefacts and media they use to support their processes.

Reflection, negotiation, mediation: concepts of dialogue in design

(Chapter 6)

Although few studies of three-dimensional design have examined differences of this nature, there are commentators from computer programming/epistemology (Turkle & Papert) and writing (Chandler) who discuss differences in individual approach which resonated strongly with the tentative ideas arising from the above study and the observations from my previous research. These differences in approach can broadly be described in terms of the nature and extent of a dialogue between practitioner and medium.

To distinguish these commentators from others who also describe the relationship between practitioner and medium in terms of dialogue, a comparative review was made of a range of commentators from design, computer programming/epistemology and writing who propose alternative models of the creative process and the relationship

between practitioners and artefacts, or alternative explanations of differences between individuals, using contrasting metaphors of dialogue between practitioner and artefacts: reflection, negotiation, and mediation.

The differences in approach described by Turkle & Papert and Chandler can be described in terms of a formal/concrete axis as an organising principle across disciplines and across a number of levels of practice. This review therefore suggests that differences may exist between individual design practitioners which are more significant than variation arising from each designer's personal style, unique experience, or working context; rather they represent wholly different approaches to design, elements of which relate to the nature and extent of a dialogue between practitioner and medium. (Within this thesis, different commentators use the term 'style' to refer to different things: when I use it in the context of a designer's 'personal style', I am not using it in the sense of an approach or process as in 'learning style', 'intellectual style', 'programming style'; rather I am referring to those personal attributes of a piece of work which make is recognisable as created by a particular practitioner. Different approaches and ways of working may contribute to this 'style', but do not constitute it.)

Dimensions of difference (Chapter 7)

An interview study was made of two groups of student 3D design practitioners, one working with physical media, the other with digital media, to establish whether the differences between practitioners identified in these other fields of practice could be observed within each group, and whether the same spectrum of individual variation was seen in each group. (If similar differences in approach were observed in both groups, a comparison of how each type of approach manifests itself in the material and digital environments could provide additional insight into elements of this relationship, arising from the similarities and differences between these two environments.)

A comparative framework was derived from a systematic analysis of the literature discussed in the previous section which suggested the formal/concrete axis as an organising principle for differences in approach across disciplines and across a number of levels of practice. This framework is presented in terms of two distinct and contrasting approaches which represent two ends of a spectrum; individual practitioners may appear at one end of the spectrum, or somewhere in between. In a preliminary analysis, each individual's approach was categorised using this comparative framework, and an assessment made of the distribution of the approaches within each group. Certain limitations with this analysis mean that it can only be relied upon to give a broad indication; however different approaches, broadly in line with those in the comparative

framework, could be observed within both groups with a similar spread of approaches within each group.

A second stage of the study involved both an examination of the collective variation within each group across a number of 'dimensions of difference' which emerged from the data, and a comparison of these dimensions between groups. (The term 'dimensions of difference' refers to distinct observable differences in aspects of practice; taken together these may indicate more fundamental underlying variation between individuals.) In both groups, a number of dimensions of difference can be observed which appear to be in line with the original framework. The dimensions emerging from the groups therefore seemed to be broadly in line with those embodied in the comparative framework; however, how these different dimensions logically related to one another within an individual's approach did not appear to be completely described by the two-dimensional nature of the framework, or by the formal/concrete axis it embodies.

Practitioner interviews (Chapter 8)

Additional insight into these matters is provided by a study of three practitioners who have what at first appeared to be quite similar approaches in terms of the original comparative framework, but where further examination revealed distinct and significant differences.

This interview study of three 3D practitioners who have an established material practice and a substantial body of work in digital practice aimed, by drawing comparisons between each practitioner's approach to material and digital practice, to gain insight into key elements of their relationships with the medium they use and the artefacts they create. For all three practitioners, their digital practice has allowed them to push the boundaries of their practice in ways that would not otherwise be possible, and to pursue work, themes, and objects that exploit the unique possibilities of the digital as a medium.

For each practitioner interviewed in this study, their approach to the medium is in line with (and largely derives from) the approach they used in the physical environment. The three practitioners' approaches are broadly similar: they are all actively engaging with the medium, and using its inherent qualities, rather than using it to represent or simulate reality; they are all exploring the digital medium in very different ways from its conventional use; and what might normally be considered limitations actively contribute towards their developing practice. Yet a more detailed examination revealed distinct and significant differences between what, in terms of the original comparative framework, had at first appeared to be quite similar approaches; these differences concerned the role of the medium within each practitioner's practice, whether their approach could be

characterised as a dialogue with or through the medium, and whether the medium was closely identified with the 'self' or viewed as 'other'. These subtle yet significant differences between practitioners confirm that in the investigation of a practitioner's approach to and relationship with their medium it is necessary to carefully examine a number of different aspects.

The comparison between material and digital environments revealed interesting aspects of this relationship that might otherwise be overlooked. For these practitioners, the lack of being physically 'hands on' with the medium or working with physical materials was not significant; other things, such as achieving a sense of 'immersion' characteristic of a maker's relationship with their materials, were more important. The practitioners worked with digital media in ways usually attributed much more to physical media, emphasising the limitations of some conventional conceptions of digital media. Comparisons between practitioners showed that what one practitioner highlights as differences between the physical and digital media they are using may be quite different from what another practitioner would be aware of. These latter points lead to one of the most important conclusions to be drawn from this study: that the characteristics of a medium are not absolute, resulting from notional inherent properties, rather they are defined through a practitioner's relationship with the medium.

Discussion (Chapter 9)

This research draws a number of conclusions about the nature of the relationship between practitioner and medium, and more particularly about differences between individuals concerning their relationship with the medium and its role in their practice: firstly, that the characteristics of a medium are not absolute, resulting from notional inherent properties, rather they are defined through a practitioner's relationship with the medium; secondly, that an individual practitioner will relate to/approach different media in similar ways; and thirdly and most importantly, that there are significant differences in the ways that individual practitioners relate to the medium with which they work, and its role in their practice. It concludes that while elements of these differences in approach can indeed be mapped directly to a formal/concrete axis, as described by the comparative framework derived from the literature, others cannot. However, even though the framework does not completely explain the diversity that can be observed within the data, it is clear from the findings of the various studies that individual differences in approach can be observed between individual practitioners; that aspects of these differences do concern a practitioner's relationship with the medium; and that elements of these differences can be attributed to the nature and extent of a dialogue with the medium. The studies therefore do support the original thesis:

> *that individual practitioners experience different relationships with the artefacts they create and work with in their processes, and that elements of these differences can be attributed to the nature and extent of a dialogue between designer and media*

However, they also suggest that there may be additional elements which contribute to individual differences in approach which require further investigation.

This examination of differences in approach has demonstrated an underlying commonality between disciplines including 3D design practice, writing and computer programming as regards how practitioners work, and their relationships with the medium they work in, on or through. Its findings have implications within a number of different areas including the design research community, creative practitioners, those involved in the application of digital technologies in design and creative practices, programming and writing. Further comparison between disciplines provides additional insights into the variation that can be observed in individuals' practice.

There are two main directions in which the research undertaken for this thesis could usefully be extended: firstly, towards a greater understanding of individual difference between design practitioners, by further analysis of the connections and correlations between the dimensions of difference within individuals' processes; and secondly, towards the development of new digital environments for creative practice, focusing on those important aspects of working and knowing revealed by this research that are not embedded in the material context of practice.

Critique (Chapter 10)

The research undertaken for this thesis has three main limitations: the extent of analysis of the data undertaken to date; the limited range of instruments used in the empirical work; and a lack of external validation of the analysis. In particular, the existing analysis of the data has not yet been able to explain just how the collective 'dimensions of difference' observed within the groups relate to one another within an individual's practice. A further, more detailed, examination of this data would enable a clearer understanding of the relationships between the dimensions within individuals' processes to emerge.

The main strength of this research is the breadth of elements which contribute to its findings, which mitigates some of these drawbacks. The broad foundation of the theoretical basis of the work adds to the weight of argument through comparisons between different disciplines. In particular, the comparative framework derived from the literature provides a strong external element of comparison within the research, which counters to an extent the current lack of external validation. Although the variety of

instruments used on this research was small, nevertheless the range of areas within which these instruments were used was broad: the research contains both theoretical and empirical elements; it has involved a range of participants; although interviews were the main instrument of data collection, the research has also involved more empirical techniques; it has examined a number of different phenomena. This variety within the design of the research has contributed to its strength as support for the thesis has come from these different quarters, thus broadening the basis on which the thesis is grounded.

In summary, although the research in this thesis has certain limitations, it has provided a substantial foundation from which to proceed. As a first stage of research in this area is has mapped out a territory, both theoretical and practical, within which subsequent investigations can be focused. It has identified ways in which the findings may impact on a variety of audiences, and it has proposed directions in which further research could usefully be pursued.

Conclusions (Chapter 11)

This thesis demonstrates that important underlying differences exist between individual design practitioners, manifesting in their relationship with the medium with which they work, and its role in their practice. It concludes that while elements of these differences in approach can indeed be mapped directly to a formal/concrete axis, others cannot, and proposes avenues for further exploration.

Although the underlying dimensions along which these approaches differ have yet to be fully determined, this examination of differences in approach demonstrates an underlying commonality between disciplines including 3D design practice, writing and computer programming as regards how practitioners work, and their relationships with the medium they work in, on or through. It reveals important aspects of working and knowing that are not embedded in the material context of practice, which should be acknowledged by theory, and could be harnessed practically in the development of future digital environments for creative practice.

2. Digital technologies and design

One broad motivation for the research described in this thesis is to bring a deeper understanding of the working processes of creative practitioners to the development of future digital environments for creative practice. This chapter sets the research within this broader context.

Parameters of the research

Bringing designers and digital technologies together involves an understanding of many areas, including design processes (both individual and social), the designer, the role of artefacts, methods of creating digital artefacts, the human computer interface in its broadest sense (where designer and digital meet), developments in digital technologies and their application to design. The knowledge base supporting research into digital environments for creative practice is thus shared between a variety of disciplines, including design, cognitive science, human computer interaction, and digital technology.

This research focuses on the relationship between an individual designer and the media with which they work. Associated areas of research into other ways in which digital technologies might assist designers, such as systems to support collaborative working (CSCW) or knowledge support systems, lie outwith its scope, as does research specifically relating to tacit knowledge or haptics (e.g. [Prytherch 2003; Prytherch & Jerrard 2003]), enhancing 'creativity' (e.g. [Eckert & Stacey 1998; Candy & Edmonds 1999; Candy & Edmonds 2000; Eckert & Stacey 2000; Candy & Hori 2003]) or the impact of computer systems on engineering design processes (e.g. [Stacey, Petre et al. 1996; Stacey & Eckert 1999]).

Digital technologies and design

Advanced computer systems for 3D design and modelling are widely used in many areas of design and manufacturing; however the types of design representations that can be created in the virtual environment are limited. The tools for creating and working with

three-dimensional models are primarily geometric techniques based on the 'design-by-drawing' paradigm. Not only do these precise, detailed techniques promote a level of accuracy unsuited to the earlier stages of design, encouraging premature commitment, but they emphasise the creation and visualisation of three-dimensional form, rather than the more dynamic and functional aspects of working with materials. Also, the models, while shareable through data transfer, are closely bound to the tool used to create them.

In the majority of systems, a complex user interface to the digital model requires long periods of training before it can be used transparently. Working with virtual models and environments has, for most people, been mediated through a flat screen, a keyboard, and a mouse, resulting in a large discrepancy between what are often highly sophisticated three-dimensional models, and current 'two-dimensional' ways of interacting with them. For many artists and designers, the perceived distance between them and their digital medium introduced by these factors, along with the precise nature of the models, can be a barrier to using such systems, particularly for the conceptual stages of work.

Recent advances in digital technologies for creating, visualising and interacting with digital models offer the potential to bring the active, exploratory, manipulative and expressive ways in which practitioners work with real materials, using their hands and tools, into the digital realm. (Appendix B, ***Visualisation and interaction in 3D*** provides a brief introduction to this area for the reader who is not familiar with the technologies, techniques and principles involved.) The potential of such technologies to allow a less constrained, more naturalistic interaction with virtual models has increased the drive towards computer support for the whole design process, in particular for conceptual design.

Integrating advanced digital technologies and design

This chapter reviews selected examples to illustrate ways in which these technologies are being, or could be, integrated into the working processes of artists and designers. It is not concerned primarily with ways in which creative practitioners are using existing digital technologies in their material practice (e.g. [Marshall 1997; Bunnell 1998; Marshall 1998]) rather on systems being developed using new technologies specifically to support artists and designers, particularly in the early stages of design.

Supporting/enhancing the sketching process

The ID-StudioLab at Delft University of Technology is addressing the use of computers to support the conceptual stages of industrial design, in particular to "combine the advantages of the traditional media, such as sketching on paper, with the extra functionality that computers can offer" [Hoeben & Stappers 2001]. Projects include research into the psychology of sketching, human computer interface research, and creation of digital objects through gesture and sketching [Stappers & Hennessey 1999].

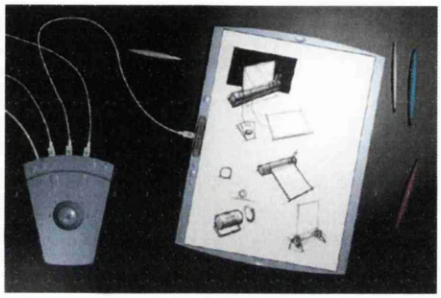

Figure 2: IDEATOR
Ralph Stuijver; reproduced by kind permission of
ID-StudioLab, Delft University of Technology

An early concept project, IDEATOR, concerned a support tool for the early stages of design, based around a stand-alone sketch tablet device on which users draw and sketch using a variety of "real-object pens": to change the style of line, the user would choose a new physical 'pen', rather than changing the properties of a single device through a menu interface (Figure 2). More recently Hoeben's 'Ideas' project has produced a first prototype of a tablet-style digital sketchbook (Figure 3) to explore the potential advantages of using a digital sketching tool: "non-destructiveness" (the ability to preserve earlier versions of a sketch, as well as changes); "unified media" (the ability to incorporate more types of digital representation than are possible in a traditional sketchbook); "transferability" (the ability to use sketches produced using this device in other media); and "portability" (the ability to store many more sketches in a similar-sized 'device') [Hoeben & Stappers 2001].

SketchBook™ Pro 2 is a drawing and painting application for tablet and stylus interface (Figure 4) [Alias]. Its "artist-friendly, gesture based interface", while based on windows and menus, is designed for use with a stylus (i.e. without a keyboard), and the stylus can represent a range of 'pressure-sensitive' tools including pens, pencils, markers, brushes

and air brushes, which can be customised as required. 'Layers' allow existing work to be preserved while further drawing development is done.

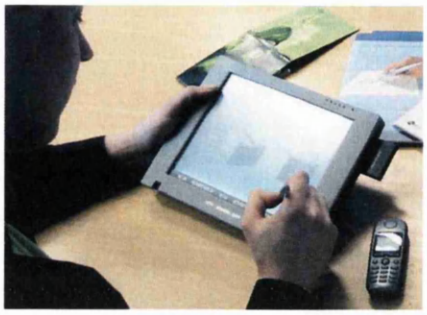

Figure 3: IDEAS
Aldo Hoeben; reproduced by kind permission of ID-StudioLab, Delft University of Technology

Figure 4: A screen shot from Alias® Sketchbook™ Pro. © Alias Systems Corp.

Sketch interfaces to 3D modelling

A number of projects aim to bring sketching processes and 3D modelling closer. Techniques include extending the concepts of sketching processes into 3D, and allowing sketching to act as the means of creating 3D models.

Digital Clay is a prototype sketch recognition program developed at the Sundance Laboratory [Schweikardt & Gross 1998]. It aimed to bridge the gap between early sketching activities and later 3D digital modelling by allowing designers to use sketching as a means of describing three-dimensional forms to modelling software. Using a tablet and stylus, designers sketch freehand projection drawings, which Digital Clay interprets using the conventions of isometric and perspective drawing to produce three-dimensional digital models (Figure 5).

A system developed at the Laboratory for Computer Science at MIT aimed to combine the fluency of sketches with the capability for variable viewpoints offered by digital 3D modelling (Figure 6) [Tolba, Dorsey et al. 1999; Tolba, Dorsey et al. 2001]. The system interprets freehand perspective sketches as lines on a spherical projective grid, the centre of which is the vanishing point. Once the sketch is in the system, the user can rotate the grid, zoom in, etc. to see different views. Designers can draw directly into the system, guided by a perspective grid, or sketch on a digital notepad. These sketches can be imported into the system, and aligned with its grid and vanishing point either manually or automatically. They can then be worked on further within the system.

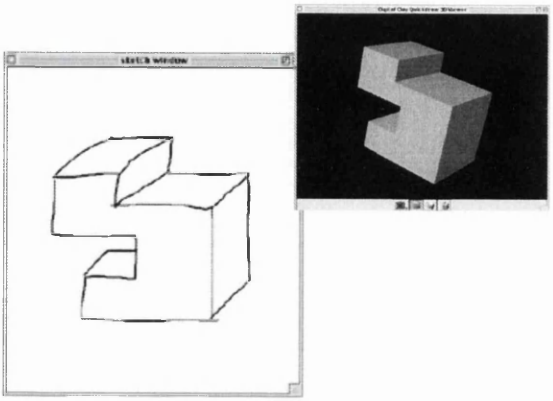

Figure 5: Digital Clay - 2D sketch and 3D model. Reproduced by kind permission of Mark D. Gross, Carnegie Mellon University

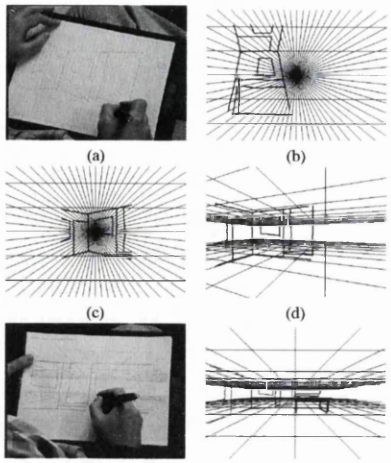

Figure 6: Sketching with Projective 2D Strokes. Reproduced by kind permission of ACM , Inc. (pending)

Researchers at Brown University developed SKETCH, a mouse-based gestural interface for creating three-dimensional models. This was later adapted into ErgoSketch for their prototype ErgoDesk framework [Forsberg, LaViola Jr. et al. 1998]. ErgoDesk integrated 2D pen-based and 3D tracked gestural input, physical props, and speech input around a 'stereoscopic-3D-on-demand' drafting-table-type display (Figure 7). It provided a variety of 2D and 3D interaction techniques, with seamless transitions between interactions and tasks, and supported two-handed interaction. 2D pen-based gestural input was used to create, manipulate and edit three-dimensional models, with the ability to switch to stereoscopic mode allowing 3D inspection of models.

Figure 7: ErgoDesk Reproduced by kind permission of A.S. Forsberg, Brown University Computer Graphics Group

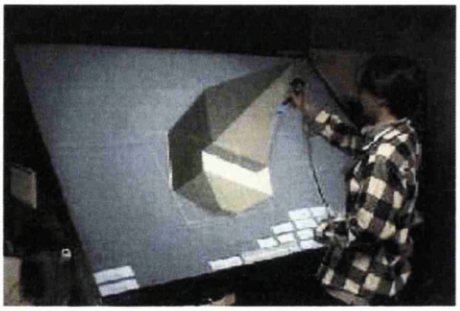

Figure 8: NAIST Immersive Modelling Environment. Reproduced by kind permission of the Nara Institute of Science and Technology

Researchers at the Nara Institute of Science and Technology (NAIST) are developing an Immersive Modelling Environment which uses a similar approach, but allows modelling in both 2D and 3D environments (Figure 8) [Yoshimori, Matsumiya et al. 2000].

Drawing as metaphor

Surface Drawing is a system developed by Schkolne at CalTech and Bell Labs to allow artists and others to create organic and expressive 3D shapes in an intuitive and immediate manner [Schkolne, Pruett et al. 2001; Schkolne, Pruett et al. 2002]. Using their hand, users sweep out 3D marks or 'strokes' which appear to 'float' in space above the semi-immersive bench-type display. Thinner strokes can be drawn with the fingertip when the hand is held in a pointing gesture. This system extends the principles of 2D drawing to 3D space, using repeated strokes to build up surfaces. A set of physical 'tangible tools' allows the user to manipulate the 3D drawing: a pair of tongs is used to move the drawing in space (two pairs can scale the drawing up or down); an eraser tool allows small portions of the drawing to be removed, and a 'magnet' tool enables small deformations and smoothing of surfaces. Figure 10 shows a work created using the system.

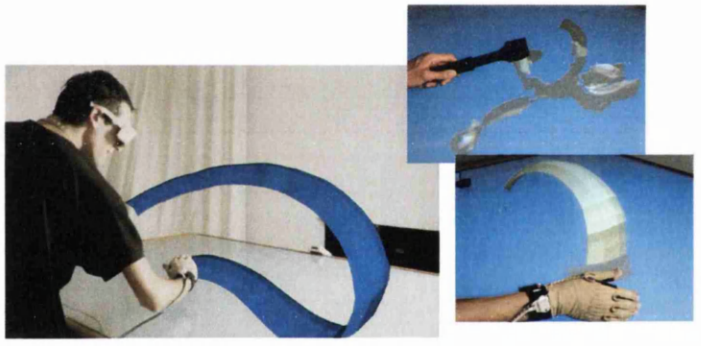

Figure 9: Surface Drawing
Reproduced by kind permission of
Steven Schkolne.

Figure 10: Artwork produced using
Surface Drawing
Reproduced by kind permission of
Steven Schkolne

A collaborative research project between an artist and a technologist in Helsinki shares some of the principles of Schkolne's work but in a CAVE-type semi-immersive environment. A prototype application 'Antrum', developed for EVE (Experimental Virtual Environment), allows freehand 'drawing in the air' (Figure 11) [Mäkelä & Ilmonen 2004]. Whereas Surface Drawing used a glove for input, and 'tangible tools', this system is single-handed and wand-based, 'extruding' an adjustable profile from a wand. Future research goals include a more flexible means of creating and modifying the line, and two-handed input.

CavePainting is a system developed by researchers at Brown University which is also designed for 3D painting in a CAVE semi-immersive environment, but uses an interface

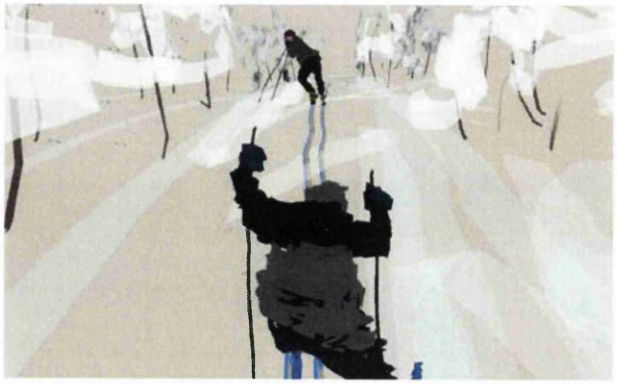

Figure 11: EVE [Mäkelä & Ilmonen 2004]
Reproduced by kind permission of IEEE. (© 2004 IEEE)

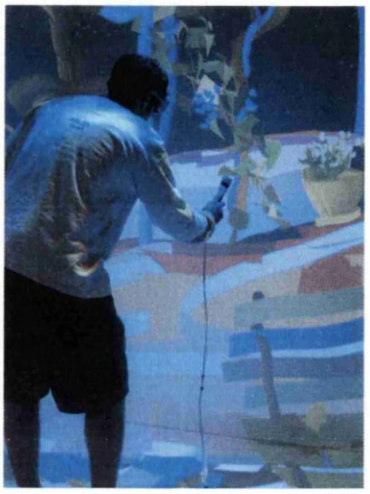

Figure 12: CavePainting
Reproduced by kind permission of
Daniel F. Keefe, Brown University

based on gesture and physical props [Keefe, Feliz et al. 2001]. The system emphasises the different types of 'strokes' that an artist will use, and the piece of work is created through the arrangement of 3D 'strokes' in space. The main elements of the interface are a tracked physical brush with an added 'toggle' button, and a table with a number of physical 'paint pots', each representing a different type of 'stroke'; a tracked physical bucket can be used to 'splash' or 'spill' paint on the CAVE's surfaces. Colour is selected via a 3D 'colour picker'. The user selects the stroke by dipping the brush into the pot – examples include 'line', 'bumpy tube', and 'Jackson_Pollack++' - and paints by moving the brush though the air while holding down the button. In some strokes the 'paint' is applied at the position of the brush tip; in others the paint continues in the direction of brush movement until it 'hits' the wall of CAVE. The system is also sensitive to the orientation of the paintbrush prop, resulting in a wide range of expressive possibilities for the artist.

Alternative techniques for creating virtual models

Other groups are devising new ways of creating virtual models as an alternative to the precise, geometric techniques currently provided. Expressive, intuitive, playful and quick methods are sought, particularly for the early stages of design. While only some of the following examples involve haptic techniques, all place strong emphasis on using the hands, and direct modelling.

'Physical' modelling

The FreeForm™ modelling system provides a 'clay sculpting'-based technique for creating 3D digital models, based around a PHANTOM® haptic device (Figure 13) [SensAble Technologies, Inc.]. Users work directly with the "digital clay" using the PHANTOM stylus as a modelling tool. The hardness and surface smoothness of the 'clay' can be varied, and different modelling 'tools' selected. Unlike real clay, you can also work from the inside out... SensAble™ recently released The FreeForm® Concept™ system: a clay-modelling application designed for use with their Omni™ device.

Figure 13: FreeForm® Modelling™
Reproduced by kind permission of
SensAble Technologies, Inc.®

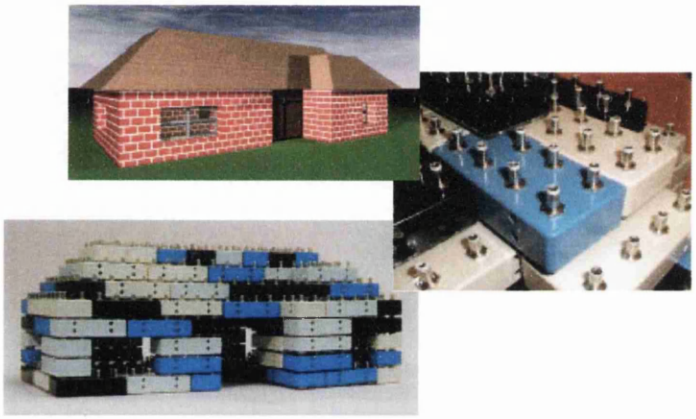

Figure 14: MERL computational building blocks
Reproduced by kind permission of ACM, Inc (pending)

Researchers at MERL[2] have developed a tangible modelling system which uses computational building blocks to build virtual 3D models (Figure 14) [Anderson, Frankel et al. 2000]. Instrumented blocks, whose physical form is based on the Lego™ block, can be built into structures in a similar way. The blocks communicate with each other, allowing the connections between the blocks to be mapped. Knowing the relative position of each of the blocks, the geometry of the resulting 3D structure is calculated, and the virtual model created. 'Literal renderings' show the virtual model similar in appearance to the original blocks, but 'graphical interpretations' of the structure, for example recognising elements as walls and roofs of a building, allow 'interpreted renderings' to be produced.

[2] Mitsubishi Electric Research Laboratory

Enhanced interfaces to existing software

Researchers at Alias® and the University of Toronto have explored new interaction techniques around ShapeTape™, a sensored strip that can measure its own bend and twist [Measurand Inc.]. Their prototype system used ShapeTape to control NURBS[3] curves in Maya, Alias's 3D modelling and animation software (Figure 15) [Balakrishnan, Fitzmaurice et al. 1999]. The user can directly manipulate virtual curves and surfaces with both hands, rather than using geometric techniques. This system explores more intuitive ways of creating and manipulating geometry in a more traditional modelling environment.

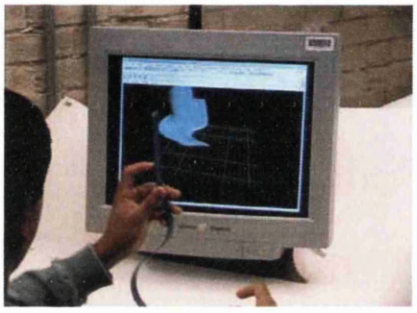

Figure 15: ShapeTape™
Reproduced by kind permission of Measurand, Inc.

Figure 16: ClayTools™
Reproduced by kind permission of SensAble Technologies, Inc.®

The ClayTools™ system [SensAble Technologies, Inc.] has been designed to extend the facility of working intuitively, organically and at high resolution with haptic, clay-type modelling systems into existing 3D computer graphics packages such as 3ds Max, Rhinoceros and Maya (Figure 16). Users can create highly detailed models in ClayTools, and then map these 'high-resolution' surfaces onto the much lower resolution polygonal models required, for example, in games applications; they can also use ClayTools to add detail to polygonal models created with the computer graphics software. The system also extends some of the tools within the computer graphics system to use haptic feedback.

InDex is a 3D modelling tool developed around the metaphors of "sculpting with blades and magnets" and modelling with "Digital Jigs" (Figure 17) [Digital Artforms Inc.]: in this way it has similarities to solid (as opposed to surface) modelling software. It allows

[3] NURBS: Non-Uniform Rational B-Spline. A type of curve where control points are manipulated to define the degree of curvature

two-handed direct interaction with the 3D model and environment via a pair of tracked LaserAid SpaceGrips button controllers (Figure 18), has the option to view the model in stereo, and can import/export to many 3D modelling software packages.

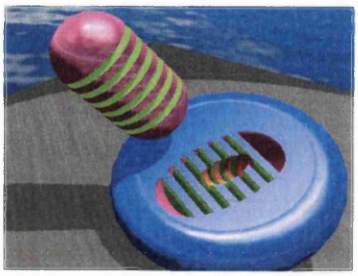

Figure 17: InDex Modelling System
Reproduced by kind permission of Digital Artforms, Inc.

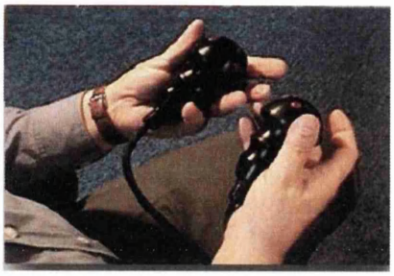

Figure 18: SpaceGrips controllers

Tangible interaction

The GeOrb is a spherical device with sensors distributed over the surface, which is held in both hands (Figures 19 & 20) [Global Haptics]. Pressing on any part of the surface deforms the virtual model mapped to the device in the direction of the pressure. Switches on the surface allow the model to be deformed inwards to or outwards from the centre of the orb, and the model to be rotated. Switching modes allows the device to be used to navigate through virtual environments.

Figure 19: The GeOrb
Reproduced by kind permission of Global Haptics, Inc.

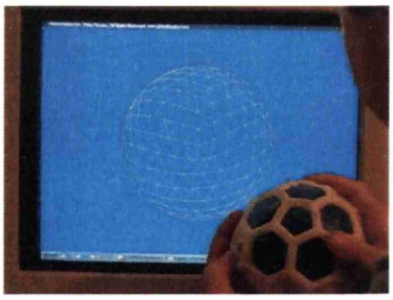

Figure 20: View of an earlier prototype in use. Reproduced by kind permission of Global Haptics, Inc.

Integrating advanced technologies for visualisation and interaction (co-incident interaction)

In an extension of their original project, researchers at the ID-StudioLab are developing 'Cubby+', which allows designers to use the Cubby 3D environment (see Appendix B) to create three-dimensional form in the early stages of design (Figure 21) [Overbeeke,

Djajadiningrat et al. 2001]. This will allow designers to create and interact with the 3D form directly in space, using both hands and a series of tools based on "a mix of tangible and augmented modelling techniques".

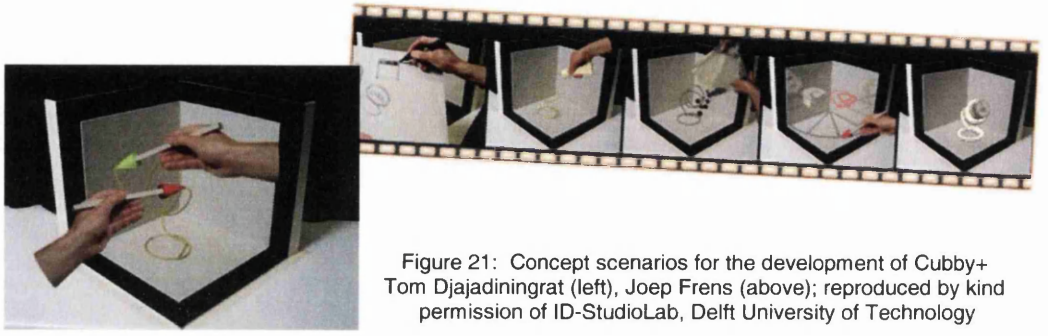

Figure 21: Concept scenarios for the development of Cubby+ Tom Djajadiningrat (left), Joep Frens (above); reproduced by kind permission of ID-StudioLab, Delft University of Technology

Research at the Digital Design Studio (DDS), Glasgow School of Art, focuses on a human centred approach to advanced digital 3D modelling, visualisation, interaction and virtual prototyping. Advanced 3D displays with integrated gesture, haptic and 3D audio technologies are being used to develop new 3D interfaces [Anderson & Slinger 2000]. AutoEval, a proof-of-concept 3D system incorporating real-time visualisation and interaction, was developed for the Ford Motor Company to support advanced design and evaluation in the automotive industry (Figure 22).

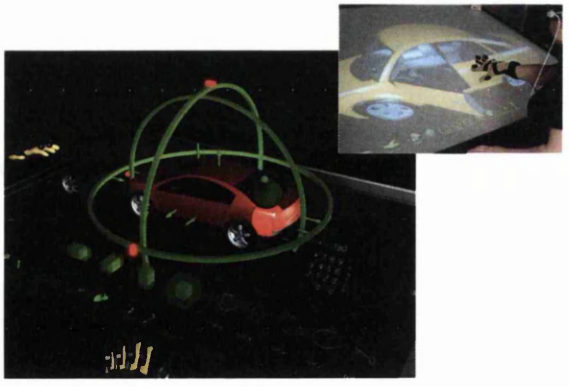

Figure 22: AutoEval - illustration of features and system in use (inset). Reproduced by kind permission of The Digital Design Studio, Glasgow School of Art

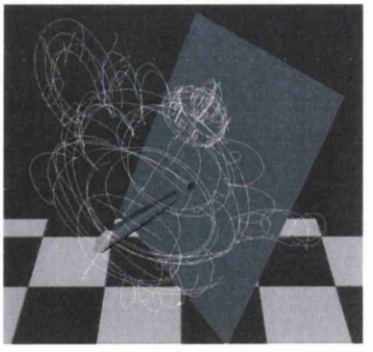

Figure 23: Tacitus project: haptics-enhanced 3D sketching application (screen capture of sketch by Tom Elliot). Reproduced from the Tacitus Project CD-ROM by kind permission of Ann Marie Shillito, Principal Investigator

The Tacitus project, a collaboration between Edinburgh College of Art and the Edinburgh Virtual Environment Centre, University of Edinburgh, has explored the potential of co-incidental haptic interaction and 3D visualisation "not to imitate the working practices of applied artists and designers, but to create a generic virtual

environment that can be applied to a variety of 3D creative disciplines" [Shillito, Wright et al. 2004]. The emphasis within the project is on developing "a new generation of interface built on a deeper understanding of the design process used by designers and applied artists, the central requirement being for rapid imprecise creation and development of designs in an exploratory manner". Haptics are used, not in the 'clay modelling' metaphor of SensAble's FreeForm software, but "as an interface element to assist interaction within a three dimensional environment" by adding an "experiential quality" to interaction. Drawing on research into artists' and designers' use of traditional media in the 'germinal' phase of the design process (particularly Physical Concept Models) [Scali, Shillito et al. 2002] a prototype system has been developed round the Reachin desktop display (incorporating the PHANTOM). This prototype is designed to engage the spatial reasoning skills that artists employ when manipulating physical objects, through a suite of tools designed on the principles of spatial, haptic, two-handed interaction. A 3D sketching application has been used to prove and develop these ideas (Figure 23). (Other aspects of this project are discussed in Chapter 3, ***Artefacts and the design process***.)

Realising digital objects

A number of artists and designers are exploring the possibilities offered by the various methods of producing physical models directly from digital data. Gordon Burnett, a metalsmith, used the unique surface characteristics produced by a CNC 3-axis milling machine in a series of aluminium clocks (Figure 24) [Margetts & Burnett 1996]. He has more recently participated in the CONNECTIVITY project, which uses rapid prototyping as part of "a collaborative international workshop that incorporates digital methods of creativity and manufacture" (Figure 25). [Connectivity]

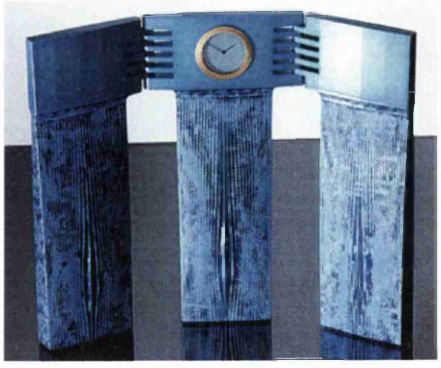

Figure 24: 'Aqua', anodised aluminium, Gordon Burnett (in collection of Aberdeen Art Gallery). Reproduced by kind permission of Gordon Burnett

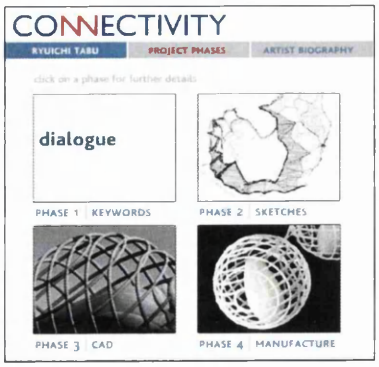

Figure 25: CONNECTIVITY project (Ryuichi Tabu). Photo, Stuart Johnstone. Reproduced by kind permission of Ryuichi Tabu

The CALM (Creating Art with Layer Manufacture) project (1998) was funded by the UK Higher Education Funding Councils to allow artists and designers to experiment with these techniques principally used by engineers and, at that time, with very high costs, and to begin to investigate their potential within this new context (Figures 26 & 27) [Hodgson 1998].

Figure 26: CALM project - 3D image and final object produced by fused deposition modelling (Justin Marshall). Reproduced by kind permission of the Learning Development Unit

Figure 27: CALM project - final object produced by stereolithography (James Jackman). Reproduced by kind permission of the Learning Development Unit

Ann Marie Shillito, an applied artist working in jewellery and metalwork, has explored a range of Rapid Prototyping (RP) techniques both in her own work, and to assess their potential for applied artists (Figure 28) [Shillito 1999].

Figure 28: Bangle with three rotating rings, produced in ABS plastic using layer manufacture technology. Designed, finished using acrylic paint and gold leaf, and photographed by Ann Marie Shillito. Reproduced by kind permission of the artist.

Conclusions

Many recent developments in digital technologies to support creative practice focus on replicating and extending the ways in which creative practitioners currently work with

materials, or in harnessing the potential benefits that can arise from combining the capabilities of computer systems with the traditional skills and working methods of artists and designers. A lot of the projects reviewed above still favour the 'design-by-drawing' paradigm: research into more intuitive methods of creating virtual design representations tends, though not exclusively, to emphasise sketching, or the use of sketch- or gesture-based interfaces to create three-dimensional form; similarly, many research projects which address computer support for conceptual design focus on sketching, even for the creation of three-dimensional virtual objects. Systems that draw on alternative approaches to design often reflect the belief that 'hands-on' access to materials is very important to makers/creative practitioners, and should be replicated when developing new digital environments for design: this thesis challenges and clarifies this viewpoint, by analysing more closely what it is that may be important in this relationship between a practitioner and the medium with which they work.

The remainder of this thesis describes an investigation of diversity in design practice which shows that significant underlying differences exist between individual design practitioners, concerning their relationship with the medium with which they work, and its role in their practice. It demonstrates that this relationship encompasses important aspects of working and knowing that are not embedded in the material context of practice, which should be acknowledged by theory, and could be harnessed practically in the development of future digital environments for creative practice.

The next chapter, ***Artefacts and the design process***, reviews a range of design research literature to identify the roles that artefacts play in a design practitioner's process; to characterise the nature of the relationship between the practitioner and the artefacts they create and work with in their processes; and to identify possible reasons for differences in this relationship.

3. Artefacts and the design process

This research is concerned with the diversity that can be observed in design practice, in terms of the relationships between design practitioners and the artefacts and media with which they work. In looking for a cohesive theory that would encompass and satisfactorily explain these differences, my starting point was the diversity I had observed within the group of designer-makers I had interviewed for my previous research where, while some designers developed their ideas using sketching, others chose to work with three-dimensional artefacts or used a combination of both. (I use the term 'artefact' to denote the physical manifestations of a designer's processes, including sketches, models, etc.)

This chapter reviews a range of design research literature to identify the roles that artefacts play in a design practitioner's process; to characterise the nature of the relationship between the practitioner and the artefacts they create and work with in their processes; and to identify possible reasons for differences in this relationship.

Studying design practice

Although there has largely been a move away from 'prescriptive' models of design to building 'descriptive' models of design through a study of what designers actually *do*, the emphasis of much design research is still on design processes (such as the relationships between analysis, synthesis and evaluation) and design 'cognition'.

This focus on 'design thinking', examining the mental and cognitive processes that go on in designing, can be seen in the titles of Lawson's major review of design, How Designers Think [Lawson 1997]; a significant symposium on design research held in Delft in 1992: *Research in Design Thinking* [Cross, Dorst et al. 1992]; and conference series such as *Creativity and Cognition*, *Computational and Cognitive Models of Creative Design*, and *Artificial Intelligence in Design*.

While much research continues in this vein, there has been a growing interest in the external representations that designers work with in their processes, and the role that these play in design. Again, this is reflected in conference and workshop series such as *Conference on Visual and Spatial Reasoning in Design*, *Thinking with Diagrams*, and the

4th International Design Thinking Research Symposium on Design Representation [Goldschmidt & Porter 1999].

In contrast to this research which has largely focused on the process of 'design-by-drawing', there has been a recent groundswell of research into the working processes of practitioners who not only design but also make. This can be seen in the *Research into Practice* conference series (in 2004 the theme was "The Role of the Artefact in Art & Design Research") [University of Hertfordshire], and the *Pixel Raiders* series of conferences on "the issues, discourse and reflective practice at the heart of digital making" [Pixel Raiders]. However, the two research communities still seem to be largely separate: a gap which this thesis hopes to bridge.

Design: problem solving or reflective practice?

The emphasis on 'design thinking' has been influenced by cognitive scientists' interests in design, which has focused research on the cognitive activities of designers. This is reflected in descriptions of "the creative designer [as] a knowledge worker involved in activities that are not readily characterised by formal procedures" [Candy & Edmonds 1996].

Goel's study of design (discussed below) takes this stance: he states how "cognitive science is in the business of explaining intelligent human behaviour. More specifically, it wants to explain cognition as symbol manipulation or information processing" [Goel 1995]. This reflects the traditional interest of cognitive scientists in predominantly mental processes; however Brereton points out that "recent writings on distributed cognition report that cognitive achievements derive not only from the internal thought processes of people but also from the material systems and information technologies with which they work" [Brereton 1999].

Studies of artefacts in design are both informed and constrained by the model of design which underlies the researcher's approach. Much research into design cognition uses the dominant paradigm of design as problem solving, where design problems are 'wicked' or 'ill-structured', and approached through systematic exploration of the problem space.

In an alternative paradigm of design as reflective practice, Schön describes design as 'reflective conversation with the materials of a design situation' [Schön 1983; Schön 1992]. Each design situation is viewed as a unique case, a problematic situation rather than a well-defined problem. Often complex, dynamic and unstable, with conflicting

requirements, such situations are not amenable to being constrained to fit standardised techniques. This requires a shift from problem solving to problem setting, from technical expertise applied in standardised ways to skilled knowing-in-action. In this model, the design process is one of understanding though change:

> *"The unique and uncertain situation comes to be understood through the attempt to change it, and changed through the attempt to understand it." [Schön 1983]*

His term 'materials of a design situation' refers not only to the artefacts with which a designer works, but also (in the architectural context in which much of his research is situated) to the site, the previous experience or 'repertoire' of the designer, the norms of the design domain within which the designer works (for example a particular 'school' of architecture), the designer's unique appreciation of the situation, etc. Each of these contributes to what Schön describes as each designer's uniquely constructed 'design world' within which they operate. Schön concludes:

> *"All of this should be contrasted with the familiar image of designing as "search within a problem space". To the extent that designing resembles the examples I have just described, it is clear that a "problem space" is not given with the presentation of design task: the designer constructs the design world within which he sets the dimensions of his problem space and invents the moves by which he attempts to find solutions." [Schön 1992]*

Schön's model of design is distinct from the 'design as problem solving' model in a number of other important ways. He acknowledges the tacit aspects of designing:

> *"Design knowledge is knowing-in-action, revealed in and by actual designing. It is mainly tacit, in several senses of the word: designers know more than they can say, tend to give inaccurate descriptions of what they know, and can best (or only) gain access to their knowing-in-action by putting themselves into the mode of doing..." [Schön 1992]*

Schön describes knowing-in-action as "a dynamic know*ing* process, rather than a static body of know*ledge*..." [Schön 1985]. This knowing-in-action "...involves sensory, bodily knowing. The designer designs not only with the mind, but with the body and senses – a fact that poses an interesting challenge to computers" [Schön 1992]. He emphasises the physical aspects of designing and the situated nature of design:

> *"Any faithful description of designing must take account of the fact that designers work in a medium – in our examples, they draw on paper – and literally see the evolving products of their work. Models of designing that treat only of conceptual matters – emphasizing, for example, the implementation of ideas, the interplay of variables, the management of constraints, or the alternation between proposals and evaluations – are bound to miss crucially important features of the design process, whatever else they may capture." [Schön & Wiggins 1992]*

The research reviewed below draws on both models of design, although the majority of studies tend towards the 'design as problem solving' model.

Different focus and scope

All the studies reviewed examine elements of the relationship between designer and artefacts, but with different focus and scope.

Focus

Some studies concentrate on examining the designer: either in the sense that they are largely concerned with a designer's "creative cognition" or creativity and innovation; or on *what* a designer is thinking about i.e. the 'content' of their thoughts. In other studies, the object of scrutiny is the artefact: although it may be the designer's processes which are being examined, the study is made largely through an analysis of the artefacts themselves. However, the majority focus specifically on a designer's interaction (in the variety of meanings given in this context to that term) with artefacts. A few studies are concerned at a broader level with a specific element of the design activity, such as Pedgley's "attention to materials and processes", or the Tacitus project's focus on the use of 3D models in the 'germinal' phase of design.

Scope

Pedgley makes a useful distinction between two different levels at which design activity can be viewed [Pedgley 1999]. His terms 'macroscopic' and 'microscopic' refer to "descriptions at contrasting levels of proximity to the observed activity". Macroscopic views

> *"tend to show a global view of designing: visible to the naked eye; spanning across long periods of a project (e.g. days, weeks); related to long-term goals; concerned with overall strategies for designing and work constraints/opportunities"*

Microscopic views, in contrast,

> *"tend to: need a specially devised data collection method in order to be captured; be contained within discrete episodes of designing (e.g. seconds, minutes); relate to short term goals; be concerned with trains of thought and designers' reasoning"*

Studies at the macroscopic level usually focus on actual design practice, including longitudinal studies on live design projects, such as Pedgley's examination of his own practice while designing a polymer acoustic guitar, reported in his thesis. Studies at the microscopic level tend to be laboratory-based, experimental studies of designers working on an artificially constrained design task. Protocol analysis is a dominant method of analysis at this level [Pedgley 1999].

In the following review the studies fall predominantly into the "microscopic" category. However, the case studies of individual designers later in the chapter could be classed as macroscopic, as they deal with designers in the context of their normal design practice.

Focus of this thesis

My research focuses on an individual designer's relationship with the artefacts they create, and how the interaction between the two contributes to, influences or comprises the design process. While acknowledging the importance of other related areas of research, such as visualisation and perception, the haptic elements of physical interaction, and knowledge-based design systems, they lie outwith the scope of this study.

The following examples are not exhaustive; research in each of the aspects discussed below is ongoing. Those included here have been selected to illustrate a range of concerns in this area of research, and the variety of roles which artefacts are perceived to play in design.

Two-dimensional artefacts

The following studies into two-dimensional artefacts (mainly sketching) cover a number of different themes: the role of sketching in the design process; the nature of sketches or sketching processes that makes them important in the early stages of design; the relationship between a designer and the sketches they produce; and what, if anything, can be said about design activity by looking at the sketches that a designer has produced/is producing, in terms of how they're designing, or in terms of what they're thinking about?

The studies mainly focus either on the process of sketching, or on the content of sketches; however some focus on the relationship between these two elements.

The symbol system of sketching

In Sketches of Thought [Goel 1995] Goel focuses on the sketches characteristic of preliminary design, and the ways in which they support cognitive processes important to these early stages of design[4]. He considers that "design is an excellent forum for studying human symbolic activity in much of its richness and diversity".

[4] A more detailed examination of Goel's position is undertaken in Chapter 6, ***'Concepts of dialogue in design'***

Goel studied the verbal protocols, writing and drawings of twelve designers (architects, mechanical engineers and instructional designers) produced during a two-hour, "real-world" design task. From the verbal protocols, he identified distinct phases in the problem solving activity, and from an examination of the drawings produced, concluded that designers use different symbol systems which correspond to these different design phases, and so facilitate different cognitive processes.

He was particularly interested in how the sketches produced by designers in the early stages of design support cognitive activity important to this phase: "the incremental transformation of a few kernel ideas". Goel identified two types of transformations important in design: *lateral* transformations, in which "movement is from one idea to a slightly different idea", and which widen the problem space; and *vertical* transformations, where "movement is from one idea to a more detailed version of the same idea", and "deepen the problem space". He observed that "lateral transformations are generally confined to preliminary design phases whereas vertical transformations generally occur in the refinement and detailing phases".

Goel observed that the sketches that supported these lateral transformations were syntactically and semantically dense and ambiguous. He reasoned that the density or fine-grainedness of the symbol system of sketching allows for the easy transformation of one *symbol* into another. This ambiguity of symbols leads to an indeterminacy in the *content* of the symbol, which in turn facilitates the transformation from one *idea* into another. He demonstrated that if designers were restricted to using an external symbol system which did not have these properties of density and ambiguity, then the lateral transformations which are important in the early phases of design were disrupted.

> *"A notational system, such as drafting, which differs from sketching in being non-dense and unambiguous, will hamper lateral transformations. Notice that these predictions have little, if anything, to do with the depictional or 'pictorial' properties of sketches."*

Although Goel emphasises the *nature* of the symbol system, as opposed to the content of the sketches, his work does link the process of sketching and the transformation of ideas: 'what' the designer is thinking about.

Symbolic conventions in design

Whereas Goel is primarily concerned with the nature of the external symbol system of sketching, and its links to the cognitive processes of design, Do with Gross has studied the symbolic conventions used by designers and how these relate to design intent ("the

association of the drawing marks with design thinking"). In this research, they are particularly interested in the use of freehand diagrams:

> *"A diagram may indicate visual phenomena such as wind, rain and sunshine, sight views and lighting, but it can also illustrate human perceptions of the environment such as noise and heat, as well as functional aspects of the environment. A diagram, unlike a sketch, contains symbols... A sketch, in contrast, is mainly about spatial form..."* [Do & Gross 1997]

(This seems to be a narrower definition of symbolic representation than that used by Goel.) In a series of studies Do & Gross discovered that designers are consistent in their use of symbols within drawings; that they "combine symbols in specific configuration to indicate design contexts... [and] have different drawing preferences for different design concerns"; and that they share and understand each others conventions.

> *"In other words, in the domain of architectural design, the graphical marks that designers make are conventional and correspond to the specific tasks that they engage in as they solve a problem..."* [Do, Gross et al. 1999]

Neiman, Do & Gross then studied 110 drawings from Neiman's personal design project, created over a fifteen year period, to see if they could retrospectively 'piece together' the designer's original intent and design process by examining the patterns of transformation and manipulation of design elements in the drawings, and between types of representations [Neiman, Gross et al. 1999]. It became clear during the investigation that this was not possible, largely because of the complexity of the patterns of transformations, and partly as there was no record of the sequence in which the drawings were produced; it also revealed that their "puzzle solving" approach was not appropriate:

> *"As we looked at all the drawings at the same time, and found ways to link different drawings by either spatial or visual relationships, we found the design project to be more a puzzle making process. As Archea suggests, designers do not clarify their goals like problem solvers do; instead, they 'treat design as a search for the most appropriate effects that can be attained in a unique context'."*

However, they made a number of observations about the relationship between the visual transformation of drawn elements and the process of designing:

> *"A designer manipulates design objects (elements) through transforming shapes and locations, and changing viewpoints and drawing types and media to explore design alternatives... The manipulations are simple, but in combination the process became complex... We found each of the design elements transformed throughout the design process: i.e. through change of dimensions, orientation and placement."*

Goel revealed a link between different types of symbol systems, and different phases of design; Do & Gross reveal a link between symbolic conventions and design intent, and a link between visual/spatial activity (e.g. manipulating "visualized representations") and design activity.

Information patterns in sketch activity

McGown, Green & Rodgers also examined links between graphical activity and 'design intent', but as a means of measuring design activity in terms of "the pattern of information flow in the conceptual sketching activity" (ideas and quotations in this section are from [McGown, Green et al. 1998]). They were concerned with the graphical characteristics of drawings as a measure of the ideas and information contained therein, and the patterns of transformations between drawings as a measure of the development of ideas.

They examined the sketchbook drawings of four students on the Product Design Engineering course at Glasgow School of Art, generated during the fifteen week conceptual design phase of their final year project, as "a measure of the ideas and information produced". To allow this measurement, two types of data were derived from the sketches: a measure of the amount of information conveyed by each drawing in terms of the complexity of the drawing, and its size; and the patterns of transformations between (dated) sketches.

The researchers devised a scale of complexity of drawings which incorporated various factors, including the number and types of lines, the use of shading to suggest 3D form, text annotation, provision of dimensions, colour, and the 'busyness' of the drawing. A scale was also drawn up with regard to the size. They proposed (in the context of computer support for design) that "an index ratio of the information in a sketch considered against the amount of sketches produced, could be used to provide a weekly track of the quality of the designer's effort".

They classified the transformations along similar principles to Goel: lateral (a "change in thinking"), vertical ("a more detailed version of the same idea"), and duplication (where one drawing is basically a repetition of a previous one). By comparing this analysis with the final project grading given to the students, the researchers concluded that it was possible to measure the quality of a designer's work by examining these patterns of 'graphical' activity:

> *"good design is a result of balance between lateral and vertical transformation at these early stages"*

They also observed that problems experienced by one of the students could be clearly seen from the analysis of these transformations:

> *"From analysis of sketch evidence* alone *it was obvious that the student's project as a whole was not progressing; there was a lack of balance between lateral and vertical transformations and a tendency to duplicate earlier work."*

The researchers appear to be equating the 'information' (as they have defined it) contained within a sketch as a measure of, and by implication a measure of the quality of, the "ideas and information produced". This position, although based on a comparison of the patterns of each student's activity with their final project grading, appears to make certain assumptions about the extent to which a designer's thoughts are made explicit on paper. While I have reservations about these apparent assumptions, and although there is no examination of how the sketching *activity* supports the development of ideas, nevertheless this study supports the findings from the studies above, that it is changes between drawings that facilitate and/or reveal the process of design.

[Seitamaa-Hakkarainen & Hakkarainen 2000; Seitamaa-Hakkarainen & Hakkarainen 2005] used a similar classification based on Goel's work, of 'horizontal sketch development' and 'vertical sketch development', to examine the different types and development of sketches produced during a short weaving design task by four advanced students and four professional practitioners in the area of weaving design. They were interested in the "strategies of visualization" used by the participants as they "solved professional weaving design tasks".

Sketching as a graphical notational language

McFadzean's research is also concerned with the links between graphical activity and design activity, specifically with the "physical details of markmaking" [McFadzean & Cross 1999]. Her research examines the proposition that sketching is a graphical notational language for visual reasoning.

From a preliminary study [McFadzean 1998a; McFadzean 1998b] she concluded that the marks made during sketching activity in the early stages of design do constitute a graphical notational language. She then investigated how this 'physical/visual' graphical notational language links to the cognitive processes of design problem solving.

Five subjects were videotaped during an architectural design task, and their sketching activity recorded using Computational Sketch Analysis (CSA)[5] [McFadzean, Cross et al.

[5] One of the first aims of McFadzean's research was to determine a suitable method of recording the marks generated, at a level of granularity that could support the types of analysis that was required. After the first study, McFadzean concluded that a computational approach was required in order to obtain sufficient

1999]. Their sketching activity was subsequently replayed using the Sketch Analyser, and their retrospective report of their design thinking during this activity was recorded on video. This allowed their verbal retrospective accounts of their cognitive design activity to be mapped to the graphical sketching activity.

First, the data was examined to identify how design activities map to the cognitive processes of the designer; a second area of research was to identify how graphical activities map to design activities, and therefore to the problem-solving processes in design. Consistent patterns of interactions between 'Design Events' - "incidents that can be considered to be important because they emphasise the state of the design problem space... identified from the verbalizations of cognitive operations that have taken place during the design process" - could be observed, revealing how design activities were linked to the problem solving processes in design. While the second stage of the research was, at the time of writing, ongoing, McFadzean's hypothesis was

> *"that there is a measurable difference in the physical activity of the graphical notation and that these differences can be mapped to the design events. It is expected that mappings will allow the extraction of denotational sub-systems that relate the designers' mode of problem solving with the syntactic structure of the external representations."* [McFadzean 1998a]

From the analysis to date, McFadzean drew a number of conclusions about ways in which sketching supports problem solving processes in design:

> *"sketches enable designers to* handle different levels of abstraction in parallel... *They* enable identification and recall of relevant knowledge... *they* assist problem structuring though solution attempts... *[and] sketching* promotes the recognition of emergent features and properties *within the problem space. Sketches help the designer to make what Goel called 'lateral transformations' in the solution space: the creative shift to new alternatives. They also help the designer to find the unintended consequences that enable exploration. Schön called this characteristic of design thinking 'a reflective conversation with the situation'."* [McFadzean, Cross et al. 1999]

McFadzean also describes the process of sketching in terms of the relationship between the designer and the sketch:

> *"Conceptual thinking, during the design process, involves an interactive relationship between the mental processing of information and the external expression and representation of that information within the sketch. The interaction between external sketch representations and the cognitive processing of design information is a 'dialogue' of thinking aloud: conversing with oneself, a process of soliloquising about design suppositions."* [McFadzean, Cross et al. 1999]

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accuracy, and developed the technique of Computational Sketch Analysis (CSA) for subsequent studies. For further details on this technique, see [McFadzean 1998a; McFadzean 1998b].

McFadzean's research suggests that the marks made during sketching are more than a symbol system; rather they form a 'graphical notational language' with which to conduct this 'soliloquy'.

Sketching as Interactive Imagery

Goel presents sketching as an external symbol system which supports cognitive processes necessary to the early stages of design. In Goldschmidt's research, the emphasis changes from sketching as a external symbolic representation of existing mental images, to sketching as a means of generating/initiating mental imagery: sketching as visual thinking (ideas and quotations in this section are from [Goldschmidt 1994]). She makes a clear distinction between visual thinking and visualisation: visualisation is visual representation; visual thinking relates to "the production of ideas, the reasoning that gives rise to ideas and helps bring about form in design":

> *"Designers invariably use imagery to generate new form combinations which they represent through sketching. But they also do the reverse: they sketch to generate images of forms in their minds."*

She gives the example of being shown a picture of a parallelogram, and being asked to find its area: those who see that the parallelogram can be re-represented as a rectangle are able to solve the problem. The facility that enables us to do this is 'imagery' – a mental visual display that allows us to 'read off' clues as to how a problem might be solved, recalling useful things from memory. In its role of external symbolic representation, sketching is a means of recording and representing visual displays. Goldschmidt proposes that in its role of visual thinking, sketching is a means of actively generating visual displays.

Like other commentators, Goldschmidt acknowledges that design concepts emerge by an incremental process of transformation, guided by 'clues' as to how to move the design problem forward. But in a design problem, the relevant images cannot all be retrieved from memory: they must be generated. Goldschmidt proposed that the primary means of generating such relevant 'clues' is sketching:

> *"It is our belief that the purpose of this early sketching activity is primarily to avail oneself of potentially meaningful clues. If picked up, these clues can be used to form and to inform emerging design concepts. To pick up clues, the designer uses imagery in a mode very similar to the one we saw in the case of the parallelogram: one reads off the sketches more information than was invested in its making... Seeing something as something else (which is not there physically) is the essence of imagery, and since in this case imaging is brought about through sketching, we call this process* interactive imagery."

Goldschmidt observed that while in many cases designers post-rationalise figures (pictorial representations) as being generated by concepts (descriptional representations), often it is a figure that has generated the concept. She concludes that the process of design features a dialectic process between figure and concept, and that such figure-concept dialogues are the building blocks of design

> *"...we notice that in these typical instances of visual thinking in designing, there is a regular and constant exchange between figural and conceptual arguments... Hence our dialectics metaphor: in the exchange between imagery in the mind and sketch on paper, we reason by way of relating figures and concepts to one another until a satisficing 'good fit' is achieved among them."*

Goldschmidt, like McFadzean, is looking at the relationship between visual thinking and design problem solving: Goldschmidt views imagery "as an interactive process of symbolic representation"; McFadzean views the marks made in sketching as a graphical notational language. Both describe an interactive relationship between the designer and the sketch, but whereas McFadzean emphasises interaction between the "mental processing of information and the external expression and representation of that information within the sketch", Goldschmidt emphasises (in the aspect of sketching with which she is dealing) that the imagery precedes the mental concept. This contrast between symbolic representation and imagery suggests that, while both are seen as enabling a process of 'dialogue with yourself', the nature of the dialogue may be slightly different.

While the above studies focus largely on the graphical aspects of sketching activity, the following two studies focus rather on what the designer was thinking about while sketching. The data for this study and the next comprised verbal protocols taken from two practising architects' and seven advanced architectural students' retrospective accounts of a 45 minute design task (generated while examining videos of their own sketching activities). Using a protocol analysis technique which focused on *the content* of the designer's thoughts, the studies investigate what the designer is thinking about, how visual aspects relate to non-visual (e.g. functional aspects), and how both of these relate to a variety of design actions, to examine the interaction between designer and sketches.

Sketching as a 'perceptual interface'

Like other studies above, Suwa & Tversky are interested in patterns of activity within the sketching process. However whereas the former examine transformations between drawings, Suwa & Tversky examined designers' retrospective verbal accounts of what

they had been thinking about during the sketching activity (ideas and quotations in this section are taken from [Suwa & Tversky 1997]).

In the first of these two studies, during which the data was gathered, Suwa & Tversky studied the verbal protocols to identify: what information architects and students perceived in their sketches; the patterns of activity (how the different types of information related to one another in a designer's thoughts over the course of the activity); and the ways in which visual aspects of design are related to the non-visual (e.g. functional, abstract). They also compared the patterns of information of experienced architects with those of students.

First, they divided the verbal protocols into segments, where each segment represented "one coherent statement about a single item/space/topic". Their analysis of the conceptual dependencies between segments revealed patterns corresponding to Goel's lateral and vertical transformations – a move to a new item/space/topic, followed by series of contiguous segments of "conceptually inter-related design thoughts", together forming what they term 'dependency chunks'.

> *"Shifts of focus allow for a lateral variety of design topics/ideas and a sequence of related thoughts allows for detailed, deep exploration of design ideas."*

Suwa & Tversky concluded that the design process consists of "cycles of focus shifts and continuing thoughts". They observed that in practising architects' protocols, shifts in focus were followed by longer contiguous segments, suggesting

> *"that once architects shift their focus of attention, they think more deeply about the topic. What causes this difference? We believe it occurs because architects are able to 'read-off' more different types of information from their sketches..."*

To examine this proposition more closely, they examined the types of information the subjects were thinking about between and within these dependency chunks, relating to depicted/emergent properties (spaces, things...), spatial relations, functional (non-visual or abstract) relations, and background knowledge. They found that in the longer sequences of segments characteristic of practicing architects there was a greater consideration of functional relations, suggesting that "practicing architects are even more adept at reading off functional issues from perception of visual features than students of architecture".

Like other studies examined here, Suwa & Tversky were concerned with the links between the visual and non-visual aspects of design, and how ideas about meanings and concepts and information are represented in or associated with visual form. They concluded that:

> *"sketches stimulate thinking about not only perceptual relations, but also about inherently non-visual functional relations..."* and that *"perception of visual attributes of sketched items, e.g. sizes and shapes/angles, plays an important role in exploring inherently non-visual functional thoughts, one important goal of a design process. In other words, sketches serve as a 'perceptual interface' though which one can discover non-visual functional relations underlying the visual features."*

Cognitive interaction with sketches

In a second study using the same data, Suwa, Gero & Purcell examined one practising architect's account of his process to identify not only what he was looking at, but also the different types of 'design actions' within the protocol, and therefore determine how a designer 'cognitively interacts' with their sketches (ideas and quotations in this section are taken from [Suwa, Gero et al. 1998]). The researchers define cognitive interaction as "a whole set of design actions consisting of drawing, paying attention to previously-drawn depictions, perceiving their visuo-spatial features, thinking of non-visual information, and so on".

The verbal protocol was segmented (as before), "in such a way that a change in his intention and in the content of his thought or actions flags the start of a new segment". Each segment was coded using four sets of categories of 'design action' - physical, perceptual, functional, and conceptual - linking the actions at the various levels to the design thoughts and intentions of the architect.

In a first stage of the research, using an excerpt from the protocol, Suwa, Gero & Purcell demonstrated a system of dependencies between these different types of design actions: perceptual actions upon physical actions, and functional actions upon perceptual:

> *"... through interaction with sketches at the physical level, designers are then able to have higher interaction at the perceptual and functional levels. This way, information 'emerges' in a bottom-up way. We conjectured that this bottom-up process is a key to understanding the roles of sketches."*

In a second stage of the research, Suwa, Gero & Purcell examined the distribution of design actions over the whole design process. They concluded that

> *"First, his design process contained three distinct phases: problem analysis, spatial arrangement, and functional exploration. Second, in the beginning of his process, the architect made depictions and perceived their visuo-spatial features without necessarily frequent thoughts of functional issues. Rather, it took a substantial time before functional thoughts began to occur frequently."*

They then examined the relationship between the physical aspects of sketching, visual perception, and the non-visual i.e. functional or abstract concepts. From their examination of the frequencies of and correlations between actions (and with their

proviso that the generality of their findings is limited due to the single subject), they concluded firstly, that sketches act as a form of external memory - ideas can be left as 'visual tokens' "so that they may be retrieved later for inspection"; secondly, that sketches provide 'visuo-spatial cues' to functional issues; and finally, that

> *"Cognitive interaction with sketches i.e. making depictions, inspecting and perceiving, enables designers to determine when to think of functional issues and how. Put differently, sketches serve as a physical setting in which design thoughts are constructed on the fly in a situated way. This coincides with the recently prevailing view ... that people act not* just *in goal-oriented or knowledge intensive ways, but more often in response to visuo-spatial features of the physical setting they are in."*

Like Goldschmidt, this study discusses a designer's interaction with his sketches. Although the types of interaction under examination are different, there is a common recognition of the importance of the physical and visual aspects of sketching activity, and that sketching provides a way of thinking and reasoning visually.

In a later study [Suwa, Gero et al. 2000] which extends this work, and provides support to Goldschmidt's position, they examined the relationship between 'unexpected discoveries' arising from sketching and the 'invention of functional issues and requirements' (what they refer to as situated or 'S-inventions') during the design process. To be counted as S-inventions "an issue should be abstracted out of specific situations in sketches and become general enough to be carried through the entire design process as one of the primary design requirements". They discovered that "unexpected discoveries of visuo-spatial features in sketches and S-inventions become the driving force for the occurrences of each other" and therefore that "having perceptual interaction with one's own sketches serves as an impetus for pushing forward the co-evolution of the solution space and the problem-space".

Drawing as the medium of reflection-in-action

Schön's model of design as reflective practice was discussed earlier in this chapter; this section considers those aspects which deal directly with the relationship between designer and design medium (ideas and quotations in this section are taken from [Schön 1983; Schön 1992; Schön & Wiggins 1992]). In Schön's model of design, each design situation is viewed as a unique case, a problematic situation rather than a well-defined problem. In order to deal with each unique and complex situation, the design practitioner has to 'set' or 'frame' the problem; impose some kind of order from which to begin. By drawing on exemplars from his repertoire of previous experience, the practitioner 'sees' a way of engaging with the situation, and 'frames' it in such as way as to impose an element of

discipline and structure to allow him to proceed. This is the start of an ongoing process of framing and reframing in response to the 'talkback' of the situation. Having made his 'move', or experiment, the designer 'appreciates' the outcome, which may or may not be what he expects:

> *"Because of this complexity [of the situation], the designer's moves tend, happily or unhappily, to produce consequences other than those intended. When this happens, the designer may take account of the unintended changes he has made in the situation by forming new appreciations and understandings and by making new moves. He shapes the situation, in accordance with his initial appreciation of it, the situation 'talks back', and he responds to the situation's back talk."*

This dialogue takes place in a physical medium. Schön describes drawing and talking as "parallel ways of designing, and together make up what I will call the *language of designing...*"; he also describes design as "a conversation with materials conducted in the medium of drawing and crucially dependent on seeing...".

The 'seeing' Schön describes has a number of aspects; one of the most important is our ability to construct 'figures' – meaningful representations – from marks on a page:

> *"...But now [the designer] begins to see other figures in the footprint, illustrating as he does so how for any given set of marks on a page, different people, or the same person at different times, may construct different figures... Seeing a new figure, he sets a new problem."*

Like Goldschmidt, he emphasises the constructive nature of this process:

> *"In all this 'seeing', the designer not only visually registers information but also constructs its meaning – identifies patterns and gives them meanings beyond themselves"*

Schön sets this 'seeing' within the context of his model of the larger process of design as reflective conversation:

> *"On the basis of a figure constructed from marks on a page, the designer sets and solves the problems that inform and motivate his further designing. The schema of conversational move experiments – seeing-moving-seeing – depends, in the first instance, on our ability to construct such coherent figures."*

Three-dimensional artefacts

Compared to the number of studies which examine the use of two-dimensional artefacts in design, there are few which address the use of three-dimensional or material artefacts in design.

Some research has focused on particular types of three-dimensional artefact, or on the role making physical artefacts plays in the broader context of design. [Yang 2005] is concerned with use of prototypes in the context of mechanical engineering. Specifically,

she examined two groups of students developing electromechanical devices to compete against one another. Comparing the results for each group, her study looked at the nature of the prototypes built, the time spent building and debugging prototypes in relation to time spent designing, and correlating these factors to the quality of design outcome, rather than the relationship between students' use of prototyping activities and the development of their design ideas. In "Experimental making in multidisciplinary research" [Rust, Whitely et al. 2000] examine the role of making as a research tool, in the context of the development of a "mechanical analogy for the human skeletal arm to inform the future developments of prostheses and other artefacts". In this project, "designing activities were the main source of new knowledge". This project showed not only "how the making skills of the designer can enhance research in a field dominated by the analytical approaches of science and engineering", but supported the authors' belief "that artefacts provide the most reliable bridge between the communities concerned with a multidisciplinary research project", relating to the communication and elicitation of knowledge. [Bucciarelli 2002] discusses the role of artefacts (in their wider sense) as a means of facilitating shared communication and understanding between diverse participants on design teams.

The following studies by Harrison & Minneman and Brereton are of particular interest to this thesis, however they differ in a number of ways to the studies of two-dimensional artefacts discussed above. Where the latter focused on individual designers, these studies focus predominantly on group design activity. In many of the previous studies, the designers were asked to 'think aloud' during the design exercise. In the studies below, the design sessions were videotaped, and it is the communication and interaction between the designers which provides the raw data which is examined to explore the design activity. Brereton comments,

> *"Activities do not reveal the individual cognitive processes... but they reveal all the verbal and gestural interactions, that is the inputs and outputs of individual thinking processes made available to the group. This provides the researcher access to the external representations used in activity."* [Brereton 1999]

These studies cover a number of different themes: the role of objects in social interaction of design teams; the ways in which interacting with objects supports design activity; the different roles that physical objects or materials play in design; and the role of objects or materials in supporting learning in engineering design.

How objects support interaction in design teams

Harrison & Minneman studied the involvement of objects in the social interaction of design teams, and the ways in which interacting with objects supported design activity (ideas and quotations in this section are taken from [Harrison & Minneman 1996]). The data for this research came from the 'Delft Protocols' - video and audio recordings of three groups and two individuals undertaking a two-hour task to design a piece of equipment for mounting a backpack on a bicycle [Cross, Christiaans et al. 1996]. The designers were provided with a backpack and a bicycle, and it is their interaction with these objects on which Harrison & Minneman's research focused.

The researchers found that interaction with the design objects was "*frequently* part of the activity" throughout the design exercise. Gesturing around or with and manipulating the objects was a significant activity, and objects were often used as "stand-ins for other objects", acting as a form of representation (including where spaces between or over objects became the location of 'imaginary' objects). While Harrison & Minneman acknowledged that this representational use of objects was important, the study did not examine the use of other representations (e.g. drawing and sketching), so this aspect was not pursued.

Harrison & Minneman then examined excerpts of the protocols to identify how interaction with the objects related to design activity: "how conversation, manipulation and design development worked across a few minutes activity". They looked at the extent of engagement with the objects (e.g. looking, touching, riding the bike); the gestural aspects of this interaction - how the designer was moving with or around the object, as a means of informing themselves or communicating with others (e.g. drawing attention to features, or animating mechanisms); how interaction with objects supported verbal communication (e.g. as 'verbal props': references such as 'here', 'this'); and the context of the activity: what triggered an interaction or resulted from it. They concluded that interaction was often used as a means of getting information:

> *"...there are also quite a number of 'spontaneous' engagements. Furthermore, there appear to be other equally compelling explanations that account for the change from an activity without to one with objects: to control the dynamics of a conversation, to change topics, to ground gestures, and to confirm or to recalibrate imaginary objects."*

They attribute a variety of roles to the objects in design activity:

> *"First, that objects are more than a source of information; they are constituents of the activity. Second, that they are constituents of and frames for the communications. Third, they alter the dynamics of interaction, especially in multi-designer settings."*

In the context of their particular interest of the role of objects in the social interaction of design teams, they conclude:

> *"The significance is not that they provide a rich source of information for the designer (which they do) or that they are superior to abstract forms of information (which they may or may not be), but rather that the processes of interaction with objects have communicative value and alter the dynamics in multi-designer settings."*

Harrison & Minneman's study focused on actual objects, not material media. Although they acknowledged the importance of the representational role of objects, and proposed that it was worthy of further examination, it was not the focus of their study. However, in the following work it is a major concern of the research.

How objects support design thinking and learning

Brereton's research examines the different roles hardware plays in design; how interaction with hardware supports students learning engineering design; and how hardware supports communication (ideas and quotations in this section are taken from [Brereton 1999; Brereton & McGarry 2000]). (Brereton uses the term *hardware* "to refer collectively to physical objects and physical prototyping materials".) This had not been the original focus of Brereton's research, but in an exercise to design a mechanism for kitchen scales, where undergraduate engineering students were asked to "develop ideas and present them on a sketch pad",

> *"students were found to opportunistically seek out all sorts of miscellaneous objects to support their thinking. In a barren design environment consisting of a classroom full of chairs, tables, sketch pad and pens, students sought out inspiration from gesturing with pens, pulling and twisting a rubber band that was spotted lying on the floor and dissecting a ballpoint pen dug out from a student's back pack. They made numerous references to prior experiences with objects."*

A more detailed analysis identified nine different 'roles' (see Table 1) in which working with hardware supported students' "design thinking and communication", illustrating that objects can be used 'as themselves' (for example when testing functional constraints); as representations of other objects, to illustrate general principles, or recall experiences of using objects; and to support communication between designers. Brereton observed "the large extent to which designers appropriate objects to help them think", and that the role of material representations depends on their context of use:

> *"The problem context derives what attributes of an object people notice and in which ways they try to use an object"*

She proposed that Goel's observations on sketches have parallels in 'physical prototyping':

The Roles of Physical Objects and Prototyping Materials in Supporting Design Thinking and Communication
Hardware as a Starting Point Hardware is tangible. It exists. It serves as a starting point it is easily noticed, remembered, seen and touched. It offers a basis for comparison.
Hardware as Chameleon Hardware is always in a context of use. What the hardware reveals depends upon the context is use. A variety of informal experiments in different contexts reveals different facts.
Hardware as Thinking Prop Hardware objects have all sorts of properties that afford different actions. Hardware that was easily accessible and had a useful property was adopted as a gestural aid to support thinking.
Hardware as an Episodic Memory Trigger Episodes of experiences with physical objects serve as memory devices.
Hardware as Embodiment of Abstract Concepts (Functional and Theoretical) Observing and testing hardware reveals fundamental concepts, physical embodiments of abstract concepts; and unanticipated design issues in hardware behaviour.
Hardware as Adversary Challenging theoretical model predications against hardware behaviour reveals discrepancies and provides clues to modelling errors. This reveals theoretical assumptions, and causal relations.
Hardware as Prompt Device behaviour prompts student questions and suggest experiments. Through repetitive interaction with hardware students bring order, distilling out key operational parameters and their relationships.
Hardware as a Medium for Integration Integrating components in their functional context reveals practical limits of use, characteristics of operation, methods of connection, causal relations, and physical quantities. This empirical knowledge extends the student's hardware repertoire.
Hardware as a Communication Medium Hardware is integral to learning communications, affecting the course of inquiry, idea generation, discovery and the dynamics of group interaction. Hardware is used to command attention, to demonstrate and to persuade.

Table 1: "The roles of physical objects and prototyping materials in supporting design thinking and communication" [Brereton & McGarry 2000] Reproduced by kind permission of ACM, Inc. (pending)

The Roles of Hardware in Mediating Design Negotiations	Design Learning Outcomes
Hardware as a Communication Medium	Hardware is integral to learning communications, affecting the course of inquiry, idea generation, discovery and the dynamics of group interaction. Hardware is used to command attention, to demonstrate and to persuade.
Hardware Starting Points and Memory Devices	Physical experiences with hardware serve as memory devices and starting points.
Hardware as Thinking Prop	Hardware with desirable properties that was easily accessible was adopted as a gestural aid to support thinking.
Hardware as Chameleon	Hardware is always in a context of use. What the hardware reveals depends upon the context of use. A variety of informal experiments in different contexts reveals different facts.
Hardware as Embodiment of Abstract Concepts (Functional and Theoretical)	Observing and testing hardware reveals: fundamental concepts; physical embodiments of abstract concepts; and unanticipated design issues in hardware behaviour.
Hardware as Adversary	Challenging theoretical model predications against hardware behaviour reveals discrepancies and provides clues to modeling errors. This reveals: theoretical assumptions, causal relations.
Hardware as Prompt	Device behaviour prompts student questions and suggests experiments. Through repetitive interaction with hardware students bring order, distilling out key operational parameters and their relationships.
Hardware as a Medium for Integration	Integrating components in their functional context reveals: practical limits of use, characteristics of operation, methods of connection, causal relations, physical quantities. This empirical knowledge extends the student's hardware repertoire.

Table 2: "The Roles of Hardware in Learning Engineering Fundamentals and the Associated Learning Outcomes" [Brereton 1999] Reproduced by kind permission of MIT (pending)

> *"Because physical objects can be interpreted in multiple ways depending on their context of use, they too are ambiguous and facilitate context-dependent interpretation as do sketch elements."*

From the video analysis of the above and other studies, Brereton observed that "hardware plays a very formative role in learning, rather than simply serving as a final physical testing ground for ideas that have been developed through abstract reasoning". In a second stage of research, she identified a number of roles by which hardware mediates the learning process (see Table 2); these are similar to the roles identified previously, but within the more specific context of learning. In an exercise for students to design and build an aluminium crane from kit hardware, she observed consistent movement between references to abstract representation ("design requirements or theoretical concepts") and material representation, revealing a learning process of "continually challenging abstract representations against material representations":

> *"This comparison reveals gaps, which inspire further design activity. The cycle of representation and re-representation in abstract and material forms advances the design, the designer's understanding of technical fundamentals and the designer's hardware repertoire"*

Brereton draws comparisons with these findings and her description of Schön's model of sketching activity, "being involved in a reflective conversation with the materials of a design situation, the sketch talking back and revealing issues to the designer". She

concludes that the learning process she has identified is similar to Schön's 'reflective conversation', because even more than a sketch, a material representation is an "active and evocative participant":

> *"It responds through physical behaviour. It may deform under loading, make noises, smell, wear or jam... It is intolerant of poor assumptions or overlooked details that may not reveal themselves in a sketch. It reveals or suggests such oversights through its behaviour..."*

There are similarities, in the sense that interacting with material representations reveals gaps between a model of the situation, and the actual situation, giving you a new way of 'seeing' or 'framing' the situation. Schön relates how "in answer to the situation's back-talk, the designer reflects-in-action on the construction of the problem, the strategies of action, or the model of the phenomena, which have been implicit in his moves", and that "The practitioner may surface and criticize his initial understanding of the problem, construct a new description of it, and test the new description by an on-the-spot experiment" [Schön 1983].

However, while the two positions are similar in the context of learning - challenging an abstract representation against a material representation and converging towards a fixed or 'absolute' end-point - in Schön's model of design, while you certainly converge towards a final position, the end-point is not fixed:

> *"[the] practitioner [cannot] know, at the moment of reframing [or framing], what the solution to the problem will be, nor can he be sure that the new problem will be soluble at all. But the frame he has imposed on the situation is one that lends itself to a method of inquiry in which he has confidence." [Schön 1983]*

Brereton's comparisons with Goel and Schön link findings from the earlier studies of two-dimensional artefacts to the material context.

Artefacts generally

While the studies above have focused specifically on particular types of two- or three-dimensional artefacts, the following studies consider the role of artefacts more generally within a designer's process.

Attention to materials and processes

In his thesis [Pedgley 1999] Pedgley examined the "significance of materials and manufacturing processes as elements in industrial designers' work"; however this largely concerns the selection of materials for the finished product, and where and how these are

considered during the process. He does discuss the role of 'modelling' within a designer's process, describing the different ways in which it can be used:

> *"When applied to industrial design, the activity of modelling refers to the generation of product ideas (or analogues thereof), held either solely in one's 'mind's eye' or expressed through media such as drawings or worked objects. Modelling is used by designers to explore and clarify ideas; stimulate thinking; simulate proposals; act as a record of ideas that might otherwise become lost; and can be used to communicate thinking to other people. In the context of this study, modelling can be usefully broken into three categories: cognitive modelling (i.e. seeing 'in the mind's eye'); two-dimensional (2D) modelling (e.g. drawing or generation of computer-based representations of ideas, of whatever degree of precision or abstraction); three-dimensional (3D) modelling (e.g. the making of physical objects, of whatever degree of precision or abstraction, that can be manipulated with the hands)"*

In this view,

> *"Designers' 2D and 3D modelling hold evidence of considerations having been made and decisions having been taken. For the purposes of documenting design activity, the products of 2D and 3D modelling... can be considered external manifestations of cognitive activity"*

Externalising through sketching and making physical models

The Tacitus project's review of the literature examines the creative process, particularly the roles of sketching and physical modelling in the early stages of design, with a view to developing new haptic digital tools to support designers in these early stages (aspects of the Tacitus project relating to tool development are discussed in Chapter 2).

> *"The first step is therefore a better understanding of the reasons behind the use of traditional media during conceptualisation despite the advantages brought by digitalisation..."*

(Ideas and quotations in this section are taken from [Shillito, Paynter et al. 2001; Paynter, Shillito et al. 2002; Scali, Shillito et al. 2002].) Figure 29 illustrates their model of the creative process, with two phases: a germinal phase, which they describe as 'goal orientated', a "search for solutions and possibilities" characterised by divergent thinking, rapid, imprecise and exploratory working, and a "willingness to go astray"; and a practical phase, "where the developments of the germinal phase are formalised through convergent thinking to create a definitive object".

The germinal phase is an iterative process between conceptualisation and externalisation. Conceptualisation is a cognitive process, "a 'thinking through' of a design problem". Externalisation is the expression of mental images on media, through activities such as sketching and making physical models. However:

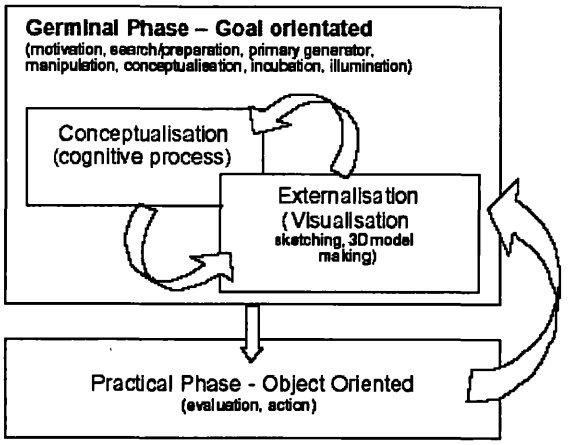

Figure 29: "Model of the creative process" by Shillito, Scali and Wright [Scali, Shillito et al. 2002]. Reproduced by kind permission of Ann Marie Shillito, Principal Investigator, Tacitus Project

> *"the purpose of externalisation is not to represent mental images but rather to describe, visually, the dialogue that gradually defines the form of the entity being developed"*

Their review identified two cognitive activities important to the creative process, relating to 'discovery' in mental imagery: 'restructuring' (figure and form), which is difficult to do mentally, and is assisted by externalisation through sketching and modelling; and 'combining', which is easier to do mentally, and can actually be disrupted by inappropriate sketching activity. Externalising using sketches and models within the germinal phase allows a designer to restructure images in ways it would be difficult to do mentally. The review also highlighted the importance in sketching of "reinterpretation through 'emergence'", discussed earlier in this chapter: the ability to 'see' elements of the drawing in new ways.

The Tacitus project focuses on the haptic elements of working, therefore the roles of physical modelling are of particular interest. Different types of models are suited to different phases of the design process: in this research, they are looking at models in the *germinal* phase of design (what they term Physical Concept Models (PCM)), not in the *practical* phase of design (the creation of a 'definitive object'). These models are therefore representations which relate in some way to the final object, but are distinct from both it and from models used in later stages of design, which have quite different characteristics.

The nature of sketches - ambiguous, 'fuzzy' and without "unnecessary precision" – is seen to support the types of cognitive activity necessary in the germinal phase of design.

The nature of models that make them useful in the germinal phase are similar to those of sketches: simple (in the sense of not detailed), 'fuzzy' (ambiguous), and vague (incomplete). Models for the germinal phase, while sharing attributes of sketches, have other attributes which make them useful: they are three-dimensional, assisting a designer to "think in space"; they should be "easily changed", "flexible" and offer "real-time feedback" (in contrast to "the snapshot in time offered by RP [rapid prototyping]", for example).

Models used in the germinal phase are therefore seen to support the creative process in similar ways to sketching, although some commentators suggest a more deliberately exploratory role. They quote Schrage:

> *"models are made to answer specific designer's questions: once the question has been answered the model is wasted and its value resides in the understanding that it brought to the design process."*

Their review highlights the widespread use of physical models in designers' processes, and identifies a number of reasons why designers may choose to make physical models over sketching. First, different types of models support particular activities. Scali et al. use Lennings et al.'s categorisation: shape models; functional models; physical behaviour testing models; presentation models; and models for stimulating group discussion.

Modelling may also reflect a preferred way of working. Paynter et. al cite studies from literature (Mawson, Borland & Welch, Anning) where subjects preferred to use modelling rather than sketching, but no additional explanation is provided. (They suggest that there are cases where such preference may be over-ridden by the practical constraints of producing models.)

> *"In the Borlex and Welch study in 2000 children and students seem to choose to begin the design process by gathering together materials and tools, moving immediately to 3D modelling as this allowed them to explore design possibilities and to strengthen mental images."*

Physical modelling offers a "'qualitatively different'" sense of engagement to drawing, and is a means to access and develop specific and different skills through spatial, haptic, two-handed interaction with physical models. Direct interaction with models supports what may be variously termed spatial reasoning, "thinking in space", or "three-dimensional reasoning", as the experience of space though manipulating three-dimensional objects with the hands is seen as an important way of understanding it. A more prosaic yet significant reason for making models is by those inexperienced in appreciating and representing 3D form in two dimensions.

Working with materials can also be seen as an integral part of an applied artist's process, both by providing a set of material constraints which provide "an affordance to the imagination, rather than a barrier", and by allowing a greater range of senses to contribute to the process.

> *"An applied artist's instinctive grasp of constructing and visualising in three dimensions, their spatial thinking and sense of touch are integral to their process of creativity. Makers combine all their sensory modalities such as sight, hand motions, and sound in order to explore and bring intended qualities to the object they are making. Results can only be achieved through ongoing dialogue between the maker, materials and process."*

In the wider context of this thesis, even though the model of design which Shillito et al. describe recognises the processes of iteration between germinal and practical phases, it is still largely 'design-then-make', with physical modelling used as a medium for design. There is no apparent suggestion that individuals might be different in their approach, or in their relationship with the artefacts that they use; although they cite studies which identify a preference for 3D modelling, the suggestion is that this might reflect a generally preferred way of working, rather than reflecting differences between individual designers.

The roles and characteristics of sketching which they identify through their review largely agree with those commentators already discussed. Scali et al. describe the relationship between conceptualisation and externalisation as a 'dialogue' and liken the designer's relationship with physical artefacts to Schön's description of design:

> *"The characterisation of the designer as "thinking with their hands" while creating or manipulating physical models echoes the sentiment of Schön when he described the act of freehand drawing as a conversation with the image."*

The role of artefacts in design

In the studies above, artefacts are perceived to play a variety of roles within a designer's process.

The majority of studies deal with two-dimensional artefacts, mainly sketching. At a cognitive level, sketches are variously viewed as an external representation of cognitive activity; an external symbol system supporting internal cognitive processes; a means of generating, as well as representing, 'mental imagery'; or a form of external memory. While some studies viewed sketching as a means of symbolic representation, others viewed it as more: a language for visual thinking and reasoning. Some studies emphasised the physical aspects of sketching, viewing it as a physical/visual language for doing design thinking, or as "a physical setting in which design thoughts are constructed

on the fly in a situated way" [Suwa, Gero et al. 1998]. Various studies stressed ways in which sketching enables thinking about the non-visuo-spatial aspects of design, either through symbolic representation of non-spatial elements, or as a 'perceptual interface' to functional and conceptual issues. Finally, it was perceived as a medium of 'reflection-in-action'.

Although fewer studies focused on the use of three-dimensional artefacts, they examined the role of objects, physical materials, and physical concept models. Objects as 'themselves' were used as a means of challenging or testing ideas, or revealing gaps in understanding; and as an embodiment of e.g. functional principles. Objects were also used to represent other objects, and to recall previous experiences of working with objects. In their role of supporting communication within design teams, objects were used as 'frames' for communication, and to alter the dynamics of interaction. Physical concept models may be used to support particular design activities; to access specific and different skills to those used in sketching; to aid spatial reasoning; or where novice designers are not skilled in representing three-dimensional objects though drawing.

At a more general level, Pedgley identifies various roles for which designers use modelling:

> *"[to] explore and clarify ideas; stimulate thinking; simulate proposals; act as a record of ideas that might otherwise become lost; and... to communicate thinking to other people."* [Pedgley 1999]

As well as the different roles which artefacts are perceived to play in design, the studies also identified various characteristics of artefacts that make them useful in design. Sketches, for example, allow designers to consider different aspects of the situation, or different levels of abstraction, in parallel. Designers in a field share symbolic conventions, where graphical marks are conventional and correspond to specific tasks. The manipulation of physical objects, or visual elements in sketches, allows designers to test both their understanding of the situation, and evaluate the consequences of design 'moves'. Sketches provide a visual means of considering non-visual aspects of the design. Marks on a page, and physical objects, can both be interpreted in different ways depending on the context of use, facilitating the development of ideas. Sketches and physical concept models share characteristics of fuzziness, ambiguity and incompleteness, supporting cognitive activity important to the early stages of design.

From this review it becomes clear that artefacts are not just passive recipients of a designer's intentions, but play a much more active role. Many of the studies emphasise

the importance of the designer's active engagement with the design situation to drive the process forwards, and view design as a process of incremental change, facilitated through and revealed by engagement with artefacts.

A number of the studies characterise the relationship between designer and artefacts not just as active, but as 'interactive'. Many commentators view the process of working with artefacts as a 'dialogue' with yourself, but this term covers a number of different phenomena. These differences relate to the level at which the dialogue takes place, and the degree of deliberate exploration or chance discovery which drives the dialogue.

Viewed at the level of the overall process, this dialogue may be driven by deliberate exploration, and arise from the external expression of ideas which the designer can evaluate and move forward. Alternatively, the dialogue is the result of unexpected consequences which arise from a designer's engagement with a unique and complex design situation: what Schön refers to as 'talkback'. McFadzean sees both as contributing to "a 'dialogue' of thinking aloud: conversing with oneself, a process of soliloquising about design suppositions" [McFadzean, Cross et al. 1999]. For Goldschmidt, the dialogue arises from

> *"...the exchange between imagery in the mind and sketch on paper... we reason by way of relating figures and concepts to one another until a satisficing 'good fit' is achieved among them."* [Goldschmidt 1994]

Neiman, Do & Gross identified both types of activity: they noted the deliberate exploration of design alternatives through transformation and manipulation of visual elements, but also that "the designer 'plays games' by defining rules, selecting strategies and design moves between self imposed rules, and discovering and evaluating the outcome" [Neiman, Gross et al. 1999].

At the level of the artefact, two similarly different concepts of dialogue can be identified. Goel described how, in the early stages of design, alternative design solutions "emerge through the incremental transformation of a few kernel ideas" [Goel 1995]. He argued that sketching facilitated *lateral* transformations, in which "movement is from one idea to a slightly different idea", and which "are necessary for widening the problem space and exploring and developing kernel ideas". He reasoned that the density or fine-grainedness of the symbol system of sketching allows for the easy transformation of one *symbol* into another. This ambiguity of symbols leads to an indeterminacy in the *content* of the symbol, which in turn facilitates the transformation from one *idea* into another. Similar to this process, but with more emphasis on discovery, is the phenomenon described by

terms such as 'emergence', 'imagery', 'seeing': our ability to construct figures from marks on a page, and to see more in the marks on a page than was originally intended. The Tacitus review identified both 'restructuring' and 'emergence' as important aspects of cognitive activity supported by externalisation.

Suwa, Gero & Purcell illustrated how sketches "serve as a physical setting in which design thoughts are constructed on the fly in a situated way" [Suwa, Gero et al. 1998]. They identified what can also be viewed as a form of dialogue at this level:

> *"... through interaction with sketches at the physical level, designers are then able to have higher interaction at the perceptual and functional levels. This way, information 'emerges' in a bottom-up way. We conjectured that this bottom-up process is a key to understanding the roles of sketches."*

Furthermore, from their subsequent study they concluded that

> *"drawing sketches, representing the visual field in the sketches, perceiving visuo-spatial features in sketches, and conceiving of design issues or requirements are all dynamically coupled with each other. These activities as a whole form the act of designing."* [Suwa, Gero et al. 2000]

While all these phenomena could be considered a 'dialogue' between designer and artefact, contrasts between them reflect underlying differences in emphasis on the role of artefacts in design, relating to the difference, for example in sketching, between symbolic representation and visual thinking; between external representation of ideas, and the external generation of ideas; and between artefacts as an external representation of cognitive activity, and working with artefacts as a means of thinking.

Differences in design

The studies above reflect different models of the design process, and different models of dialogue between designer and artefact, but few deal with individual differences between designers. Some of the studies, as well as being 'experimental' in the sense of using an artificially constrained design task, have examined very few subjects; in many cases this reflects the fine level of detail at which the design processes were being studied, but in the context of this thesis, it lessens the likelihood that any differences between designers will become apparent.

Most of the studies also focus on the use of one type of artefact, and comparisons between two- and three-dimensional artefacts, such as those by the Tacitus project and Brereton, are rare. However, as a group, the studies cover both types, so it is possible to look for similarities and differences between these two areas.

Similarities and differences between 2D and 3D artefacts

In her study of how objects support design thinking and learning, Brereton drew comparisons between her findings with 'hardware', and Goel and Schön's findings with two-dimensional artefacts. These relate to ambiguity of interpretation (the ability to interpret marks on a page or objects in different ways depending on the context within which they are being considered), and 'reflective conversation' (the ability of both sketches and physical objects to reveal gaps in our understanding of a problematic situation (in design or learning) or to suggest previously unanticipated ways to proceed). Sketches and objects are both seen as ways of recalling previous knowledge or experience. Pedgley's list of ways in which modelling is used within the design process applies to all types of artefacts:

> *"Modelling is used by designers to explore and clarify ideas; stimulate thinking; simulate proposals; act as a record of ideas that might otherwise become lost; and can be used to communicate thinking to other people"* [Pedgley 1999]

Although Brereton identifies similarities between working with sketches, and working with 'hardware', she also identifies differences. These appear to relate mostly to the material or 'real' properties of the physical object or prototype, which make it "a yet more active and evocative participant that the sketch", particularly in its role of challenging understanding of abstract concepts:

> *"It is intolerant of poor assumptions or overlooked details that may not reveal themselves in a sketch. It reveals or suggests such oversights through its behaviour"* [Brereton 1999]

The studies on sketching emphasise its use as symbolic representation or a means of visual thinking. Physical objects are seen largely as a means of testing ideas previously conceived by other means, or of supporting communication, although it is recognised that they also can have a representational role. In their review of the literature Shillito et al. identify a number of reasons why designers may choose to make physical models in the early stages of design, but there is less evidence as to where and why an individual designer might choose sketching over modelling, or vice versa.

There is some suggestion in the Tacitus project's review of the literature that modelling might be a preferred way of working, replaced by sketching where time and cost constraints prevail. However although the characteristics of physical concept models used in the germinal phase are similar to those of sketching (simple, incomplete, fuzzy, vague), it is not clear whether other aspects identified by commentators earlier in this chapter as important in sketching activity, such as a designer's ability to deal in parallel

with different aspects of the design, and different levels of abstraction, would be reflected in this three-dimensional modelling activity.

As there are only a small number of studies on three-dimensional artefacts, or comparisons between two- and three-dimensional artefacts, it would be unwise at this stage to draw too many conclusions about the different ways in which two-dimensional and three-dimensional artefacts might support the design process.

Differences between individual designers

Most studies in design look for consensus, not difference. This focus is evident from methods of enquiry such as Video Interaction Analysis used by Brereton, in which

> *"an interdisciplinary team (of engineers, a linguistics expert, a sociologist, an anthropologist and a computer scientist) viewed segments of tape selected by the primary investigator and identified routine practices, routine problems and resources for their solution. Only those practices confirmed by the raw data that occurred repeatedly in different parts of the tape were considered admissible in the analysis... The examples presented... are representative of activity in that they have been observed in many different groups and in many different segments of videotaped footage."* [Brereton & McGarry 2000]

Few studies are directly concerned with differences in the way designers work; many of these focus on differences between novices and experts, for example [Kavakli & Gero 2002; Atman, Cardella et al. 2005]. Some studies have focused on individual styles of problem solving in design, defined as "an individual's preferred way of action regulation in dealing with complex problems" [Eisentraut & Günther 1997; Eisentraut 1999]; these concern activities such as 'goal elaboration', 'information gathering', 'prognosing', 'planning and acting', and 'effect monitoring'. Other studies have focused on different learning styles or cognitive styles (" the term 'cognitive style' affords a narrower definition as it refers to an individual's preferred way of thinking, organising and representing information within the mind" [Roberts 2006]); these studies from architectural design examined the ways in which students with different styles performed in different stages or aspects of their architectural design studio activities, as these may require different styles [Demirbas & Demirkan 2003; Kvan & Yunyan 2005; Roberts 2006].

Two studies from engineering design are briefly reviewed here: the first, reported on by Ehrenspiel (sic), Dylla & Günter (sic) [Ehrenspiel, Dylla et al. 1992]and Fricke [Fricke 1992] compared individual designers to identify successful and less successful design processes; the second, conducted by Günther & Ehrlenspiel [Günther & Ehrlenspiel

1999], compared the design processes of methodologically educated designers, and designers from practice.

The studies have common features in their design: the subjects were engineering designers; the experimental design consisted of a very specific design task concerning the design of a mechanical device, quite tightly constrained although with no time limit for completion; and the data consisted of video-tapes of the designers working and their 'thinking aloud', along with the drawings and notes produced. In both cases, the analysis was based on formal design methods: in Günther & Ehrlenspiel's study, "the division of the design process into four phases is the basis for analysis of the process and the character of the design problem" (the linear phases are task clarification, conceptual design, rough embodiment design, and final embodiment design); a similar classification was made in the earlier study. Individual designers' processes were compared to an assessment of the quality of their final design by a panel of experts based on the layout drawings produced.

The study on which Ehrenspiel (sic), Dylla & Günter (sic) and Fricke report was concerned with "individual ways of thinking and acting in mechanical engineering design". One of the aims was to identify differences in approach between successful and less successful designers. Of the two papers reviewed[6], the first paper was largely concerned with the method, the second with the "limitations and difficulties" of implementing projects with researchers from different disciplines. However, selected findings are discussed regarding the differences between successful and unsuccessful designers (distinguished by the quality of the final design as assessed from the drawings). Fricke drew a number of conclusions about successful designers: they analyse the task intensively before starting; they focus on "important problem areas", and the "steps necessary to solve the problem"; they generate appropriate variants and reduce by assessment (less successful designers generated "too many or purposeless solutions", more successful designers "retain an overview, in that they can repeatedly reduce this multiplicity by intermediate assessment"); and they "possess a better imaginative spatial faculty and a higher heuristic competence" (the latter relating to " the capability for long range procedural planning and the correct weighting of problems").

Günther & Ehrlenspiel's study focused on different groups of designers rather than differences between individuals (although individual subjects' processes were examined

[6] A number of papers were produced on different aspects of the study

for the study). They compared "experienced designers from practice who have neither education at a university nor education in design methodology" (i.e. "a practical education as draughtsman, technician or master craftsman", who they termed 'p-designers') and "designers with education in design methodology at a university" ('m-designers'). They identified a number of differences in process. 'm-designers' tended to clarify the task extensively before proceeding to the next stage, while 'p-designers' tended to clarify the task through engaging in the conceptual design phase. The patterns of activity relating to each phase of activity were different: 'm-designers' tended to deal with each phase of the overall design through the recognised stages; 'p-designers' tended to cycle through phases for a series of individual 'sub-problems'. 'p-designers' documented their work at the conceptual stage less: rather they "elaborate concepts mainly in the head... these results are then used to draw up the rough embodiment design". 'p-designers' generate design variations in series, with new variants replacing previous ones; 'm-designers' generate a range of variants, which they assess, and select one. Finally, 'p-designers' tend to document the final product rather than the process: "solutions are worked out on a concrete level and very rapidly". Günther & Ehrlenspiel proposed a number of reasons for these differences in the processes of 'p-designers', including an educational focus on product, not process; extensive practical experience providing a "concrete idea of solutions", and the very real time constraints in design practice.

The types of differences being examined in these studies are not directly related to this thesis (although some of the individual characteristics described are interesting in the light of later chapters of this thesis); however the underlying view of 'design' revealed by these studies, with its emphasis on formal design methods and an underlying model of 'design as problem solving', is interesting in this context.

Some studies reviewed earlier in this chapter concerned differences between designers, but the differences in question are not related to this thesis: McGown, Green & Rodgers used comparisons between designers' sketching activity as a method of measuring the quality of a designer's work; Suwa & Tversky drew comparisons between practising architects and architecture students.

Pedgley [Pedgley 1999] does address the different ways in which engineers and artist-designers 'know about' materials and processes, but the differences he discusses focus largely on the characteristics of the materials to which both groups pay attention, rather than any difference in underlying approach to design. He quotes Norman [1997]:

> *"'Artists might be more concerned with colour, texture, reflections, contrasts, translucency and patterns etc. Engineers might be more concerned with surface, roughness numbers, refractive index, conductivity, resistivity, tensile strength and modulus of elasticity. These traditions represent different ways of knowing about materials.' "*

In an interview with a mechanical engineer and an artist-designer working in ceramics, he noted that in the area of ceramics,

> *"the prevalent approach to designing is to generate and develop ideas by experimenting with the end-material or a modelling material... The benefit of 3D modelling in clay is that the manipulation of the material itself solves disputes or queries over whether a particular shape, surface detail, decoration or finish (that might work on paper) is indeed achievable."*

This suggests that the modelling materials are used as a practical means of verifying design ideas, rather than that working with materials represents a different way of 'doing' design.

Case studies in design

One group of studies, referenced above but not yet reviewed, does discuss differences which are related to this thesis (and are 'value-free', in the sense that one approach is not considered superior to another), although these differences were not the specific focus of the research.

Roy, Cross & Clayburn Cross, and Candy & Edmonds have studied individual designers who have developed innovative products, to identify common key characteristics in the design processes of highly creative individuals. Roy examined the working processes of James Dyson in designing the 'Ballbarrow' and cyclone vacuum cleaner, and Mark Sanders in his design of the Strida folding bicycle. Cross & Clayburn Cross studied Gordon Murray's working methods in racing car design, and Candy & Edmonds examined the creative cognition of Mike Burrows by tracing his development of the LotusSport bicycle.

To use Pedgley's terminology, these studies take a 'macroscopic' view of design activity: actual design projects and processes, over long periods of time, concerning overall strategies for design. Significant in the context of this thesis is that many of the designers featured in these studies design and make, i.e. they are responsible for the whole process from concept to final product (including in some cases the process of getting products to market). In the industrial context within which some of these designers work, what I refer to here as a 'final product' may be a fully working 'prototype', as opposed to a product ready to exhibit or sell to the public; what is important is that the final product

has been fully realised. These case studies complement and make an interesting contrast to the studies at 'microscopic' level reviewed earlier in this chapter.

The studies variously drew on combinations of background research, informal discussions and formal interviews with the designers, and examination of artefacts – sketches, drawings, models and prototypes – produced by the designer. Although all of these case studies focused largely on creativity, creative thinking and the development of ideas – a designer's 'creative cognition' - each of the studies paid attention to the roles of sketching and modelling with the designers' processes. All the studies make reference, in Roy's case by comparison between the two designers in his study, and in Cross & Clayburn Cross and Candy & Edmonds' studies by comparison to other studies, to differences in approach relating to the roles of sketching and drawing or working with materials between different individuals' practice.

James Dyson & Mark Sanders

(Ideas and quotations in this section are taken from [Roy 1993].) In Roy's study, the main differences he identified between the designers were when immersion in the problem occurred, and the method of developing ideas.

> *"Dyson moves forward by working with physical prototypes and relatively little drawing, whereas Sanders uses sketching as his main means of problem exploration"*

Sanders' process is characterised by sketching and drawing in the generation and development of ideas. He started with a product specification, and a long period of mental immersion, "thinking about folding bicycles and jotting down ideas as they occurred". In the conceptual design stage he again "...'immersed himself in the problem' by making sketches of as many designs of folding bicycle as he could find in the literature and elsewhere and sketching new ideas as they occurred". In more detailed design stages extensive sketching was again used to "...'clarify and develop the ideas I was having in my head'...". Roy characterises the role of sketching in Sanders' process as "a dialogue with yourself". Dyson's process, in contrast, revealed a strong preference for 'thinking with the hands', and reserving the exploration of what else is 'out there' till the development stage of the process, leaving himself "relatively uninformed at the early concept stage so as not be hampered by prior solutions". For Dyson, solutions to problems come largely when working with materials:

> *"[His] particular approach to invention and creative design depends on getting ideas and solving problems when working with and observing physical objects (what Thring and Laithwaite call 'thinking with the hands') rather than by drawing or theorizing. Dyson says he almost never solves problems by getting 'brainwaves in the bath', on*

the classic psychological model of creativity; for him solutions come when 'welding or hammering something in the workshop'."

Gordon Murray

(Ideas and quotations in this section are taken from [Cross & Clayburn Cross 1996].) Unlike Dyson, for Gordon Murray, designer of the McLaren Formula 1 racing cars, creative leaps really do occur 'in the bath'. Breakthroughs in a design problem occur as sudden illumination, usually after long periods of immersion in the problem:

"... 'I know it's a cliché, but I did have a lot of good ideas in the bath, I really did.'..."

His approach to design is to work very much by "reconsidering the problem situation from first principles" ("fundamental physical principles") and this he considers crucial to innovative design:

"Gordon Murray insists on keeping experience 'at the back of your mind, not at the front' and to work from first principles when designing."

His design process is based heavily on sketching, from the early stages through to more detailed drawings, and the ability which this medium offers to work on many different levels is important to his process.

"Gordon's design process is based on starting with a quick sketch of a whole idea, which is then developed through many different refinements. 'I do a quick sketch of the whole idea, and then if there's one bit that looks good, instead of rubbing other bits out, I'd put that bit to one side; I'd do it again and expand on the good bit, and drop out the bad bit, and keep doing it, doing it; and end up with all these sketches, and eventually you end up throwing 90% of these away.' He also talks to himself – or rather, writes notes to himself on the sketches... Eventually he gets to the stage of more formal orthographic drawings, but still drawing annotated plans, elevations and sections all together."

Cross & Clayburn Cross compare Murray's approach to that of other "highly creative or innovative" designers. In a comparison with Lawson's study of architects, they remark on the importance of drawing as a 'design aid', both in its ability to support working on a number of different levels at once, and also "as a means of thinking 'aloud' or 'talking to themselves', as Gordon put it."

"The common elements in these similar descriptions are the use of drawing not only as a means of externalising cognitive images but also of actively 'thinking by drawing', and of responding, layer after layer and view after view, to the design as it emerges in the drawings."

They observe similarities to Murray's approach of working from first principles:

"There is also a sense of focusing on, or framing a problem, so precisely that it can be approached from 'first principles'; as Santiago Calatrava said: 'It is the answer to a particular problem that makes the work of the engineer... you need a very precise problem."

In a comparison between Murray's approach and that of James Dyson, as reported in Roy's study, they note the strongly contrasting ways in which the designers gain insight into problems:

> *"Roy studies two innovative industrial designers, one of whom, James Dyson, reported that (unlike Gordon Murray) he almost never solved problems by getting 'brainwaves in the bath', but more often when doing some practical work, 'welding or hammering something in the workshop'. However, this practical work may in itself be a way of letting the mind relax."*

Mike Burrows

(Ideas and quotations in this section are taken from [Candy & Edmonds 1994; Candy & Edmonds 1996].) Candy & Edmonds investigated the 'creative cognition' of Mike Burrows through interviews in conjunction with an examination of the 'artefacts' – the different models of bicycle - created during the development process which resulted eventually in the LotusSport carbon fibre monocoque bicycle. (Candy & Edmonds are using the term 'artefact' to refer to a product of the design process, rather than sketches, models etc., although on one level they too are looking at intermediary stages or 'representations' on route to a final product.) By examining (retrospectively) his processes in tandem with the way the designs for each bicycle model develop on the previous one, they draw conclusions about his processes, and the development of these processes through the long period over which the final design was achieved.

Date	Artefacts	Design Process	Knowledge Evolution
1979	First Bikes	Adopt Adapt Improve	Learning Conventions
1980	Funny Bikes	Exploration	Break Rules
1982	Universal Bike	Analysis	Formulate Problem
1985	Monocoque 1	Emergence	Evolve New Concept
1986	Monocoque 2	Analogy	Modify Concept
1988	Inter Bike	Refinement	Add Features
1990	Monocoque 3	Synthesis	Combine Features
1992	Olympic Bike	Completion	Apply Measures

Table 3: "Bicycle History Design Process and Knowledge Development" [Candy & Edmonds 1994]
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Candy & Edmonds' research is concerned with future computer systems to support designers, specifically knowledge support systems. Their studies focused on "...bike designs, design process characteristics and the knowledge evolution that took place" (see Table 3).

> *"Two forms of analysis of the interview data were made. First, the bicycle design history was examined in terms of the way each design represents a progression or extension in the knowledge that the designer used. Secondly, the design process was examined in terms of the various activities that comprised the designer's practice."*

While they are primarily interested in his 'creative cognition' – "ideas generation, problem formulation, strategies, methods and expertise" - Candy & Edmonds remark on distinctive elements in Burrows' approach, relating to the use of sketching and working with physical materials in his work. For Burrows, while sketching was used to capture ideas at the early stages of designing, much of his development work was done 'hands-on' in the workshop (although for later bike designs using carbon fibre, Burrows had to produce detailed drawings for others to manufacture).

> *"The act of designing and making an artefact was necessary to a full understanding of what had been done. Designing 'between my ears' and drawing on paper did not provide sufficient feedback: it was the thinking 'with my hands' that was essential. 'I literally think with my hands. I very seldom draw any sort of dimensions on a piece of paper. I occasionally doodle things to work at them, but I'll basically just pick pieces of metal out of the rack and drill holes in them literally and it will get bolted together...'."*

Candy & Edmonds observed a change in Burrows' design process over the ten year period of developing the bicycle:

> *"...the designer moved from adapting existing models and customising them to suit individual requirements, towards a complete re-formulation of the guiding principle of the design of the bicycle i.e. to maximise the aerodynamics. By the time the monocoque frame emerged, there had been a radical transformation in the designer's process and the knowledge he had acquired and was applying... changes took place towards a more principled and analytical approach to his designing."*

Despite what Candy & Edmonds describe as Burrows' "highly individualized approach", a comparison with Cross & Clayburn Cross' study of Gordon Murray identified similarities in cognitive style.

> *"The agreement in respect of innovation, personal goals, working from first principles and immersion and expertise across related areas of knowledge is notable. It would seem from this that the cognitive issues in the design process are similar even when the scale of complexity of the artefact, as measured in terms of component number, is far greater."*

Summary of case studies

A collective examination of these studies reveals distinct differences in design approach relating to the roles of sketching and drawing or working with materials between different individuals' practice. Differences that were identified relate to: a preference for using sketching and drawing or working with materials to develop design ideas; 'thinking with

the head' or 'thinking with the hands'; and whether creative 'leaps' occur 'in the bath' or when working with materials.

These differences are explained (at this macroscopic level, at least) either as resulting from the complex and innovative nature of the project and the product being developed (e.g. where Dyson's cyclone vacuum required "extensive empirical experimentation"), or accepted as idiosyncrasies of each designer's approach: Candy & Edmonds, for example, comment on Burrows' "highly individualized approach", and describe his process as "very dependent upon personal ways of working" [Candy & Edmonds 1996].

However, none of the studies examine these differences any further. Cross & Clayburn Cross appear to suggest that the differences between Dyson's solving problems when engaging in practical work, and Lawson's 'brainwaves in the bath', simply represent different ways of achieving a state of mental relaxation. Even though these studies acknowledge the importance for some designers of 'thinking with the hands', there seems to be no suggestion that the role of 'making' may be quite different in different designers' practice, or that it is indicative of different underlying ways of knowing:

> *"As well as drawing, innovative designers frequently like to undertake practical work related to the design solution, such as building models or mockups, or participating in construction."* [Cross & Clayburn Cross 1996]

Rather, it seems to be viewed as a practical solution to accessing information which cannot be achieved in other ways. Candy & Edmonds comment that,

> *"Sketching has a limited role in the eyes of [Burrows] because it does not take him into the detail of engineering the object."*
> *"Making design ideas into working products required the necessary methods and, therefore, craft skills play a significant part... Burrows learnt his craft skills because he needed to realize some design ideas that could not be commissioned elsewhere. However, he had no interest in craft for its own sake."* [Candy & Edmonds 1996]

Conclusions

From this review, it can be seen that while there are differences in emphasis on the role of artefacts in design (relating to the contrast, for example in sketching, between symbolic representation and visual thinking; between external representation of ideas, and the external generation of ideas; and between artefacts as an external representation of cognitive activity, and working with artefacts as a means of thinking) artefacts are considered to play an active role in a designer's process. Whether viewed as problem solving or reflective practice, design is viewed as a process of incremental transformation, facilitated through or revealed by engagement with the artefacts a

designer works with in their design process. Moreover, artefacts can be seen to play an *interactive* role, allowing the designer to have a 'dialogue with themselves' about the design situation. However the term 'dialogue' is used to refer to a number of different phenomena: differences relate to the level at which the dialogue takes place, and the degree of deliberate exploration or chance discovery which drives the dialogue.

Research into the role of artefacts in design has focused predominantly on two-dimensional artefacts, including drawings, diagrams and sketching. A smaller number of studies have examined the role of three-dimensional or material artefacts within designers' processes, and even fewer are concerned with differences in the way that 2D and 3D artefacts might support designers' processes.

There are not many studies which deal with differences in the way designers work: of those, the comparisons tend to relate to novice/expert, styles of problem solving or learning/cognitive styles, the relative quality of designers' work, good and bad design strategies, or 'trained' designers and designers from practice. In the realm of this thesis, very few studies have investigated differences between individual designers that relate to their use of artefacts within the design process.

There are a number of possible reasons for these 'gaps' in research. 'Traditional' design research in this area has focused mainly on design-by-drawing, where designers work with representations of reality, and on formal design methods, less on other areas of design which do not fit this model. A lot of studies focus on design as a cognitive activity, and view sketching as a form of symbolic representation of internal cognitive activity. It could be supposed that a designer's work with material artefacts might not be considered in this light, and therefore be of less interest to researchers in this field; however the Tacitus project's review of the role of physical models in the early stages of design, and Brerton's examination of the roles objects play in supporting design thinking, learning and communication, suggest that three-dimensional material artefacts may play similar roles in supporting design cognition.

In terms of differences between designers many studies are broadly concerned with what is to be learnt about "designing as a basic human capacity" [Pedgley 1999], viewing it as a single process to be discovered. Most studies look for consensus, rather than diversity, and the 'microscopic' level at which many of the studies are conducted is less likely to reveal differences in approach, particularly where there are few subjects, and particularly

where there are differences which may be most clearly observed in the wider spectrum of practice.

This review highlights the importance of placing the relationship between design practitioner and artefact at the core of this research, and of using a method of enquiry which enables individual differences to emerge. Comparisons within and between a number of case studies of individual designers revealed quite different personal approaches to design, relating to the roles of sketching and drawing or working with materials between different individuals' practice. These findings strengthen the position of this thesis: that clear differences in approach can be observed between individual designers, which are worthy of further investigation.

The next chapter, ***Difference as a means of enquiry***, describes the method and instruments chosen to investigate these differences, and explains the rationale behind using difference itself as the primary means of investigation.

4. Difference as a means of enquiry

This chapter explains that diversity in design practice is not only the focus of this research, but why and how it has also been used as the primary means of investigation. The details of each study are described in the relevant chapter (see ***Annotated list of chapters***), but the general principles of enquiry and how they were implemented in each study are discussed here.

Examining diversity in design practice

As discussed in Chapter 3, ***Artefacts and the design process***, 'traditional' design research has focused mainly on design-by-drawing and formal research methods, less on other areas of design which do not fit this model. In assuming that there is a single design method to be discovered, much of this research has been blind to individual differences in design practice. Previous researchers examining aspects of this relationship between designer and artefact have tended to focus on very specific aspects of practice, frequently using an experimental approach in an artificially constrained situation. Some of these studies have examined very few subjects. In many cases this reflects the fine level of detail at which the design processes were being studied, but in the context of this thesis, it lessens the likelihood that any differences between designers will become apparent. At the other end of the scale, some studies focus on an in-depth study of an individual designer.

These approaches have a number of drawbacks when exploring diversity in design practice. In an experimental situation, if you are not looking for diversity, it will not be built into the 'model', therefore it is unlikely you will find it, other than as an apparent anomaly in the data. Also, the very specific focus of many experimental studies will not pick up differences which may be most clearly observed in the wider spectrum of practice. In-depth studies of an individual designer's processes will give a very rich picture of practice, but lack the means of comparison with other designers required to elicit the dimensions of variation. (A broad comparison between such studies did reveal different personal approaches to design, relating to the roles of sketching and drawing or working with materials between different individuals' practice, but no further investigation had been made, as discussed in the previous chapter.) These factors have

prevented much existing research from observing the natural diversity in practice, and the dimensions of its variation.

One of the challenges in starting to explore this area was that there seemed to be a number of possible factors involved in this diversity, which appeared to be interdependent and difficult to isolate, and which were at different 'levels' of process. One approach to examining this diversity would be similar to the experimental studies above: constrain the context to look at each of those factors, while eliminating the influence of the others. To do this it would be necessary to predetermine what you were going to look at, but in this situation it was not clear at the beginning what factors to constrain, and what the interdependencies might be. Also, to get a clear picture of differences in approaches using this method, it would be necessary to carry out a number of different studies with the same subjects, and find ways of linking these studies.

The alternative selected for this research was to choose a method which allows the situation to be examined as a whole, and somehow 'discriminate' between the possibly interdependent factors, but further than that, enables an investigation into what some of the interdependencies might be. This method is based on a number of key principles, which are described below, but broadly uses a comparison of the differences between individual instances as a means of developing a descriptive model of an underlying phenomenon: firstly, by identifying what differences there are (or appear to be) between individuals; and secondly, by examining the relationships between these differences, to discover|propose|test an underlying model of the phenomenon.

Principles

Three related principles underpin the means of investigation used in this thesis: the comparative framework; the comparison of the individual against the collective (*difference*); and the added insight from comparing phenomena which are similar-but-different (*distance*).

Comparative framework

One way of addressing the problems identified above is to establish a comparative framework by which to describe and within which to examine this diversity in design practice. The benefit of using such a framework in this type of research is that it adds rigour to comparisons made between individual items (whether personal approaches or physical objects) by providing a context and structure within which to make the

comparison. To create such a structure, it is necessary to identify both what differences there are (or appear to be) between individuals, and what the relationships are between these differences.

The characteristics of such a framework are that it should provide a means of placing different factors in relationship to one another (and testing this relationship i.e. recognising that the original format of the framework might need to change, as the relationship between the factors may not be immediately clear). This then provides a way of examining differences between people, by using the same framework to compare and contrast individual approaches, through placing them in relation to one another.

Once established, such a framework has a number of benefits: rather than dealing with differences in design practice by constraining factors, it aims to actively use them as a means of investigation; it is one approach to dealing with a situation where there appear to be many interdependent factors; and finally, it enables a collective picture to be built, against which an individual's practice can be viewed. Building up a collective picture of the variety of ways in which designers perceive and relate to the artefacts they use, affords insight into what individuals do not do, as well as what they do. This last point is particularly important. In The Act of Writing, Chandler notes:

> *"In studying the nature of mediation, a powerful technique is the search for that which is* excluded *(or 'conspicuous by its absence'), and that which is taken for granted (which goes without saying)"* [Chandler 1995]

For this research, a variety of frameworks have been used. They differ in a number of respects: how they were created; the level of detail at which they apply; and what they were being used to compare.

A framework may be predefined and then used to examine the data, or it may be derived through an exploration of the data itself. In this thesis both approaches are used (and are discussed in more detail below for each individual study). In one case, the results emerging from one study were used as the basis of an analytical framework for another.

In some cases, the comparative frameworks used have been relatively broad: at the level of theoretical models of the creative process and disciplines, for example, in Chapter 6, ***Concepts of dialogue in design***. In other cases, they have been more detailed, such as the model of dialogue derived from a selection of these theoretical models, which has over thirty individual elements of comparison (see Chapter 7, ***Comparative study***). This latter framework could also be described as very 'tight': it was derived from a number of theoretical models, and closely specifies the structure of the framework i.e. how the

different 'differences' relate. In contrast, the frameworks derived in some other studies were quite loose, particularly where the study was of an exploratory nature.

Finally, the comparative frameworks have been used to examine a number of different phenomena: models of the creative process from different disciplines or theoretical viewpoints; physical artefacts; and people's creative processes and their relationship with the media they work with (through interview data).

Comparison of individual against collective variation (*difference*)

The primary method chosen for this research is to examine an individual against the collective variation that can be observed within a group. This involves exploring, through comparison between all the individuals in a group, the 'dimensions of difference' within that group to determine the collective variation against which an individual can be viewed. (The term 'dimensions of difference' refers to distinct observable differences in various aspects of practice.) The studies described here include a range of individual v. collective comparisons: between artefacts; between theoretical positions; and between practitioners, through interview accounts of their own practice.

In the context of this research, this approach has a number of benefits: as the 'dimensions of difference' emerge from the data, it provides a route in to exploring a situation where there may be little previous knowledge; it can identify dimensions along which individuals may differ, particularly in regard to aspects which may not have been expected; and most importantly it can identify aspects of interest which may not be apparent from looking at one individual's practice.

This approach also has a number of drawbacks. The comparisons are not against absolute criteria, but within the domain of enquiry (e.g. an individual's approach in different contexts, the current set of students, all the artefacts in the collection). As the collective variation is derived from the data, it will only reveal the variation that is present within that specific group (although it may be possible to infer additional information from apparent 'gaps' in the resulting framework). There is frequently a large amount of data within which to start investigating, although it can be viewed at whatever level is considered appropriate. Perhaps the most significant drawback is that knowing the collective variation within the group is only the first stage of understanding the phenomenon under investigation, although it is fundamental to the next. Understanding the relationships between the different dimensions of variation is what will reveal the underlying causes or reasons for these differences.

In this research, these drawbacks have been mitigated to an extent by the different studies which comprise the research. In the Comparative Study, for example, the conceptual framework derived from a comparative review of the different theoretical positions discussed in Chapter 6 provides: an external reference against which to compare the findings from the groups under investigation; an initial point from which to start investigating the 'dimensions of difference' between individual practitioners; and an initial proposition to explain the relationships between the differences that can be observed between individuals.

The comparisons can also be made more robust by comparing frameworks, such as the comparison between the two different groups participating in the Comparative Study (see Chapter 7). This type of examination leads on to the third principle on which this research is based: that you can gain insight by comparing differences between phenomena which are similar in some respects, yet different in others.

Added insight from comparing similar-but-different (*distance*)

In The Act of Writing, Chandler states:

> *"To become aware of the ways in which we engage with a medium we need to* distance *ourselves from it: to look with other eyes, to feel with other hands and so on; making the medium more visible or tangible."* [Chandler 1995]

This idea of distancing is particularly important for those aspects of engagement of which people may not normally be explicitly aware. An element of distancing arises through contrasting individual approaches against the collective background by beginning to reveal, in Chandler's words, "that which is *excluded* (or 'conspicuous by its absence'), and that which is taken for granted (which goes without saying)". However, for this research it was desirable to find a way whereby these things could be deliberately brought into the foreground without reverting to the idea of artificial, experimental studies.

The studies in this research incorporate a number of such elements of 'distancing', as discussed below. However, the main way in which it is designed into this research is through a comparison of design and making practices in the material environment with those in the 3D digital environment. While they share the three-dimensional context, contrasts between the two environments make them suitable for the comparative role in this research.

Characteristics conventionally attributed to the digital medium (or at least those attributes which may be most immediately apparent) are immateriality; intangibility; the need to

work to a large extent with abstract, formal representations; working at a distance from the 'real' world; and freedom from material constraints. For example, digital media such as 3D computer modelling and animation software require, at least on first examination, users to be very explicit when creating objects, working with geometric representations and operations. Material practice, on the other hand, is frequently regarded as 'hands on'; rooted in physical materials; with a concrete and intuitive approach marked by a close relationship with the materials.

My interest in examining the relationship between designer and artefact more closely is to dissociate some of the ways in which design practitioners work from the physical artefacts that they use, and to gain insight into ways of working and knowing that are not embodied in the material context of the real world, that could be used to inform new digital environments for design. This research focuses on the approach, less on the *specific* physical nature of the context within which this is practised (although the significance of *a* context is recognised). Contexts which are similar enough in terms of their three-dimensional nature, yet different in terms of their physicality, are therefore of particular interest, as a means of 'factoring out' some of the elements related to the specific material context. (This position is discussed and critiqued in greater detail in Chapter 8, ***Practitioner interviews***.)

Additionally, in many respects the indeterminate nature of the digital medium - its ability to be many things to many people - makes it an ideal environment for delving deeper into the nature of this relationship, by looking at the ways in which people choose to use it. Also, because it typically is viewed as being less immediately intuitive to use, this can bring to the foreground aspects of practice which might otherwise remain unseen.

In order for these comparisons between material and digital environments to be valid and useful (particularly between similar approaches in different groups, as in the Comparative Study), it has to be demonstrated that the basis of comparison between the two environments is sound. Chapter 8, ***Practitioner interviews***, demonstrates that, at least for the participants in that study, each practitioner's overall approach is consistent across media, therefore the basis of comparing approaches between physical and digital material appears to be sound.

A phenomenographic approach?

This method has similarities to the phenomenographic approach described by Marton & Booth in their book, Learning and Awareness (all quotations in this section come from [Marton & Booth 1997]):

> *"The unit of phenomenographic research is* a way of experiencing something... *and the object of the research is the* variation *in ways of experiencing phenomena. At the root of phenomenography lies an interest in describing the phenomena in the world as others see them, and in revealing the variation therein..."*

In the general context of this thesis, the 'unit of research' is the relationship between designer and artefact, and the object of research is to explore the variations in this relationship, as a means of highlighting individual differences:

> *"...phenomenography focuses on variation. The objective of a study is to reveal the variation, captured in qualitatively different categories, of ways of experiencing the phenomenon in question, regardless of whether the differences are between individuals or within individuals..."*

Marton & Booth's area of research is learning. In that context, the different ways of experiencing phenomena are related to one another in a hierarchical manner, and of interest is the way in which individuals move from one to another: "differences between them are educationally critical differences, and changes between them we consider to be the most important kind of learning". However, my research shares the stance of Turkle & Papert and Chandler (commentators discussed in Chapter 6) that the variety of ways in which designers relate to their artefacts are of equal importance, and have to do with underlying differences in orientation *between* individuals.

Marton & Booth describe two elements of variation: the dimensions of variation (all the different ways of experiencing the phenomenon, within the collective data), and the structure of variation (the logical relationship between these different ways of experiencing):

> *"The observation was that when people read a text or listen to a presentation or try to solve a problem or reflect upon a phenomenon, that which they encounter appears to them in a limited number of qualitatively different ways. The different ways in which they experience the text, the presentation, the problem or the phenomenon are observed to be logically related to each other and to form together a complex that we have called the outcome space."*

In part of this research (see Chapter 7, ***Comparative study***), I chose to use a comparative framework as a means of examining diversity in design practice, which in effect represented a preliminary model for both the dimensions and structure of variation within

the data. Although this may be a more structured initial aspect to the study than is normal in phenomenographic studies, nevertheless it still shares elements of the approach:

> *"The researcher has a responsibility to contemplate the phenomenon, to discern its structure against the backgrounds of the situations in which it might be experienced, to distinguish its salient features, to look at it with others' eyes, and still be open to further developments. There are various ways of going about this. One way is by considering the phenomenon's treatment in other research traditions: how it appears in literature, in treatises and in textbooks or how it has been handled in the past or in different cultures"*

Marton & Booth's phenomenographic approach emphasises the importance of the figure/ground distinction - the need to view the individual against the collective picture from the group – and the particular strength of this approach:

> *"In phenomenography individuals are seen as the bearers of different ways of experiencing a phenomenon, and as the bearers of fragments of different ways of experiencing that phenomenon. The description we reach is a description of variation, a description on the collective level..."*
>
> *"In accordance with what we said earlier about not only categories of description but even their fragments being distributed across individuals, the data at the collective level are particularly robust compared with the data relating to individuals. Even if it is difficult or impossible to draw from the data, or even from the phenomenographic enterprise, the ways in which individual subjects experience a phenomenon, the ways in which idealized individuals do so can be abstracted owing to the overlap of the material seen at the collective level."*

Implementation

The next part of this chapter describes the variety of ways in which these principles have been implemented in the four main studies of the thesis. The particulars of the methods used in each study will be described in the relevant chapter, but the general principles and how they were implemented in each case are included here.

Artefact study

Chapter 5 describes an exploratory study which focused on preferences students might have for using different 'types' of artefact for generating design ideas, e.g. drawing as opposed to materials, two-dimensional as opposed to three-dimensional. This emphasis on 'dimensionality' is reflected in the design of the study, in which the participants were asked, through a series of short exercises, to use words, markmaking and materials to respond to a selection of words, markmaking outcomes and objects, then to generate design ideas. In this way, a variety of combinations of 'one'-, two- and three-dimensional artefacts could be explored. In total, nearly 200 individual 'artefacts' were produced during the study. These, together with audio recordings of short seminars held

with each sub-group of students, photographs of the students working, and notes taken during the study, formed the raw data for analysis.

In this exploratory study an examination of these artefacts (in conjunction with the students' verbal accounts, supported by the other data) to identify differences was made at a number of levels: within each individual's work (e.g. a preference for using words rather than markmaking); between individuals (e.g. different ways of using a particular type of media within the whole group of students); and within all the artefacts produced (i.e. looking at them as one giant collection without regard to media type or individual).

A loose framework for comparison emerged from this investigation which allowed a broad assessment of variation within the group at a number of different levels, but provided limited information on the relationships between these differences within each individual's practice, i.e. the structure of this variation.

Theoretical review

Chapter 6 describes a comparative review of commentators from a range of disciplines who propose alternative models of the creative process and the relationship between practitioners and artefacts, or alternative explanations of differences between individuals. The commentators can be distinguished by the nature and extent of dialogue they attribute to the relationship between practitioner and artefacts, reflected in the choice of metaphor they use, and whether such dialogue is used to characterise the overall design process, or is a degree of individual difference in approach between practitioners.

This review therefore links both the underlying models and different disciplines to form a robust comparative framework: a rigorous framework to provide strong basis for comparison between disciplines, and to understand how models from other fields might apply in design; and a complete framework which can also accommodate the broader range of studies included in the literature review.

This diversity of commentary adds to the strength of this approach in two ways: firstly, the similarities and differences between their descriptions of these differences in approach allows one to illuminate another, adding clarification, or highlighting aspects which may not be immediately obvious; secondly, it contributes to the genericity (broad applicability) and completeness (the breadth of elements of practice covered) of the model. This study also incorporates the element of 'distance', in the sense that if similar

'different' approaches appear in quite different fields, then comparing elements of these approaches across these fields will provide clarification and additional insight.

Comparative study

Chapter 7 describes a comparative study between two groups of student 3D design practitioners, one working with digital media, the other working with physical media. This study had two main aims: to establish whether differences relating to the nature and extent of a dialogue between design practitioner and media could be observed within each group; and to establish whether similar differences could be observed within both groups. If similar differences in approach were observed within these two groups of 3D practitioners, a comparison of how each type of approach manifests itself in the material and digital environments could provide additional insight into elements of this relationship, arising from the similarities and differences between these two environments. Interviews were chosen as the most appropriate method of data collection for this study, as the aspects of practice with which I am concerned involve people's experiences, opinions, and emotions, as well as accounts of their own process.

Two different stages and contrasting modes of analysis were used in this study. First, a comparative framework was derived from a systematic analysis of the literature discussed in Chapter 6, which suggested the formal/concrete axis as an organising principle for differences in approach across disciplines and across a number of levels of practice. This framework comprised a set of around thirty 'indicators' representing those aspects of a practitioner's process that can be examined to determine the nature and extent of the dialogue they experience with the media. In a preliminary analysis, each individual's approach was categorised using this comparative framework, and an assessment made of the distribution of the approaches within each group.

The second stage of the study involved both an examination of the collective variation within each group across a number of 'dimensions of difference' which emerged from the data, and a comparison of these emergent dimensions between groups. The process of identifying these emergent dimensions partly referred back to the framework used in the preliminary analysis, but did not assume that the relationships between these dimensions would follow the inherently 'two-dimensional' structure of this original model. It also allowed for the possibility that other 'dimensions' might emerge. The comparison between the emergent dimensions from each group contributes the element of 'distance',

clarifying aspects of individuals' approach and affording insights which arise from the differences between the physical and digital environments.

An additional element of distancing in this study comes from those working in the digital medium who have previously worked with physical media, through their own experiences of the similarities and differences in their practice. These might include, for example, those aspects which they had previously 'taken for granted', in Chandler's terms, and which now have been foregrounded for the practitioner through their relationship with this different medium.

Practitioner interviews

Chapter 8 describes an interview study of three 3D practitioners who have an established material practice, and a substantial body of work in digital practice, to examine how their experience, perceptions, skills and working processes transferred from the material to the digital environment. An important aim of the study was to determine whether, in support of the principle of 'distancing' described earlier in this chapter, a practitioner's approach is consistent across media, and what insight into their approach can be gained from the differences in their processes between physical and digital media. These interviews also provide a useful insight into issues that are important, but which might not be immediately obvious in the two 'single' environment elements of the comparative study between digital and material practice described in Chapter 7.

This study uses a comparison between each practitioners' material and digital practice to gain insight into key elements of their relationships with the medium they use and the artefacts they create. (These might have explicitly come to the practitioners' attention through their move from material to digital practice, or be things that they may not be aware of, but which can be inferred from their accounts of practice or revealed by the types of comparison made during this study.) In particular, I was interested in how they view the digital medium, how they engage with it, and how their material practice relates to their digital practice. I was also keen to identify insights they had obtained into their own practice in moving from material to digital, and the differences they highlight between the two working environments. There are a number of levels at which this 'foregrounding' or 'distancing' between media may take place, giving insight into the practitioner's general practice, approach, and relationship with the medium, or the concerns, content or theme of their work.

A two-stage analysis was made of the interview data, in both cases examining themes that emerged from the data, but within the broad theoretical framework discussed in Chapter 7. Firstly, a comparison was made between each individual's digital practice and their material practice, to characterise their approach in each. Secondly, a comparison was made between practitioners, focusing on aspects of their digital practice including: their view of the digital as a medium; their overall approach to the medium; and the role of the medium in their practice.

While the primary focus of this study was the 'distancing' that could be achieved through the comparison of material and digital practice, this second part of the research did contribute aspects of 'difference', through the differences that could be observed between practitioners in terms of their relationship with the medium, and its role in their practice.

Summary

This chapter has described how, through a number of principles described above, diversity in design practice has been used as the means of enquiry as well as the focus for this research.

The following chapters describe the studies outlined here in more detail, and illustrate how this approach has allowed the research to move from an initial position of exploration and uncertainty to its thesis:

> *that individual practitioners experience different relationships with the artefacts they create and work with in their processes, and that elements of these differences can be attributed to the nature and extent of a dialogue between designer and media.*

5. Artefact study

In Chapter 1, ***Introduction***, I described how the starting point for this research was a previous investigation I had made of the working processes of designer-makers to better understand the role of materials within their processes, as a possible paradigm for future computer systems for creative practice. At that time I was looking for characteristics of 'the' designer-maker approach to creative practice: an approach typified by a close relationship with materials. However, my interviews with a range of designer-makers revealed a spectrum of approaches, ranging from design-then-make, to design-through-make, to make-as-design. While some practitioners developed their ideas using sketching, others chose to work with materials (either to design, or making with the medium), or used a combination of both. This suggested that the role of materials in different practitioners' processes might not be the same, and require further investigation. Chapter 3, ***Artefacts and the design process***, describes how very few studies have examined differences in the ways that 2D and 3D artefacts might support designers' processes, or differences between individual designers that relate to their use of artefacts within the design process. An empirical approach was therefore adopted to investigate these differences further.

This chapter describes an exploratory study of a group of 3rd Year undergraduate students on the Silversmithing & Jewellery degree course at Glasgow School of Art (GSA). The study had two main objectives: to ascertain, broadly, whether clear differences could be distinguished between students' approaches to and preferences for using 2D or 3D artefacts to generate design ideas; and to identify any other significant observations relating to individual differences which could inform the design of future, more focused, studies.

Design of study

This study was conducted as one element of a Technical Roundabout in which third year Silversmithing & Jewellery students are introduced to new techniques such as working with the lathe, enamelling, colouring and printing on aluminium, and working with

plastics. It was presented in the form of a one-day workshop – an 'Artefact Mini-roundabout' – in which students were encouraged to explore ways of working with a variety of media, then to use these media to generate design ideas. A research proposal was produced for the course leader, outlining the context of the research, the research objectives, the learning objectives (as the study was being carried out as part of the students' coursework), data collection techniques that would be used, an explanation of consent procedures, and the format of the study (see Appendix C). Normal procedures were used to obtain consent from the participants.

This study focused on preferences students might have for using different 'types' of artefact for generating design ideas, e.g. drawing as opposed to materials, two-dimensional as opposed to three-dimensional. This emphasis on 'dimensionality' is reflected in the design of the study, in which the participants were asked, through a series of short exercises, to use Words, Markmaking and Materials to respond to a selection of words, markmaking outcomes and objects, then to generate design ideas. (The term 'markmaking' is used to describe the practice of using a variety of techniques to produce marks on a page. It is used in a less restrictive sense than people may associate with the term 'drawing'.) Although the original comparative emphasis was on 2D/3D, the use of 'one'-dimensional media (Words) was included for completeness, resulting in a spectrum of 'materiality'. In this way, a variety of combinations of one-, two- and three-dimensional artefacts could be explored.

Figure 30: A workshop in progress within the studio

Four workshops were held over a four week period, each with a small group of students (thirteen students participated in total). All four workshops were held in the students' normal studio (Figure 30). Before the workshop, each student was given a handout which introduced the workshop and its aims, described the format it would take, and gave a timetable for the day (Appendix D).

Workshop plan

Each workshop started with a general introduction discussing the role of artefacts in design, and the aim of the day. This was followed by three sections focusing on a different media type (Words, Markmaking and Materials), each of which consisted of a short introduction and a set of exercises. A group seminar completed the day. A plan of the workshop, giving details of the introductions, each exercise and the times allotted, is given in Appendix E.

Exercises

The exercises in each 'media' section were of two types, reflecting both reflective/appreciative and constructive aspects of designing. The first group of exercises asked students to respond, using the media type, to a selection of artefacts. The final exercise in each section asked students to use the media to generate design ideas in response to a brief. This brief was deliberately left non-specific: the aim was to give a focus for the students to work towards, without overly constraining their response. The Markmaking and Materials sections also included an exploratory exercise where students could try out a variety of techniques: this allowed students to gain some degree of familiarity in working with what might be unfamiliar media or in unfamiliar ways. A full listing of the exercises is given in Table 4; Appendix F lists these along with the times taken in each workshop.

The term 'respond to', when asking students to do the exercises, was chosen very deliberately to avoid as much as possible the idea that they were being asked, for example, to draw an object in the traditional sense, or describe an object in the Words exercises. I wanted to prescribe as little as possible the ways in students felt they could respond to the object, within the given media confines of the exercise. Similarly, the categories were defined as Words, Markmaking and Materials to allow as broad an interpretation as possible. In Markmaking, for example, this was partly to dissociate the

Words Please respond using words to: • an object that interests you • an experience - eating a cake/cakes or fruit • a person or animal that is significant to you • a piece of text from the sheets provided Using only words, generate design ideas for an object to be worn to celebrate a special personality (i.e. human, animal), place or event in your life. (You can use words both to generate ideas, and to represent the actual piece)
Mark Making Explore a variety of techniques to make marks Please respond using marks to: • an object - suggest using a number of different techniques • an object that you can touch, but not see • a piece of text / words from earlier workout Using only marks, generate design ideas for an object to be worn [if you like, to celebrate a special personality (i.e. human, animal), place or event in your life]. (You can use marks both to generate ideas, and to represent the actual piece)
Materials Exploring a variety of techniques and types of material, make some objects that appeal to you Please respond using materials to: • an object • a piece of text / words from earlier workout • one of your mark-making outcomes Using only materials, generate design ideas for an object to be worn [if you like, to celebrate a special personality (i.e. human, animal), place or event in your life]. (You can use materials both to generate ideas, and to represent the actual piece)

Table 4: List of exercises

two-dimensional aspect from the representational and/or depictional aspects often associated with drawing.

The result of having a number of combinations of dimensions e.g. words responding to an object, or the experience of eating a cake; or marks responding to words, or an object that couldn't be seen, is that normal ways of working with media, or the normal context of working with media, is disrupted while retaining elements of the underlying relationships with media. This allowed the students (and me) to become more aware of ways in which they related to different types of media while creating and working with artefacts. (In retrospect, this has resonances with the technique of *distancing* that Chandler describes in The Act of Writing [Chandler 1995], as a way of examining mediation in working with media: see Chapters 4 and 6). It also provides several different 'ways in' to seeing how a student approaches and uses the media, on the principle that looking at something from a variety of angles is an appropriate alternative to repeated observations from the same angle.

Figure 31: A selection of the materials, tools and source objects available during the workshops

A variety of source objects, including excerpts from texts, were provided for the students to use, along with a range of different tools, inks, paints, paper, card and a whole mixture of other materials including fabrics, plastics and an assortment of recycled materials. The pictures in Figure 31, taken during the workshops, illustrate the range of items provided (a copy of the texts is given in Appendix G). In some cases the students augmented these with implements and materials that they had available in the studio.

Seminar

The structure of the group seminar was similar to critiques at the end of projects, where students meet as a group with their tutor to review the project work. However, the seminar did not focus on a critical evaluation of each student's work, but was rather an opportunity for students to describe the approach they had taken (and why), along with any observations of their own on aspects of the work they had found difficult, surprising, familiar, unfamiliar, and so on. It also let them see, compare and discuss the range of approaches that had been taken.

In terms of the design of the study, the group seminar provided the only opportunity to gather comments directly from students on their preferences, opinions, reasons for acting in particular ways, difficulties and surprises, etc. These generally emerged from the

discussion, although some prompts were given. It could be argued that a more rigorous approach, where greater care was taken to ensure that identical data was collected for each student, would have been more appropriate. However, the exploratory nature of this study was not designed to accommodate such a prescribed approach. It was not clear before the study what parameters would have been most appropriate, and the preference was to focus on aspects of working which had been most noticeable to the student, considering that any such aspects highlighted by the student (or indeed not highlighted) would be those that were most significant.

Although the emphasis of the design is clearly exploratory, and may at first appear to be extremely open in the sense that the students were given a large range of source objects to choose from, in an overall respect it is highly structured. The combination of exercises given to the students allows a variety of comparisons along the dimensions of 'dimensionality' to be made within the data.

Implications of the educational context

As this study was being carried out in an educational context, the introductions to the workshop and each media section included examples of ways in which the various types of media might be used. Also, the students were encouraged to explore a variety of techniques and ways of working other than they might normally use or be familiar with. It could be argued that this prejudiced the ways in which students approached using the different media, and influenced them to work in ways not natural for them: one of the aims of the study was to see if students had preferences for particular ways of working, and this might therefore distort the results. I believe that this concern, while to some extent legitimate may, for the following reasons, be of less significance than might be supposed.

Some students did say that they had tried things because they had been suggested. However, quite different approaches were taken by students even within the same workshop, who were given exactly the same introduction. This implies to a certain extent that even if students did try techniques because they were suggested - and certainly if they kept using these techniques - that they had aspects that appealed to the student's underlying approach.

The very nature of the workshop (and part of its educational objectives) meant that students were quite deliberately liable to find themselves working in ways outwith their

normal experience (this could be the case even if the 'dimensions' were the same), as a means of examining their underlying approach. Further, it became clear during the study that the ways in which the students used media in the context of the workshop did not necessarily relate to ways in which they would use them in design, in any case.

Implementation

The first workshop acted as a pilot for the following three and a number of changes, mostly administrative, were made for subsequent workshops. Most importantly, a written plan was created listing key points for the introductions to the workshop and the sections, possible 'prompts' for students during the exercises, and the intended timings of each exercise, to ensure as much as possible a consistent approach for each workshop. Other changes included altering the layout of the printed materials (the consent form, the introductory handout, and the text handout for the workshop) after consultation with GSA's dyslexia co-ordinator, to try and minimize any disadvantage to students who might be dyslexic, particularly within the Words section. These changes are not likely to have materially affected the outcomes of the workshop.

Two changes to the content of the workshop were made (one unintentionally, one deliberately) which may have had a more significant impact. In the first workshop, the full range of materials was not available during the Words section, as it was for subsequent workshops. As a wider range of materials was used in this section by students in subsequent workshops than I had anticipated, this could have affected the first group's response to this section. However, although some students in later workshops made use of this wide range of materials, others did not, so the impact cannot be accurately assessed. Secondly, an additional exercise was added to the Markmaking section of the workshop: the 'feely bag' exercise, where students were asked to respond to an object they could touch, but not see. The only impact this had is that the data for this exercise is not available for three of the students, which has to be taken into account during analysis.

Data collection

In total, the students produced nearly 200 artefacts during the study, which were photographed for permanent record. These, together with audio recordings of the

seminars held with each group of students, photographs of the students working, and notes made by myself during the study of actions or comments of particular interest made by the students, formed the raw data for analysis.

Finding a suitable means of storing, cataloguing and analysing this large quantity of chiefly visual data (around 750 images, comprising photographs of the artefacts, and photographs taken during the workshop), but also text presented a number of practical challenges. StorySpace (software designed for developing hypertexts, which can hold images and text within its data structures and create dynamic links between them) was chosen as an appropriate means to catalogue and support the analysis of the visual and textual data from this study [Eastgate Systems Inc.]. Linked coding structures could be built up in a similar way to standard qualitative analysis packages available at that time, but with more flexibility, including the ability to examine any selection of artefacts at one time. A screen shot illustrating the StorySpace software with excerpts of the analysis structure is shown in Figure 32.

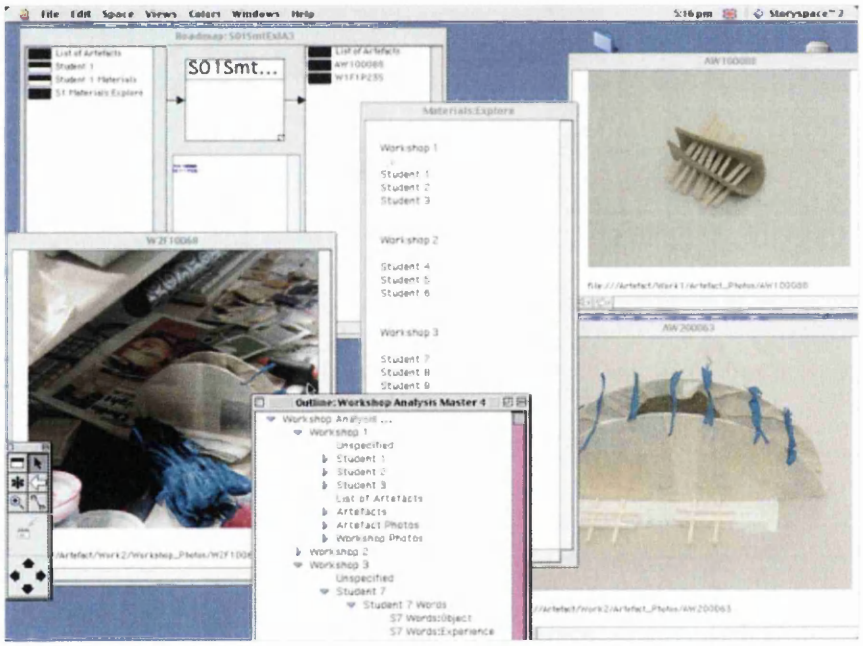

Figure 32: Screen shot showing the data structures in StorySpace

Analysis

In line with the overall method, this study was designed to use the examination of differences between students and artefacts as the primary means of analysis. There are a

number of reasons why this approach is appropriate. In a study of this type, the majority of the data is not information-based; it is visual and material, where the qualities under investigation are neither explicit nor absolute. This makes it difficult to evaluate an object in isolation: comparison across a group provides a method of examining and evaluating individual practice/outcomes against the collective background of the group. (Whilst this does not allow 'absolute' claims to be made of the data, it does allow for a comparison between the members of the group, which is the aim of this study.) This collective view makes it easier to see what people have *not* done, as well as what they have done, giving additional information about their approach. Finally, the exploratory nature of this study meant that the results were not anticipated in advance, making evaluation against pre-arranged criteria less useful.

Initial analysis of the data comprised an examination of the transcriptions of the group seminars and an examination of the artefacts produced by the students, by exercise, for each media section: Words, Markmaking, and Materials.

The transcriptions were examined to see what students had said about: preferences for one way of working over another; particular benefits or drawbacks they had noticed in working with each media type; within each section, any differences in the methods they had used, due to taking a different approach, or because they had experienced difficulties; how familiar they were with the media types, and if they used them in their design processes; information to complement and support the analysis of the artefacts themselves (for example where students explained why they had used a particular technique, or acted in a particular way); and any unexpected points that the students made.

In the analysis of the artefacts themselves, I was looking for: ways in which they differed, either in an aspect of the artefacts themselves, or in differences in approach that could be deduced from the artefacts; consistency, or especially distinctive differences, between artefacts produced by a student within a section; and cases where students had responded to the same source – text or object – which could give additional insight into any differences, particularly in the Markmaking and Material sections where differences may be less obvious to spot.

The examination of the artefacts (in conjunction with the students' verbal accounts, supported by the other data) to identify differences was made at a number of levels: within each individual's work (e.g. a preference for using words rather than

markmaking); between individuals (e.g. different ways of using a particular type of media within the whole group of students); and within all the artefacts produced (i.e. looking at them as one giant collection without regard to media type or individual).

Different dimensions

These inspections of the textual and visual data resulted in a series of categories for each section (Words, Markmaking and Materials) in which differences were observed. A full listing is given in Appendix H, but the most notable will be described below, with examples. It should be re-emphasised that the differences identified in these categories are collective: they emerged from the examination of all the artefacts in each exercise. Individual artefacts may include more than one of the features identified. The important thing is that the categories provide a collective comparative structure, derived from an examination of the artefacts themselves, against which individual artefacts and practice can be examined.

Words

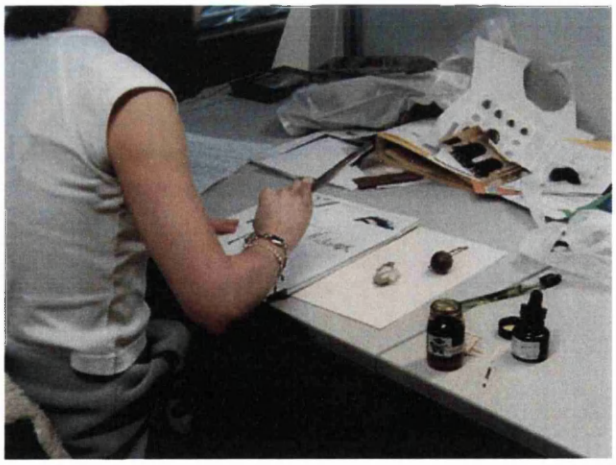

Figure 33: A student using Words to respond to an object

The differences between artefacts in the Words section were particularly striking. This may be for a number of reasons: of all three media types, this was the one most likely to be unfamiliar to students in the design context (a number of students said they 'weren't words people'); as one student commented, "you're very explicit with words", therefore some types of evidence of different approaches are more easily recognised in this than in

other media; and when the focus is on words/language, any significance placed on other media becomes particularly obvious.

Differences in the Words section can be observed on a number of different levels. The first of these is the extent to which the physical qualities of the words are significant, for example their look or sound: in effect, the word as an object. This can be observed where people have used the style of writing to convey some aspect of the object being responded to, for example (see Figure 34).

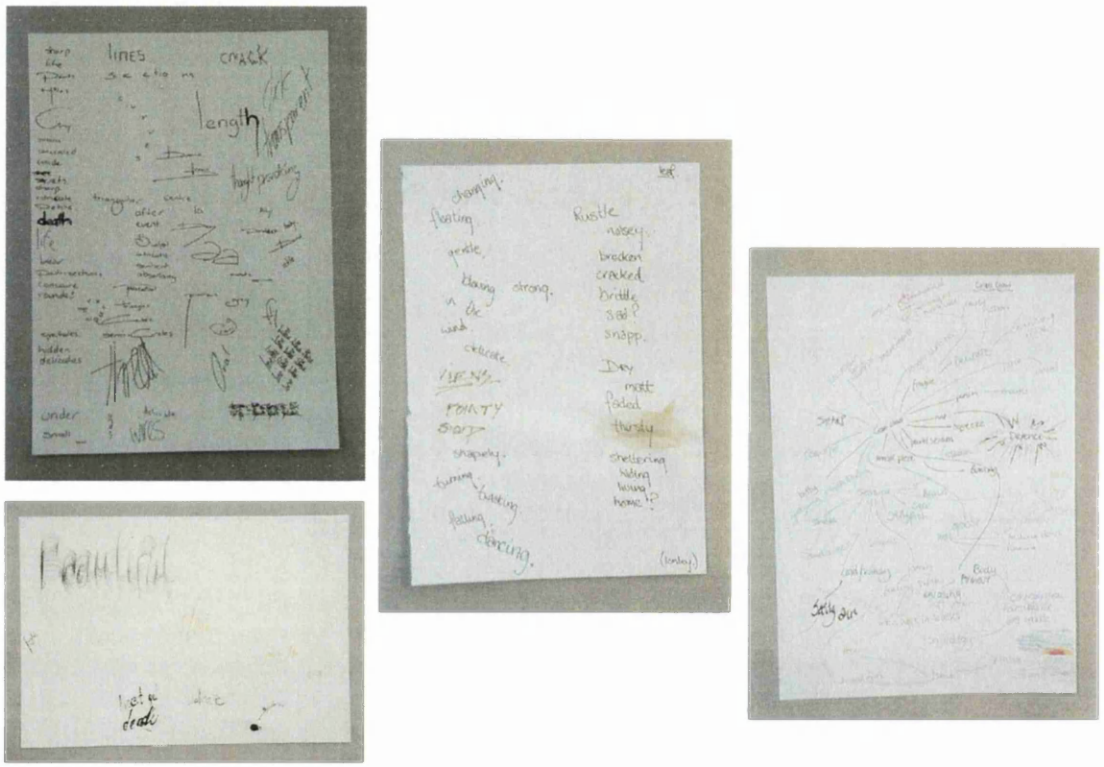

Figure 34: Examples illustrating the physical aspects of words

A second difference relates to the 'content' of the words – what they are being used for (signified as opposed to signifier). I have identified three major categories: descriptive, where the student is primarily describing qualities or aspects relating to the source itself; responsive, where the student is primarily concerned with their feelings or personal response to the source; and generative, where the student is using words to generate new ideas (found primarily, but not exclusively, in the design exercise). Examples can be observed in the exercise where the students were asked to respond to a person. Two students chose their Mum: one student's artefact emphasized descriptions of her Mum and her qualities, and what she was like; the other student's piece emphasized her feelings about her Mum, and about her relationship with her Mum. Similar contrasts can

be observed in responses to poems: one student seemed to approach the poem 'literally' and dissect it, examining each phrase as she went along; other students responded to the poems they had chosen with how it made them feel. (See Figure 35). This contrast between objective and subjective approaches to the source continues through each of the media types, and suggests that this may be an important element of the relationship between designer and artefact.

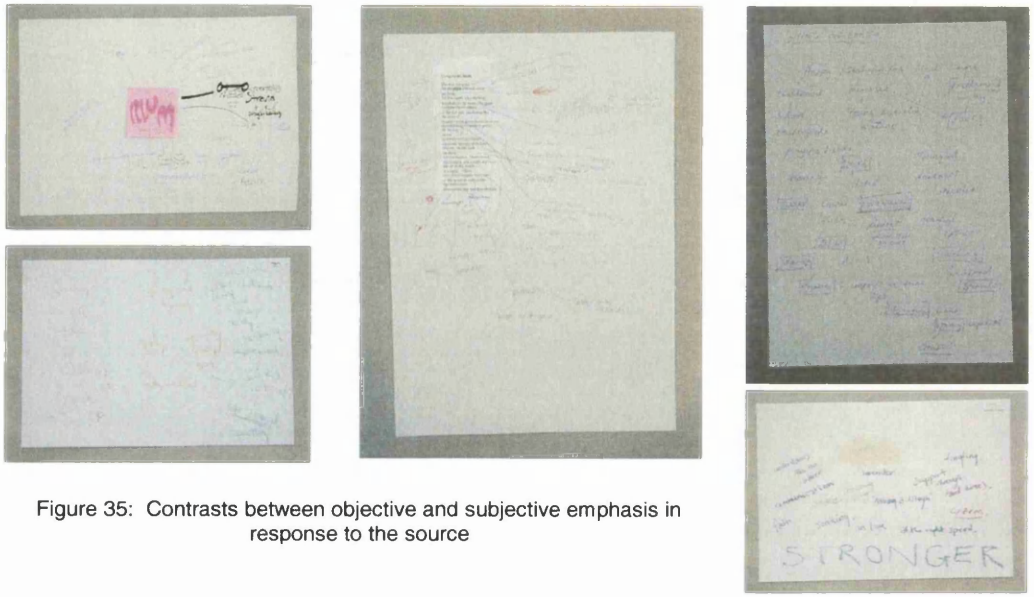

Figure 35: Contrasts between objective and subjective emphasis in response to the source

A third difference concerns the organization or placement of words on the page, relating to how they were being used. This ranged from mind mapping and brainstorming approaches, to narrative approaches, to one student who used words almost like physical objects in a material piece. Related to this was the use of single words, short phrases, or longer narratives. (See Figure 36.)

One of the most noticeable differences was the role of the physical materials within the artefacts produced. Although Words was the 'medium' in this section, the importance of the materials ranged from almost incidental to being integral to the piece to the extent that they had certainly equal, possibly higher significance than the words themselves (see Figure 37). The difference between students in the extent to which the material played either a background or foreground role was striking. This material aspect was not something that was suggested to the students, but arose spontaneously from their individual practice.

Figure 36: Different styles of layout of words on page

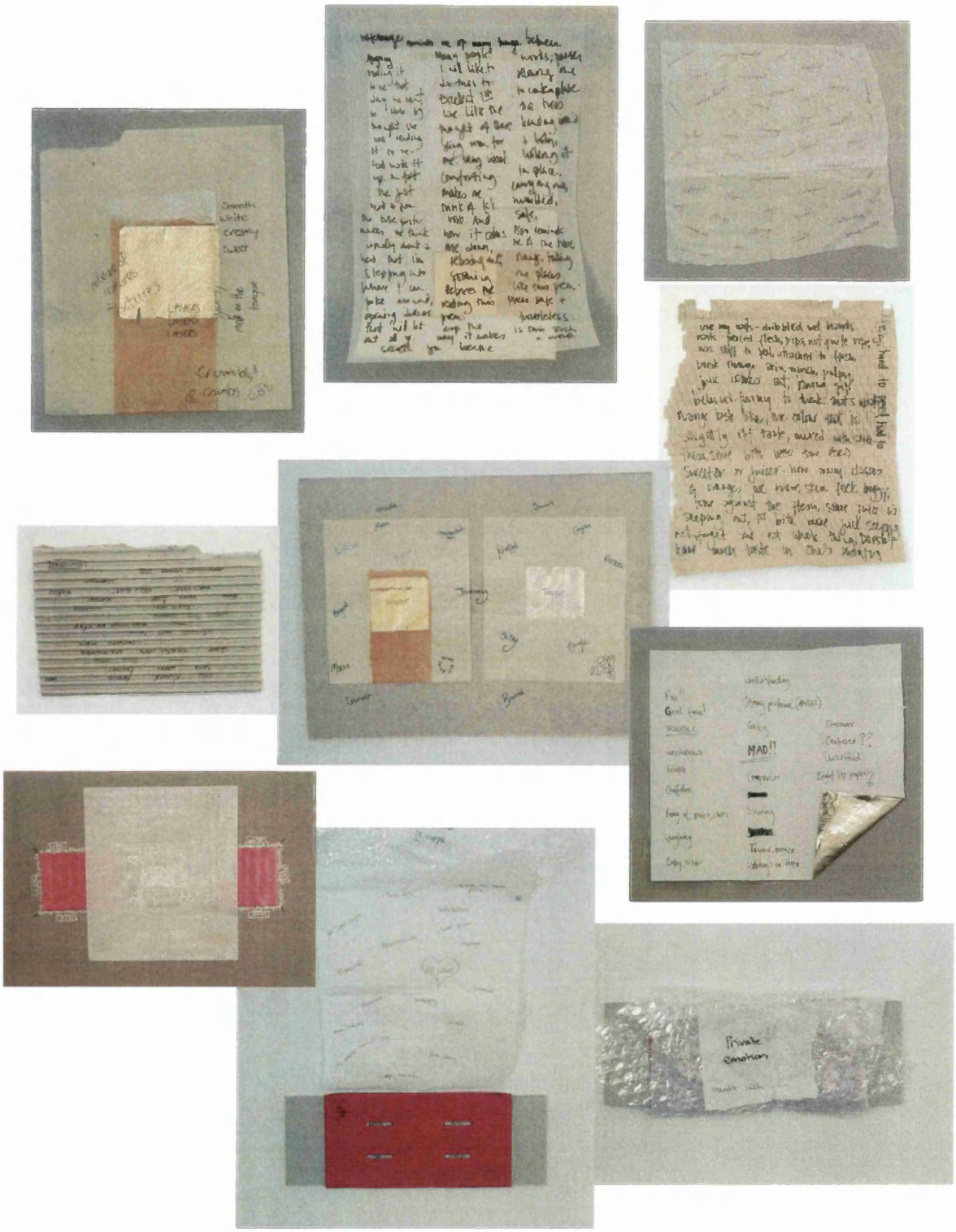

Figure 37: Examples illustrating a range of 'importance' of physical materials within the students' responses

Relationship with Words

Some interesting remarks were made about using words during the seminar. A number of students commented that they normally did not use words or felt uncomfortable using words. One student said,

> *"I don't like working with words, I have to say... I have a kind of block as if I can't do it therefore it was quite difficult but I quite enjoyed it."*

Another student observed that using words in this way was very personal: "a bit too personal", more so than drawing. This resonated with a number of students. One commented that she found using words "kind of disturbing". This disclosive nature of words was particularly relevant in the educational setting, where work is viewed by tutors and others. It was also interesting, given the visual emphasis within designing, that one student commented,

> *"you can be more ambiguous if you're drawing, but you're very direct with words"*

Some students found the Words exercises particularly difficult in situations where the source they were responding to wasn't physically present, for example 'a person or animal significant to them', or designing a piece for an event that happened in the past (e.g. getting into art school). One student felt that this was because "we didn't have an object or anything", and therefore she had to "sort of think back", whereas in the other exercises the source was in front of them.

A number of students changed their approach depending on which exercise they were doing, particularly if they were recalling things from memory. One student moved from a more narrative approach to a brainstorming technique; another from a narrative approach to making lists.

Some students, most of whom did use words in the normal course of work, liked the way that it helped generate ideas, and for going back to if you got stuck:

> *"You can go off on a tangent and maybe get better ideas by doing that."*

Although a number of students found it very frustrating that they couldn't draw in the 'design' exercise using Words, nevertheless some had a very clear image of the piece they would make in their head by the end of the exercise. However, they joked, "whether we'd be able to draw it..."

Markmaking

Figure 38: A student using Marks to respond to an object

Differences between artefacts in the Markmaking section can also be observed at a number of levels.

As with Words, differences can be observed in the 'content' of the marks: the type of response the student is making to the source. The categories are similar to those defined in the Words section: descriptive, responsive, and generative (see Figure 39): whether the student is responding to qualities of the source object itself, their personal associations to the object, or using marks to generate ideas (again, notably in the design exercise). (It should be emphasised again that this was an exploratory study, and that these preliminary categories emerged from an examination of apparent differences within the data.)

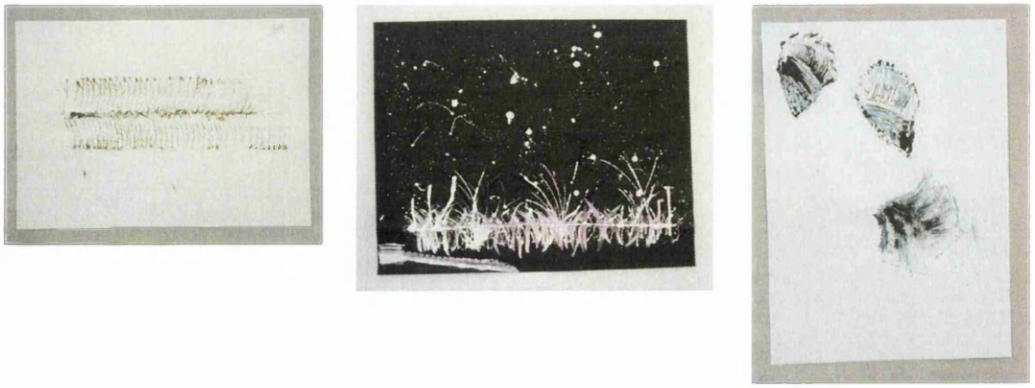

Figure 39: Examples of descriptive, responsive, generative responses

A related difference concerns the 'representational' extent of the artefact. Whereas the categories above concern the type of response to the source object, this category is concerned with the extent to which the marks used are literal or abstract, illustrative or evocative. Some students in this section responded with almost traditional drawings (in an 'illustrative' sense): for others the marks were more expressive or abstract. (See Figure 40.)

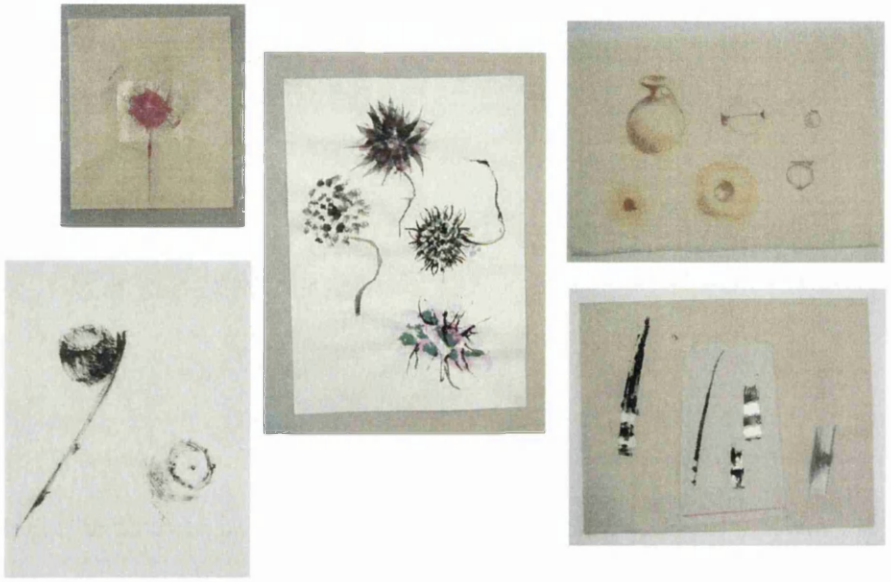

Figure 40: Examples of different representational extent of responses

Within this section, differences could also be observed relating to the role of the physical materials in the artefacts the students produced, ranging from 'background' to 'foreground' as with Words (Figure 41).

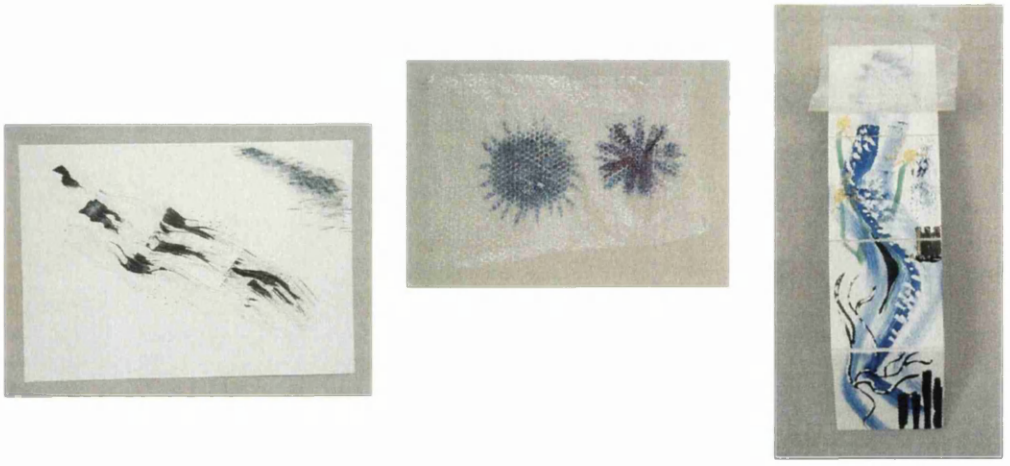

Figure 41: Examples illustrating a range of 'importance' of physical materials within the students' responses

A 'cluster' of categories (including techniques used, types of marks, use of unusual tools or techniques, and use of media) collectively relate to the extent to which students appeared to exercise control over the marks, or leave it to chance; and an openness to try new techniques, and experiment (Figure 42). These differences were not so readily observed in the Words exercises; however it may be that the underlying differences (control, chance) would, on further investigation, reveal themselves but manifested in other ways.

Figure 42: Variations in degree of control or chance, unusual techniques

Relationship with Markmaking

The majority of students did not normally use Markmaking: some were aware of it as a technique, but others had never used it before. For example, one student said she had been exposed to it in First Year but struggled with it because she "didn't really understand it".

One student commented that she had liked it because it was "much more painterly and loose" that the usual way she drew, and thought it would be a technique she would use again. Another student described it like "sitting on the phone doodling".

One student commented that through using it she'd come up with ideas for objects that she didn't think she would have otherwise. Another student commented that with

markmaking "you didn't always know what impression it would make, like it... could be hard impression could be... faded or... and that led to other possibilities".

Materials

Figure 43: Student exploring Materials

As with Words and Markmaking, differences at a number of levels were observed in the Materials section.

One difference concerns they way in which the artefact is linked to the source: in a sense its representational extent e.g. illustrative (like making a model), symbolic, or abstract (Figure 44: top row). Another concerns the qualities of the source that the student is responding to: for example its visual/physical/material qualities, its evocative or associative qualities, or the student's personal response to the object (Figure 44: bottom

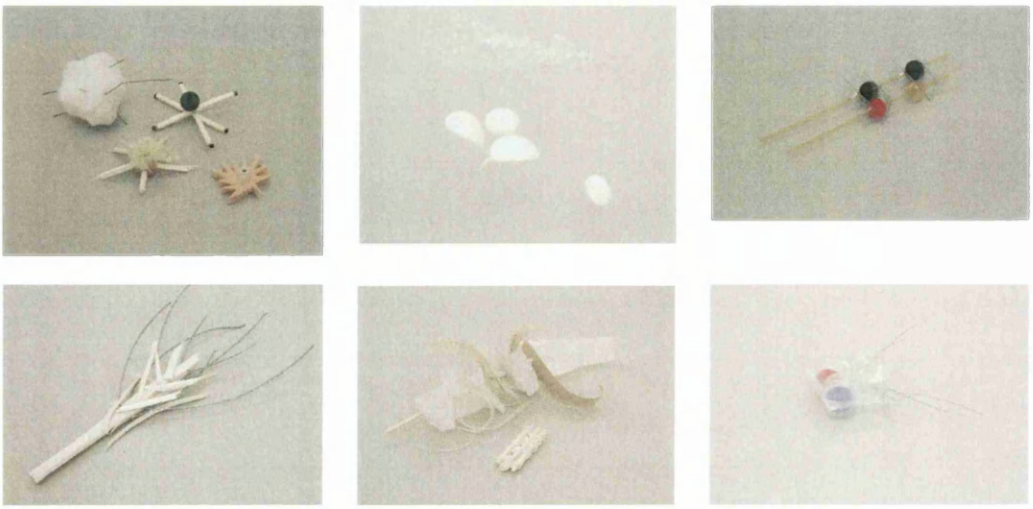

Figure 44: Responses illustrating different representational extent (top)
Three students' responses to a head of barley (bottom)

row). (This is similar to categories identified in Words and Markmaking.)

Other differences concerned the extent to which the materials were tailored to suit, or were used 'as is' (Figure 45). For example, materials like beads or bits of plastic might be used as they are, as elements within a construction. On the other hand, materials might be modified quite significantly. This is linked to differences in the ways in which an object is created e.g. assembly, construction, modelling/addition, carving.

Figure 45: Materials used 'as is' or tailored to suit

A cluster of categories are collectively related to the extent to which the materials are subordinate to an 'idea' that the student has had, or significantly influence the final artefact produced. These include 'aspects of materials used' (e.g. colour or texture, its symbolism or associations), 'choice of material' (e.g. chosen for its visual/aesthetic qualities, its material/functional qualities, or its associations), 'extent of response due to material' (how much the final form of the artefact was influenced by the materials that were used) (Figure 46).

Figure 46: (l) Materials subordinate to idea. (r) Idea for puppet came from old tights!

Relationship with Materials

As they are on a design/applied art course, the students are familiar with working with a range of materials in the production of pieces, but their experience of using materials in the idea generating element of design was less universal. Some who did like using

materials said that they really liked making models, or that as soon as they got their hands on materials they wanted to make something.

Some students commented that they liked the Materials exercises because you "kind of got an end result... you could do something with it if you wanted to take it further", or "you're just getting stuck right in there". One commented that "I could see possibilities for that, going onto make something, make some sort of object of that... which I wouldn't have thought, I would have came up with."

Another student said "when you first said Materials it was just like, oh no...", and "the idea of constructing things, really doesn't appeal to me". However, she began using a folding technique which she liked. Interestingly, despite this dislike of being asked to use materials, it was the material aspects of the Words exercise that she enjoyed: the pens, the paper and the physical act of writing.

One student who had enjoyed the Materials exercises, but who didn't usually make models said she felt she should use this approach more often: she commented that a friend who was an architectural student had previously suggested the technique to her when she had got 'stuck', and she had found that it had helped. Another student said that she didn't use materials much, but seemed to feel that she should:

> *"I sketch more but it's probably more out of laziness than anything else, you know just starting to sketch, instead of actually getting down and getting the materials together..."*

Given the recognised importance of drawing as a means (though not the sole means) of developing ideas within the design context within which the students work, a feeling of guilt for not using materials is interesting.

Limitations of the study

While these observations, derived during the production of the categories of difference, are individually interesting and collectively useful, they offer little in the way of direct comparison between students. The true power of this analytic approach would only be derived through a second examination of all the artefacts, using a selection of the most significant categories identified during this first examination to assess each one. Patterns observed within the categories would allow each student's work to be assessed against the collective view. This would more reliably determine whether differences in approach do exist for students *between sections* (e.g. Markmaking as opposed to Materials), and

also whether there are clear indications of more fundamental differences in approach *between students*, along the lines suggested by the differences already noted. An examination of the patterns of difference would quite probably reveal other significant factors; likewise, it might reveal more subtle distinctions than can be observed from the current data.

However, although some of the differences and comments noted for Words, Markmaking and Materials may seem incidental, or non-generalisable due to the variety of responses and variations in exercises, taken together they begin to build a picture of very different ways in which the students relate to the objects they work with.

Conclusions

The original objectives of this study were to ascertain, broadly, whether clear differences could be distinguished between students' approaches to and preferences for using 2D or 3D artefacts to generate design ideas; and to identify any other significant observations relating to individual differences which could inform the design of future, more focused, studies.

While a number of students expressed preferences for ways of working, this cannot necessarily be correlated to preferences for ways of working in their design processes. For example, one student who did not consider herself a 'words person', and who did not use words when designing, nevertheless liked the Words section because she found it challenging; one student commented that she normally did use words to an extent in design, but had not found in the Words design exercise that it had sparked off any ideas (perhaps because it was playing a different role in the workshop context, or being used in isolation); and one student's approach in the Words section changed quite dramatically between the 'responsive' exercises and the 'design' exercise, because she was 'designing' (Figure 47). (Possible explanations for these observations are addressed in Chapter 9, ***Discussion***.)

Within the limitations of the existing analysis of the data, no clear conclusions can be drawn that the primary differences between individuals related to a preference for working in 2D rather than 3D, although some students did say that they were more comfortable working with some types of media than others. What became apparent

during the study was that striking differences could be observed *within* as opposed to *between* media type.

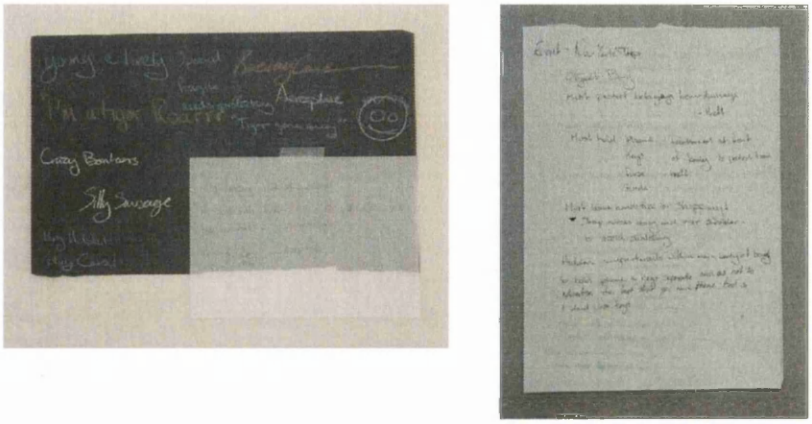

Figure 47: Change in type of response from 'responding' to 'designing'

A number of recurrent differences emerged from the collective examination of all the artefacts: regarding the relationship between the student and the source object, a subjective or objective approach towards the object; the extent to which the materials play a background or foreground role in the artefact (this is especially noticeable in some students' work in the non-Materials exercises); within the design exercises, the extent to which the design is derived by the student and then expressed in the media, or is derived through working with the media. Without further analysis it cannot be claimed that an individual student will relate in a similar way to objects across all media types, although a number of examples suggest that this might be the case. These preliminary themes, while emerging from the data within this study, have counterparts in themes arising from the comparative study of literature from a variety of disciplines (Chapter 6, ***Concepts of dialogue in design***), later empirical studies (Chapters 7, ***Comparative study*** and 8, ***Practitioner interviews***), and from further comparisons between literature from different disciplines made in Chapter 9, ***Discussion***.

The findings from this study suggest that design practitioners may well use the same media quite differently; that for some participants, materials seemed to play a much more significant part in *all* their responses than others; and that a blunt comparison between 2D and 3D may therefore be of little value. This is not to deny that there may be differences between individuals which relate to a preferences for working in 1D, 2D or 3D, and which might be revealed by a fuller analysis of the data, but that the differences I had observed between individuals did not relate specifically to a preference for 2D/3D,

but more to different ways of relating to artefacts, and the role of media within their creative practice.

These findings reinforced the position that the research should focus on the relationship between an individual design practitioner and the artefacts and media they work with within their creative practice. They also suggested that for future studies it would be not only necessary but valuable to look beyond my original categories and examine more closely differences in the ways that individual design practitioners perceive and relate to the artefacts and media they use to support their processes.

The next chapter, ***Concepts of dialogue in design***, describes how, while few studies of three-dimensional design have examined difference of this nature, commentators from other fields – writing, epistemology & learning, and anthropology – discuss differences between practitioners which resonate strongly with the tentative ideas arising from this study, and from my previous research. A review of these commentaries indicates that differences exist between individual design practitioners which represent wholly different approaches to design, elements of which relate to the nature and extent of a dialogue between practitioner and medium.

6. Concepts of dialogue in design

The research undertaken so far in this thesis has revealed design as a process of incremental transformation, facilitated through or revealed by a practitioner's active engagement with artefacts. It thus reinforces the importance of placing the relationship between practitioner and artefact at the centre of the research. However, it has made less progress in providing a satisfactory explanation for the diversity between practitioners which I had observed in my previous research.

The review of design literature in Chapter 3, ***Artefacts and the design process***, discusses case studies of individual designers which make reference to differences in approach relating to the roles of sketching and drawing or working with materials between individuals' practice, but do not examine these further. It concludes that there exists little design literature to assist in explanation. Chapter 5, ***Artefact study,*** reported on initial enquiries concerning practitioners' preferences for working in two or three dimensions to generate design ideas, which concluded that there may be more fundamental differences between individuals in their relationship with the medium in which they work. It identified differences in the ways in which individual design practitioners perceive and relate to the artefacts and media they use to support their processes, but the tentative evidence from this exploratory study could only hint at possible explanations.

While existing research in design has little to offer in this regard, Chandler's phenomenological study of writers [Chandler 1995] and Turkle & Papert's studies of student programmers [Turkle & Papert 1990; Turkle & Papert 1991] discuss differences in approach which can broadly be described in terms of the nature and extent of a dialogue between practitioner and medium, although the metaphors used by the two commentators are slightly different. They are therefore of direct relevance to this research. This chapter provides a comparative review between these commentators and other studies from design and writing which propose alternative models of the creative process and the relationship between practitioners and artefacts, or alternative explanations of differences between individuals.

Reflection, negotiation, mediation: concepts of dialogue in design

These commentaries can be distinguished by the nature and extent of dialogue they attribute to the relationship between practitioner and artefacts, which is reflected in the choice of metaphor used to describe this relationship: reflection, negotiation, or mediation. In some cases the dialogic metaphor is used to describe the design process generally, as in Schön's description of "design as reflective conversation with the materials of a design situation" [Schön 1992]; in others it is the extent of dialogue between practitioner and medium which characterises differences between individual practitioners.

The review examines, for each commentator, the role of artefacts/media in the creative process, the nature of individual differences in approach, if any, discussed by the commentator, and how these differences relate to the nature and extent of a dialogue between designer and artefact. It also examines the conceptual view of the design process which lies behind each of these models, and how these influence/impact the model of dialogue which is being proposed. This review therefore links both the underlying models and different disciplines to form a robust comparative framework.

The chapter starts by revisiting two commentators who exemplify the main models of the design process and the relationship between design practitioner and artefacts so far discussed in this thesis, which are shared by a number of other commentators discussed here: Goel's description of design as ill-structured problem solving where sketches, for example, are viewed as an external symbol system to support internal cognitive processes [Goel 1995]; and Schön's description of "design as reflective conversation with the materials of a design situation", where the artefact is the medium of reflection-in-action.

Goel

Chapter 3 discussed Sketches of Thought, Goel's intensive exploration of design activity, which he views as a good example of ill-structured problem solving. (The ideas and quotations in this section come from that publication [Goel 1995].) He focuses on the sketches characteristic of preliminary design, and proposes that the cognitive processes associated with sketching activity are important in the early stages of design; that the dense and ambiguous nature of the symbol system of sketching supports these cognitive

processes; and shows that when the designer is restricted to using an external symbol system which does not have these features, these cognitive processes are disrupted.

Goel focuses on design as a cognitive process, which has a number of implications. In the early stages of design with which he is dealing, his emphasis is very heavily on the transformations of ideas, supported by the properties of the external symbol system of sketching. He proposes that "different thought contents may require different symbol systems for their expression", suggesting that, in this context, the sketch is a direct and external representation of internal cognitive activity. It is also reflected in the way the designer's relationship to the environment and the design context is seen in terms of information:

> *"This transformation and exploration of alternative solutions is facilitated by the abstract nature of the information being considered (a large percentage still concerned with people and behaviour)"*

In Goel's studies, he observed that the exploration of ideas characteristic of the early stages of design emerges by "incremental transformation of a few kernel ideas", particularly through "a large number of lateral transformations". Although the lateral transformation of ideas is crucial to the exploration, there is little sense of a dialogue between designer and sketch in this transformation - certainly not in the sense that Schön describes - more the notion that sketching is a form of external thinking, as can be seen in his description of the comparison between the effects of the two different external symbol systems (sketching and draughting):

> *"One actually gets the sense that the exploration and transformation of ideas is happening on the paper in front of one's eyes as the subject moves from sketch to sketch. Indeed, designers have very strong intuitions to this effect. When a new idea is generated in MacDraw, its external representation (in MacDraw) seems to fixate and stifle further exploration. Most subsequent effort after the initial generation is devoted to either detailing and refining the same idea or generating the next idea. One gets the feeling that all the work is being done internally with a different type of symbol system and recorded after the fact, presumably because the external symbol system can not support such operations."*

In the study, Goel doesn't consider any individual differences in process (other than that his subjects came from different disciplines – 2D and 3D - and the design briefs they were given were appropriate to those disciplines). This may have a number of different reasons: firstly, and probably most significantly, the purpose of the studies was not to examine difference; secondly, the studies were focused on one very particular aspect of the design process (sketching in the early stages of design), and the types of differences in which I am interested may not be observed at this level; and thirdly, although the

subjects were given a two-hour, "real-world" design task, it nonetheless was an artificially constrained experimental situation, where again, individual differences may not as easily be observed.

Schön

In his paradigm of design as reflective practice, discussed in Chapter 3, Schön describes design as 'reflective conversation with the materials of a design situation'. (The ideas and quotations in this section come from [Schön 1983; Schön 1992; Schön & Wiggins 1992].) Each design situation is viewed as a unique case, a problematic situation rather than a well-defined problem. This requires a shift from problem solving to problem setting, skilled knowing-in-action rather than technical expertise applied in standardised ways, where each designer's repertoire of experience contributes to their uniquely constructed 'design world' within which they operate. Schön's model of the design process is one of understanding through change. By drawing on exemplars from his repertoire of previous experience, the practitioner 'sees' a way of engaging with the situation, and 'frames' it in such as way as to impose an element of discipline and structure to allow him to proceed. This is the start of a process of framing and reframing: having made his 'move', or experiment, the designer 'appreciates' the outcome, which may or may not be what he expects, and responds to the 'talkback' of the situation. This dialogue is a factor of the uniqueness and complexity of the design situation. Underpinning this process is another type of dialogue, dependent on visual 'seeing' - the ability to construct figures from marks on a page. This emphasises the situated nature of design, where the medium in which the designer works is the medium of reflection-in-action.

Yet even though Schön's model of design incorporates these aspects of dialogue, it does not seem to accommodate the differences that can be observed between design practitioners. He recognises the uniqueness of each individual's practice, but the differences he discusses arise from the personal and situational context within which the practitioner is working - their unique 'design world' - rather than wholly different approaches to design. While Schön stresses the importance of the interaction between designer and artefacts, the dialogue he describes is a dialogue with yourself *through* the medium - shifting internal appreciations through reflection on external representations -

rather than what I would characterise as a dialogue *with* the medium experienced by many makers.

Much of Schön's research focuses on architectural practice: the design is substantially complete before 'making' commences; the designer rarely builds the final outcome; and the designer works with representations of reality, rather than reality itself. (Schön further refines his description of design in this context as "conversation with materials, conducted in the medium of drawing and crucially dependent on seeing".) The context with which I am concerned is closer to the studio practice of designer-makers, where the practitioner is in charge of the whole process from concept to execution, and where it is possible to observe differences in approach that in more focused situations might not be seen.

Louridas

Design as Bricolage: Anthropology Meets Design Thinking offers a possible extension to Schön's model of dialogue. In this theoretical paper Louridas compares two types of design - unselfconscious design and selfconscious design[7]. (The ideas and quotations in this section come from [Louridas 1999].) Unselfconscious design is design without designers, vernacular design in a context of stable cultures, where 'good' design is the produce of a long tradition of design. Selfconscious design is contemporary design, professional design, characterised by design-by-drawing. Unselfconscious design is 'literal' design, design at the level of the artefact; selfconscious design is 'metaphorical' design, design at the level of the representation.

Drawing on Levi-Strauss's distinction between the concrete approaches of the bricoleur and the formal approaches of the engineer as a metaphor to explain his ideas behind the contrast between science and mythical thought [Levi-Strauss 1966], Louridas proposes that self-conscious and unselfconscious design can both be viewed as processes of bricolage: a 'dialogue with the materials and means of execution':

> *"we show that both are the same activity applied to different means; both follow the same logic applied to different contexts"*

[7] The terms 'unselfconscious design' and 'selfconscious design' were introduced by Christopher Alexander in Notes on the Synthesis of Form [Louridas 1999].

The bricoleur does not go out and seek materials specifically for each project, but makes do with the materials, tools and skills available in a 'heterogeneous' collection he has built up over time, i.e. he works with an inventory that is 'closed'. Because of this, items in the inventory may be used for purposes other than which they were intended, for their 'secondary' qualities: what they could be or could do, rather than what they are or are 'for'. Because his inventory is closed, the bricoleur must enter into a dialogue with this inventory to see the 'space of possibilities' that exist within it, and how he might use it for the project in hand. Because the bricoleur is using items other than for their original purpose, there is an uncertainty about the consequences of his actions, which leads to the bricolage process being one of continual dialogue with the items in the inventory as 'interlocutors':

> *"Bricolage is therefore at the mercy of contingencies, either external, in the form of influences, constraints and adversities of the external world, or internal, in the form of the creator's idiosyncrasy. This is in contrast to the scientific process: science brackets out events and secondary qualities to arrive at the essentials and primary qualities. It uses structures, in the form of its underlying theories and hypotheses, to arrive at its results, which take the form of events. Bricolage works in the opposite way; it creates structures, in the form of its artefacts, by means of contingent events."*

Using bricolage as a metaphor for design, Louridas argues that unselfconscious and selfconscious design can both be viewed as processes of bricolage, with respect to the contingent events of occasion, execution and purpose, and with respect to the bricoleur's characteristics of immediacy and directness in working with his inventory. *Occasion* is an external contingent, relating to what the project is, and why it is being done; *execution* is internal to the process (Levi-Strauss talks about communicating with the materials, but Louridas includes "the artist's style and skill"); and *purpose* is an external constraint, but looking to 'after the event', a 'dialogue' with the wants and needs of a future user.

Unselfconscious design (vernacular design) is characterised by tradition and directness – these force a bricolage process on the designer, by imposing these contingencies:

> *"Since tradition determines what constitutes a problem, it limits the purpose contingencies. Since it determines what materials can enter in the designer's consideration, it limits the execution contingencies. Since it determines the way the designer perceives the situation, it limits the occasion contingencies."*

In selfconscious design (professional design), these contingent events are no longer determined by tradition: the designer is free to determine them - indeed he is responsible for determining them. This freedom apparently contradicts the argument for selfconscious design as bricolage. However, Louridas argues that the difference between selfconscious design and unselfconscious design in this matter is not qualitative, but

quantitative. The designer may be free to choose his inventory, but once it is chosen he has to design within it; he has to work within many constraints, "financial, environmental, social, regulatory and so forth..."; and he is not free to control the interpretation of his work. Moreover,

> *"this threefold liberation of the design process imposes significant demands on the designer. The designer must now possess special skills to handle the increased complexity of the design problem... It is, therefore, imperative to find ways to handle design complexity. Design-by-drawing is such a way. In fact, it is the major way and it is the most distinguishing characteristic of selfconscious design."*

Selfconscious design, by working with a model of the artefact, rather than the artefact itself, appears to contradict the bricolage characteristics of immediacy and directness in working with materials; Louridas proposes that this too can be resolved, by relating these to the context and level at which the designer is working: the unselfconscious designer is working at the literal level, the level of the artefact; the selfconscious designer is working at the metaphorical level, the level of the model, or representation.

Both unselfconscious and self-conscious design can therefore be viewed in terms of bricolage; both can be seen as a dialogue with the equivalent of the bricoleur's inventory: the 'contingent events' of occasion, execution and purpose. Differences arise partly as a matter of degrees of freedom or choice (a selfconscious designer has responsibility for selecting his 'materials and means of execution', within which he then has to work; an unselfconscious designer has the choices forced upon him by tradition; and a bricoleur chooses to work within the boundaries of his inventory) and partly as a matter of context (the selfconscious designer is working at the 'metaphorical' level, at the level of the model or representation, while the unselfconscious designer and bricoleur are working at the 'literal' level, at the level of the artefact).

Viewed this way, these are not different ways of working, but similar processes along the lines of Schön's model, one at the 'metaphorical' level of design representation, and one at the 'literal' level of the artefact:

> *"This is in accordance with the view of design as a reflective conversation with the situation at hand. In this view, design is a discussion conducted with the materials in the medium with which the designer works. It is a hermeneutic process, a process of iterative understanding."*

Louridas is primarily comparing two different types of design: traditional/vernacular, and contemporary/professional. He doesn't explicitly discuss differences between individuals although, as with Schön's model, an element of difference will arise from each individual's way of seeing the situation, and the skills and experience they bring to

it. Nevertheless his comparison between design-by-drawing and design with materials is interesting within the context of this thesis, and his proposal that they are not different processes, but the same process on different levels.

The practice of design on which I am focusing does not fit neatly into Louridas' two categories. Most designer-makers are professionally trained designers, but they do not all work in a design-then-make fashion, where

> *"The object of design is primarily the diagram; this is translated to the real world object later on."*

Those designer-makers who prefer to work at what could be considered a 'literal' level do not conform to the profile of unselfconscious design where their process is bounded by tradition. Indeed, designer-makers as a body are characteristically viewed as pushing the boundaries of what is possible with materials. However, by dissociating the two elements with which he deals, designer-makers could be seen as more like selfconscious designers in terms of their freedoms within the process, while choosing to design primarily at either a metaphorical or literal level. This is in line with his view that differences don't relate to the process itself, but the context within which it takes place. So is my suggestion that there are in fact two quite different approaches spurious in the context of Louridas' argument?

It is worth emphasising that Louridas is not saying that design *is* bricolage, but that is can be viewed *as* bricolage. In the next section, I discuss a study from another discipline which also draws on Levi-Strauss's work and ideas on bricolage, but which proposes that individuals differ quite fundamentally in their approaches to design activities.

Turkle & Papert

In Epistemological Pluralism and the Revaluation of the Concrete and Epistemological Pluralism: Styles and Voices Within the Computer Culture Turkle & Papert describe the approaches which they observed both in children working with computer systems and in college students' programming styles (the ideas and quotations in this section come from these publications [Turkle & Papert 1990; Turkle & Papert 1991]). While the canonical approach to computer programming is structured, planned, and hierarchical, Turkle & Papert's research revealed a diversity of approaches and intellectual styles. They draw parallels with Levi-Strauss's metaphor of bricolage:

> *"Lévi-Strauss used the term 'bricolage' to contrast the analytic methodology of western science with what he called a 'science of the concrete' in primitive societies. The bricoleurs he describes do not move abstractly and hierarchically from axiom to theorem to corollary. Bricoleurs construct theories by arranging and rearranging, by negotiating and renegotiating with a set of well-known materials.*
> *Lévi-Strauss's descriptions of the two scientific approaches, divested of his efforts to localize them culturally, suggest the variety of ways that people approach computers. For some people in our study, what is exciting about computers is working within a rule-driven system that can be mastered in a top-down, divide and conquer way. This is the 'planner's' approach taught in the Harvard programming course... Lisa, Robin and others like them offer examples of a very different style. They are not drawn to structured programming; their work at the computer is marked by a desire to play with the elements of a program, to move them around almost as though they were material elements – the words in a sentence, the notes in a musical composition, the elements of a collage."*

(Note that Turkle & Papert's use of the term 'style' is different to my use when referring to a designer's 'personal style', as discussed in Chapter 1.) Turkle & Papert's research revealed two quite different approaches to programming: "we isolate two approaches which serve as ideal types, theoretical prisms through which to see simplified projections of more complex realities". Turkle & Papert designate these two types 'hard' and 'soft':

> *"The ideal typical hard and soft approaches are each characterized by a cluster of attributes. Some involve organisation of work (the hards prefer abstract thinking and systematic planning; the softs prefer a negotiational approach and concrete forms of reasoning); other attributes concern the kind of relationship that the subject forms with computational objects. Hard mastery is characterised by a distanced stance, soft mastery by closeness to objects."*

Within these two broad categorisations, an examination of Turkle & Papert's papers reveals several 'dimensions of difference', covering a wide range of aspects of the work and process. (These have been analysed in detail to contribute to the development of the analytical framework discussed in Chapter 7, ***Comparative study***; the main characteristics of each approach are described below.)

The *hard* ('planner') approach is characterised by control and conscious purpose. *Hards* focus on explicit goals; they predetermine the form of their work by planning, maintaining control of complexity by breaking the problem down, and imposing a hierarchical structure. They think algebraically: computational objects are viewed as abstract, and for their formal properties ('what they are for'). This preference for control is also seen in *hards'* attitude to unexpected events: risk is minimised, and mistakes are viewed as problems to be overcome. The *hards'* relationship with computational objects is objective, formal and distanced: they prefer to maintain boundaries between themselves and the details of the implementation, using opacity and 'black-boxing' to

work at an abstract level. Their approach to thinking is characterised by analysis, abstraction and reasoning in terms of rules. *Hards* approach learning through analysis, and a desire to know how things are 'supposed to' work. In dialogic terms a *hard's* relationship with their medium could be characterised in terms of a monologue: the programming 'medium' is a tool to achieve a predetermined purpose.

In contrast, the *soft* ('bricoleur') situated, relational approach is characterised by negotiation and a willingness to 'forget yourself' and be open to experience. *Softs* have tacit aims which allow the form of the work to emerge through processes of negotiation with the medium. Complexity is handled through "a mastery of associations and interactions" by finding pattern or 'rhythm' within the work, or a process of 'growing' or 'sculpting'; it is therefore imperative to maintain contact with the details at all times. The *softs'* approach to risk is quite different to that of their *hard* counterparts: mistakes and unexpected events are seen as an essential part of the process of negotiation. The *softs'* close relationship with objects is subjective, concrete and situated, with a contextual approach to thinking characterised by transparency and a mastery of details, and concrete, bodily and intuitive forms of reasoning. Computational objects are viewed for their concrete or tangible properties ('what they can do'). The *softs*' approach to learning has similar characteristics:

> *"...the bricoleurs are happy to get to know a new object by interacting with it, learning about it through its behaviour the way you would learn about a person, while the planners usually find this intolerable. Their more analytic approach demands knowing how the program works before interacting with it. They demand the assurance that comes from transparent understanding, from dissection and demonstration"*

In dialogic terms, therefore, a *soft's* relationship with the medium could be characterised as a conversation: they achieve their goals "in a collaborative venture with the machine".

The following example illustrates some of these differences between the canonical 'formal' approach to programming and the 'soft', 'concrete' style of programming observed by Turkle & Papert. They discuss one student's approach to producing a Logo program which uses 'sprites'[8] – in her program birds fly over the horizon, disappear, and then reappear elsewhere on the screen:

> *"One method of achieving this end calls for an algebraic style of thinking: you make the program store each bird's original colour as the value of a variable, then you*

[8] "A sprite is a second Logo icon... Once you give a sprite a speed and a heading, it moves with that state of uniform motion until something is done to change it..."

change all colours to invisible and recall the appropriate variable when the bird is to reappear. Anne knows how to use the algebraic method, but prefers one that allows her to turn programming into the manipulation of familiar objects. As Anne programs, she uses analogies with traditional art materials. When you want to hide something on a canvas, you paint it out, you cover it with something that looks like the background. Anne uses this technique to solve her programming problem. She lets each bird keep its colour, but she makes her program hide it by placing a screen over it. Anne designs a sprite that will screen the bird when she doesn't want it seen, a sky-colored screen that makes the bird disappear. Anne is programming a computer, but she is thinking like a painter."

These descriptions of different approaches to programming, itself a creative activity, resonated very strongly with my earlier observations: the 'hard' or formal approach characterised by control, planning and working at the level of the representation had similarities with the design-then-make approach, while the 'soft' situated relational approach characterised by negotiation, transparency and a closeness to objects had its counterpart in those whose design develops through working with materials. This observation of similar differences in a quite different area suggested that there may indeed be underlying differences in approach between the designer-makers I observed, which relate to the relationship between each practitioner and the media they use in their creative processes.

The above studies are drawn from a number of different disciplines and areas of practice. However, similarly different models of the creative process and the relationship between practitioner and artefacts can be found within the discipline of writing. The chapter next discusses three studies of writing which relate closely in ideas to the studies by Goel, Schön and Turkle & Papert. All of these discuss the writer's relationships with external media, but from different viewpoints.

Sharples & Pemberton

Sharples & Pemberton's view of the writing process has strong links to Goel's view of the design process (the ideas and quotations in this section are from [Sharples & Pemberton 1992]). Like Goel, they are examining it from the viewpoint of cognitive science. Goel sees design as an 'ill-structured' or 'wicked' problem; Sharples & Pemberton see writing as "goal directed and decomposable into a series of subgoals", but where there is no well-defined goal state. As it isn't a "simple goal-directed search", general problem-solving methods are not appropriate; however, it can be viewed as "a goal-directed task governed by multiple constraints". Goel identified distinct phases in

the design problem solving activity, and from an examination of the drawings produced, concluded that designers use different symbol systems which correspond to these different design phases, and thus facilitate different cognitive processes. Sharples & Pemberton describe writing as a sequence of stages (not necessarily linear), in each of which the writer may use different external symbolic representations to facilitate cognitive processes.

They discuss how previous models of the writing process, such as that by Flower & Hayes, have focused very broadly on the relationship between internal process and external representation. In their model Flower & Hayes class the main operations of the writing process as planning, translating and reviewing, where translating is "the action of taking material from memory, under the guidance of plans and goals, and transforming it into coherent sentences".

These and other studies have contributed to what Sharples & Pemberton describe as the 'consensus model' of writing:

> *"the picture of cognition and writing that has emerged from the past ten years of research is a goal directed task governed by multiple constraints. There is no simple progression from one stage to another, but instead a cycle of planning, text generation and revision, with the written words acting as triggers for further planning."*

Within this consensus, there is recognition that there are broadly different approaches to writing, which can be described in these terms: for example, Mozartian ("who produces detailed plans before text") and Beethovian ("who creates text to find out what he thinks, interleaving planning and translation").

However, this model of writing has a number of limitations: it does not differentiate between different types of external representations the writer may use; there "is no clear distinction between mental structures and analogous ones on an external medium"; and they also perceive the need for an "'intermediate representation', a bridge between mental structures and text, with some of the properties of each".

Sharples & Pemberton present a framework comprising different external representational structures that support different cognitive phases in writing [Sharples & Pemberton 1992]. Although they focus on cognitive processes, they recognise that this process is not independent of the medium, as the choice of medium constrains the process of writing, by influencing the construction of the symbolic representations.

	UNINSTANTIATED	INSTANTIATED
UNORGANISED	Techniques: • brainstorming Representations: • idea-labels	Techniques: • note-taking (verbatim) • collecting quotes Representations: • notes
NON-LINEAR ORGANISATION	Techniques: • following a thread • writing as dialectic Representations: • network of idea-labels	Techniques: • organising notes • filing Representations: • network of notes
LINEAR ORGANISATION	Techniques: • linear planning Representations: • list of idea-labels • table of contents	Techniques: • drafting text • revising text • copying text Representations: • linear text

Table 5: "A framework for describing the writing process" [Sharples & Pemberton 1992]
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This framework accommodates different types of 'external representational structures', along with techniques used to produce them (see Table 5). They propose that there are three types of text item a writer produces: instantiated items (pieces of connected prose, large or small); uninstantiated items or 'idea labels' ("index to a mental schema and as a placeholder for a piece of text still to be created"); and annotational items (a comment on another item – used in editing and revision). In this particular framework, they focus on the first two types. They propose that there are also three types of view: unorganised, non-linear, and linear. "Normally, non-linear views act as intermediate representations between the arrangement of items in the writer's semantic memory and the string of words in a finished text".

> *"The two dimensions, of* instantiation *and* view type, *characterise a writer's representation of items on some external medium"*

Within this framework of views (external representational structures), they define strategies as movements across views, operations as manipulating material within or between representations, techniques as "a means of creating all or part of a representational structure" (e.g. brainstorming) and methods as "techniques carried out on a particular medium". (The views or representational structures are therefore distinct from the methods and media used to generate them.) In their view, "one advantage of the six-box framework is that it allows an explicit distinction to be made between those processes which a writer carries out on some external medium, and those which are performed mentally or bypassed altogether". For example, "a writer who has already

mentally assembled the material she needs for a document may begin at box 4 [e.g. organising notes] or even box 6 [e.g. drafting text]"

Like Goel, there appears to be a direct correlation between the external representations used and the mental processes going on. Further, like Goel, they conclude "that the choice of writing medium constrains the process of writing and influences the structure of these representations". Again, there appears to be little sense of dialogue in the manner that Schön describes: although the 'Beethovian' approach proposed by others might seem to be along these lines – the writer "creates text to find out what he thinks, interleaving planning and translation" – it is more an internal cognitive process: "as the text emerges it serves to direct the search of long term memory and to constrain the selection and organisation of ideas". However, whereas Goel does not address individual differences in process (he focuses solely on sketching in the early stages of design, not on the whole 'design and make' process), Sharples & Pemberton provide a framework within which it is possible to map out not only those different approaches and strategies which have already been observed by a number of studies, but also to suggest other possible approaches, other sequences through the framework. Differences in approach relate to the sequence of stages the writer goes through, and those aspects of the process which they do mentally versus those for which they generate 'external symbolic representations'.

Sharples

In Writing as Creative Design Sharples extends this previous work "to consider the writer as a creative thinker and a designer of text" (the ideas and quotations in this section come from this publication [Sharples 1995]). In this model, writing is no longer viewed as a problem solving process, rather as a process where "the problem must be generated as it is being solved"; in this it has parallels to Schön's model of design with the shift from problem solving to problem setting. They have other similarities: Schön describes the designer as constructing their own unique design world; Sharples describes the writer as "a thinker in a self-constructed environment which affords, constrains, and mediates the writing process".

In his earlier paper, Sharples with Pemberton examined the variety of representational structures that writers may use within their processes, and described the writing process in terms of operations on and moves between these views. This later paper looks more

broadly at the "interaction between creative thinking and the recording of ideas as text on an external medium". The emphasis is still largely on cognitive activity: the new model of writing is based around a model of creativity as the deliberate exploration and transformation of the writer's conceptual space:

> *"creativity involves setting appropriate constraints to form a conceptual space that is relevant to the writer's purpose, and then deliberately exploring and transforming it to create an original and valuable product"*

Sharples describes the process of writing in terms of two activities relating to the writer's conceptual space: 'engagement' and 'reflection'.

> *"writing involves both engagement (the direct recording of conceptual associations) and reflection (the deliberate and cognitively demanding process of re-representing embedded processes and exploring cognitive structures). An engaged writer who has created an appropriate context and constraints can be carried along by the flow of mental association, without deliberate effort."*

These activities are quite different. *Engagement* is the production of text through conceptual association: it requires "devolving full attention to the task of creating text", and is "guided by tacit constraint". Engagement involves tacit forms of knowing and thinking. "The act of transcribing into text is sequential and demanding, leaving no opportunity for deliberate mental exploration" - it is "thinking with the writing". What has been set down on paper acts "as a prompt for further association and writing" and "provides material for consideration". *Reflection*, on the other hand, is "the deliberate and cognitively demanding process of re-representing embedded processes and exploring cognitive structures". Reflection involves explicit forms of knowing and thinking. It is a process of standing back, "thinking about the writing", and reinterpretation.

Sharples proposes a model of writing as cycles of these two activities:

> *"in order to reflect on past actions we must be able to re-represent them as explicit mental structures... Reflection is an amalgam of mental processes. It interacts with engaged writing through the component activities of reviewing, contemplation and planning"*

He also uses this framework to explain differences in approach that have previously been be observed between writers: 'planners' and 'discoverers'. While he points out that most writers can, if necessary, adapt the way they work to fit other demands, for some writers the emphasis is on the generation of text by conceptual association, guided by tacit constraints, while others place a strong emphasis on deliberately exploring and transforming the conceptual space.

> *"Writers with a Planner orientation are driven by reflection - for these people, writing flows from understanding. They spend a large proportion of their time on*

> *exploring ideas and on generating plans and constraints to guide their composing. When they write, it is primarily to carry out a pre-prepared plan. Conversely, those with a Discoverer orientation are driven by engagement with the text - for them, understanding arises from writing. They may prefer to begin a writing task by scribbling out a draft which reveals their thoughts to them"*

The other significant difference between this and earlier models is the role of external media. In their previous study Sharples & Pemberton were concerned with different types of symbolic representations, and how "the representational properties of resources affect the processes of idea generation and written composition" [Sharples & Pemberton 1992]. However, in Sharples' model of the 'writer as designer of text',

> *"the emphasis is not on problem solving, but on writing as design, with the task environment not just influencing performance, but extending cognition"*

External representations play a number of roles within the process: they act as external memory, they are used for communicating ideas to others and oneself at a later date, and they provide "a means of capturing intermediate products in a form that is intermediate between mental schemas and a finished text." However, more particularly,

> *"cognition is not simply 'expressed' or 'amplified' through the use of external representations, but rather the nature of thought is determined by the mind's dialectical interaction with the world as constructed by human beings. Notes, sketches, outlines, tables, topic lists, concept maps, and argument structures are both representations of mental content and things in themselves, new stimuli dissociated from the moment of their production and available for reinterpretation."*

This account that Sharples gives of writing has similarities to Schön's view of design as 'reflective conversation with the materials of a design situation', where a designer 'surfaces' their understanding of the problem in order to consider how to proceed:

> *"As a writer's thoughts are externalised in sketches, notes, drafts and annotations, these designs become grist for an iterative process of interpretation and redrafting"*

Sharples' cyclic relationship between the two types of activity - ***engage-reflect***[review, re-represent, contemplate, plan]-***re-engage*** - has similarities to Schön's process of 'seeing-moving-seeing'; Schön's 'unique design world' compares with Sharples' description of the writer's environment, with its mix of constraints, external and internal: "the schemas, inter-related concepts, genres, and knowledge of language that form a writer's conceptual space".

However, unlike Schön, Sharples discusses more particular individual differences in approach, characterising them in terms of those who are driven by reflection, with its emphasis on planning and explicit forms of knowing and thinking, and those who are driven by tacit engagement with the production of text. Sharples does not deal solely

with the equivalent of 'design-by-drawing', working with models of the finished artefact. His writers are more akin to designer-makers, taking the writing from initial ideas to finished text. It is interesting, therefore, to compare his model of different approaches to writing with Louridas' contrast between 'literal' and 'metaphorical' design: the same process but at different levels.

Sharples concludes that this type of examination of the writing process needs to be extended:

> *"Accounts of writing as a cognitive process have been almost exclusively concerned with the writer's mental states and processes. There needs to be a corresponding study of external representations. It should provide an understanding of the type of marks and signs that the writer makes on paper or screen, the techniques for working with them, and the function that these external representations perform in recording, structuring and mediating cognition"*

Sharples himself makes a more extensive examination of the model of writing as creative design in How We Write: Writing as Creative Design [Sharples 1999]. In particular, he explores the relationship between the cycle of reflection and engagement (what he refers to as "the cognitive engine of writing"), the main activities of writing (planning, composing and revising), and the role of external representations. He also examines different composing strategies used by writers (as distinct from the Planner and Discoverer approaches or orientations towards writing); these are discussed further in Chapter 9, ***Discussion***.

Chandler

In The Act of Writing, his phenomenological study of writing, Chandler "highlights major processes of mediation involved in writing, including the writer's engagement with media such as language, the written word and writing tools". (The ideas and quotations in this section come from this publication [Chandler 1995].) He describes two quite distinct approaches to writing, like Sharples: 'planners' and 'discoverers'.

> *"Some writers (in my terms Planners) seem to regard thought as quite separate from the words they use in writing about their ideas. Planners write primarily to record or communicate what is already clear in their mind." "For Discoverers, the act of writing does not simply involve a transcription of ideas which are already clear in their minds: writing is a way of thinking."*

Chandler describes a number of more specific composing strategies used by writers (see Chapter 9, ***Discussion***), but he concludes that writers have an underlying orientation towards 'goals' or 'discovery':

> *"...it seems that the ways in which many writers habitually describe their experiences of the process of composition do focus either on* discovery *or on* goals. *Such terms of reference may be interpreted as polar extremes relating to a basic long term orientation towards the experience of composition."*

These different approaches can broadly be expressed through different metaphors of engagement with the medium of language:

> *"Those for whom language is experienced primarily as a tool which they use I will characterize here as Planners... those who tend to experience language as a medium which acts upon them I will refer to as Discoverers"*

Like Turkle & Papert's 'hard' and 'soft' approaches, Chandler's two orientations to writing are quite distinct 'ideal types', characterised by clusters of attributes concerning different aspects of the writing process, and which differ along similar lines to those observed in the studies of programmers.

A *planner*'s approach to writing is characterised by control and conscious purpose. They focus on explicit goals, and the form of the work is preplanned before writing commences. They emphasise 'product': writing is viewed as a tool, a means to an end. A *planner*'s relationship with language is objective: a *planner* acts upon the medium of language to express their ideas. Language is experienced as transparent: thought is separate from words; writing is used to communicate what's clear in the mind. Revision is largely an internal, mental process. Chandler quotes William Lutz:

> *"...'Before I write, I write in my mind. The more difficult and complex the writing, the more time I need to think before I write. Ideas incubate in my mind. While I talk, drive, swim and exercise I am thinking, planning, writing. I think about the introduction, what examples to use, how to develop the main idea, what kind of conclusion to use. I write, revise, agonize, despair, give up, only to start all over again, and all of this before I ever begin to put words on paper... Writing is not a process of discovery for me... the writing process takes place in my mind. Once that process is complete, the product emerges. Often I can write pages without pause and with very little, if any, revision or even minor changes'..."*

In contrast, a *discoverer*'s approach is characterised by discovery and an openness to experience. *Discoverers* have tacit aims which allow the form of work to emerge through playing with ideas, finding a pattern and shape within the writing.

> *"For John Cheever, there was a painterly sense of 'shape': knowing when a story was right was 'a question, I guess, of trying to get it to correspond to a vision. There is a shape, a proportion, and one knows when something that happens is wrong... I suppose that [with] anyone who has written for as long as I have, it's probably what you'd call instinct. When a line falls wrong, it simply isn't right'."*

Discoverers emphasise process: writing is viewed as a way of thinking and a "way of knowing". A *discoverer*'s relationship with language is subjective; they engage with the medium of language to find ideas, and have a sense of being 'acted upon' by the medium.

> *"[Quoting Russel Hoban] 'I'm not in the business of making clockwork novels which go from A to B when you wind them up. I'm at the service of the material that enters me. It takes me where it wants to go, and I might not know why I'm going there'... Evidently there is amongst some literary writers a sense of* being used *by language. Writers sometimes feel that the ideas for what they finally write have existed in their entirety prior to their conscious awareness of them, awaiting discovery... It is understandable that such accounts smack of mysticism to those whose experience of writing is quite different."*

(In his book, On Writing [King 2001], Stephen King describes his similar belief:

> *"...stories are found things, like fossils in the ground... Stories are relics, part of an undiscovered pre-existing world. The writer's job is to use the tools in his or her toolbox to get as much of each one out of the ground intact as possible."*)

Language is experienced as concrete and material, with externalisation and physical revision critical to the writing process.

> *"For Discoverers, visible, physical revision is of central importance, and writing is a way of thinking. Theirs is, to borrow W.B. Yeats' phrase, the 'thinking of the body': thought in spatio-temporal action. Such bodily thinking is often associated with art, but since Maurice Merleau-Ponty, phenomenological writers have emphasized the primacy of the body in everyday life, in clear contrast to the rationalistic emphasis on the mind. Whether or not thinking is sensed as a 'bodily knowing', revision is a* physical act *for Discoverers."*

Chandler concludes:

> *"...it is possible that Planners also 'revise' extensively, having interiorized writing to such an extent that such revision is largely mental rather than physical, making them less dependent on the visible word than Discoverers. Stephen Witte, an evident Planner, argues that Planners perform mental revisions on 'pre-texts'. Suggesting that Planners revise in their minds may seem to reduce the usefulness of any descriptive distinction between Planners and Discoverers. However, the need of Discoverers for physical revision may be the difference that makes the difference. Discoverers seem to need to play with their ideas and words as textual objects. Since they experience externalisation and spatialization as an integral part of their thinking they may be more sensitive than Planners to the characteristics of various writing tools and media."*

While his metaphors of language as tool-medium-environment may give insight into elements of my design-then-make, design-through-make and make-as-design categorisations, in terms of individual designers' relationships to their materials what is most significant is his assertion that

> *"descriptions in terms of Planning or Discovery are not simply different ways of describing the same experience: they represent quite different experiences reflecting basic orientations"*

As can be seen from these descriptions, the two approaches Chandler identifies have strong similarities to the two approaches observed by Turkle & Papert in their study of programmers. Like Turkle & Papert's distinction between 'planners' and 'bricoleurs', Chandler's distinction between writers who experience language as a tool, a medium or an environment suggests a more fundamental difference between individuals than the models used by Schön, Louridas, Pemberton and Sharples: that for some practitioners, their 'conversational' involvement with artefacts may be more than reflection on external representations, that creation itself happens through engagement with mediating forms. Moreover, it suggests that the extent to which artefacts mediate experience is a factor of the relationship between the practitioner and the artefact, not an inherent property of the artefact itself.

Conclusions

This chapter has compared different models of dialogue which commentators from various disciplines have used to characterise the relationship between creative practitioners and the medium/artefacts with which they work, and examined the nature of individual differences in approach, if any, discussed by these commentators. This comparative review has identified literature from two quite different disciplines, writing and computer programming/epistemology, which describe fundamental differences between individuals in their approach to creative practice. Moreover, the differences described in each commentary are similar across a number of different levels of practice. Both Chandler and Turkle & Papert contrast two distinct approaches, 'ideal types' encompassing a number of 'dimensions of difference'.

The differences in approach identified by Turkle & Papert and Chandler can broadly be described in terms of the nature and extent of a dialogue between practitioner and medium, although the metaphors used by the two commentators are slightly different: Turkle & Papert describe the 'soft' or 'bricoleur' approach in terms of negotiation with the medium; Chandler's characterisation of the Discoverer-Planner distinction through different metaphors of engagement with the medium suggests an even stronger mediatory role for the medium in some practitioners' practice. Like Turkle & Papert, he stresses that these distinctions between approaches, although not absolute, are nevertheless significant:

> *"The spectrum of media metaphors... is perhaps useful in suggesting that to talk simply in terms of 'using' tools maybe as extreme a position as to talk solely of 'being used' by them: we both act on and are acted on by, transform and are transformed by, the media with which we engage (a phrase which I find more apt that 'use'). In the making of meanings both give and take are involved. Ends and means are not easy to disentangle. The* purposes *of a 'user' (we have no word for 'engager'!) not only shape but are also shaped by the* functions *of a medium. And mediating circumstances shift the locus of control. But noting the give and take of our engagement with media should not undermine the importance of differences which individuals experience in their relationships with media."* [Chandler 1995]

The characteristics of these different approaches appeared to correspond to the observations from my previous research, and the tentative ideas arising from the Artefact Study. This comparative review therefore suggests a model of diversity in design practice where differences exist between individual design practitioners which are more significant than variation arising from each designer's personal style, unique experience, or working context; rather they represent wholly different approaches to design, elements of which relate to the nature and extent of a dialogue between practitioner and medium. It therefore leads to the second part of the thesis of this research:

> *that individual practitioners experience different relationships with the artefacts they create and work with in their processes, and* ***that elements of these differences can be attributed to the nature and extent of a dialogue between designer and media.***

A systematic analysis of this literature, described in the following chapter, suggests the formal/concrete axis is an organising principle for differences in approach across disciplines and across a number of levels of practice. This analysis provides the analytical framework for an empirical investigation into whether the differences between practitioners identified in these other fields of practice could also be observed in two groups of 3D design practitioners, one working with digital media, and the other working with physical media.

7. Comparative study

The previous chapter drew on literature on creative processes from other disciplines - writing and computer programming - to propose that differences exist between individual design practitioners which are more significant than variation arising from each designer's personal style, unique experience, or working context; rather they represent wholly different approaches to design. These differences in approach can broadly be described in terms of the nature and extent of a dialogue between practitioner and medium, and encompass a number of 'dimensions of difference' visible across a number of levels of practice.

This chapter describes an investigation into whether the differences between practitioners identified in other fields could also be observed in design practice, therefore testing my thesis,

> *that individual practitioners experience different relationships with the artefacts they create and work with in their processes, and that elements of these differences can be attributed to the nature and extent of a dialogue between designer and media*

In particular, it is concerned with whether these differences could be observed in two groups of student 3D design practitioners from Glasgow School of Art, one working with digital media (final year postgraduate students on the M.Phil. in Advanced 2D/3D Motion Graphics - Figure 48), the other working with physical media (final year undergraduate Silversmithing and Jewellery students – Figure 49).

Design of study

Aims and objectives

This comparative study had two main aims: to establish whether differences relating to the nature and extent of a dialogue between design practitioner and medium could be observed within each group; and to establish whether similar differences could be observed within both groups. If similar differences in approach were observed within these two groups of 3D practitioners, a comparison of how each type of approach manifested itself in the material and digital environments could provide additional insight into elements of this relationship, arising from the similarities and differences between

these two environments (Chapter 4, ***Difference as a means of enquiry*** explains these different aspects of the method in more detail).

In order to achieve these aims, the study had also fulfil two primary 'structural' objectives: firstly, to establish the 'dimensions of difference' within groups, against which each individual's practice could be viewed; and secondly, to establish a basis of comparison between the two groups.

Subjects

The two groups of students participating were:

- 12 final (2nd) year students on the M.Phil. in Advanced 2D/3D Motion Graphics course at the Digital Design Studio, Glasgow School of Art
- 11 final (4th) year students on the B.A.(Hons.) Design in Silversmithing and Jewellery course at Glasgow School of Art

These students represent two groups of 3D practitioners suitable for this comparative approach. Although the first group work predominantly in a digital medium, and the outcome of the work is quite different, in a sense they too are 'designer-makers', wholly in charge of the process from initial concept to final outcome. (Comments from previous students on this course suggested that similar differences in 'global' strategy to those observed in my prior study of designer-makers [McLundie 1998], may also appear in their design processes.) While the practices may be different, they share similar 'traditional' design processes – 'design then make'.

Both groups were undertaking one full academic year of self-directed study, allowing a comparison of processes over time. The groups are similar sizes, and in both cases, nearly the whole year group took part. As the nature of the study is concerned with looking for dimensions of difference within groups, the small size of the groups was an advantage: I would have been reluctant to work with sample groups, as no basis for sampling had been determined at that stage.

Method

The design of the study incorporates all three principles that underpin the means of investigation used in this thesis: the comparative framework; the comparison of the individual against the collective (*difference*); and added insight from comparing phenomena which are similar-but-different (*distance*). These are reflected in the design

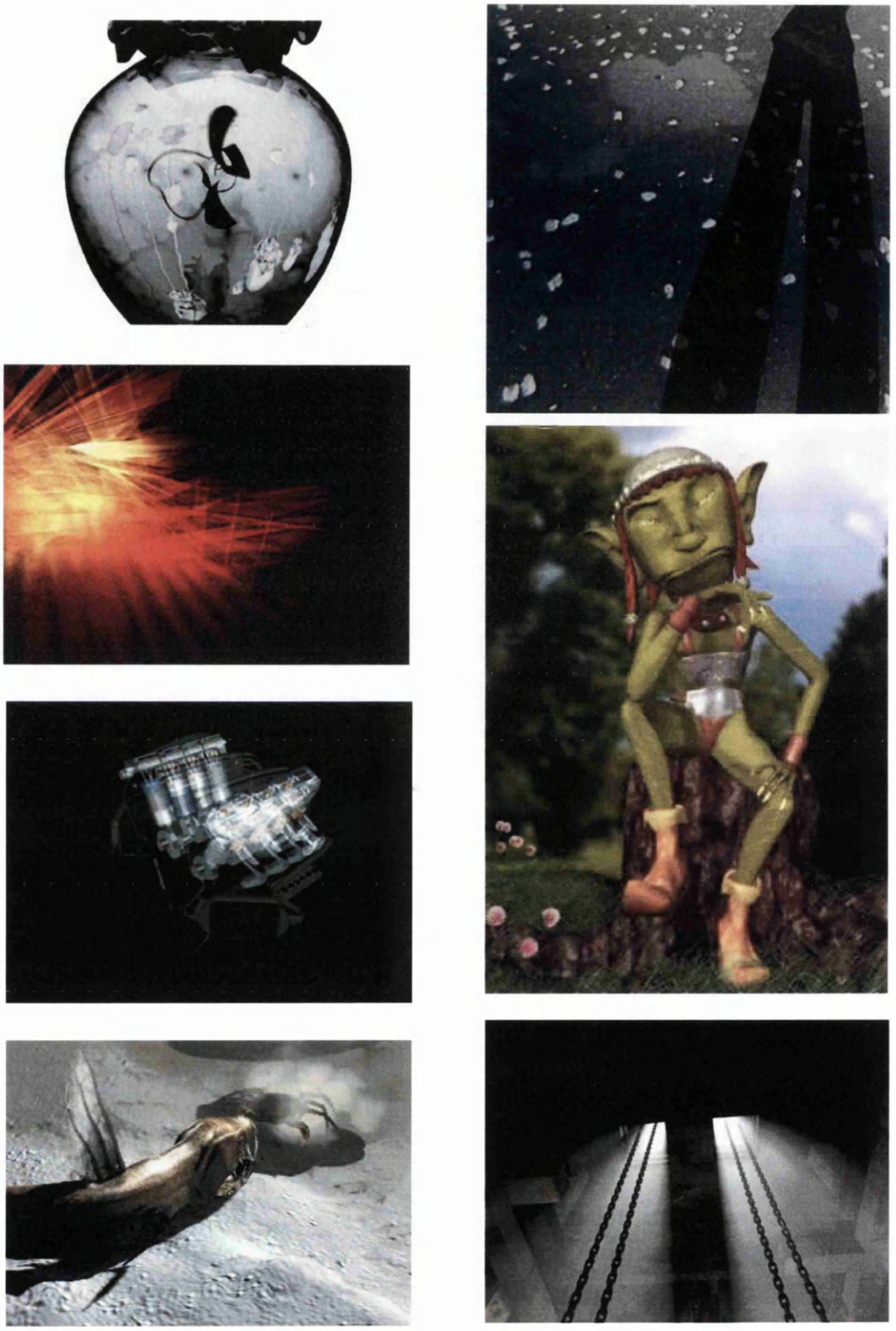

Figure 48: Still shots from a selection of the animations from the M.Phil. Degree Show

Figure 49: Selection of pieces from the Silversmithing and Jewellery Degree Show

of the data collection and analysis, where data from the individual designers in each group is compared and contrasted to build the collective picture against which individual differences can be observed; and in the choice of subjects: two groups of students in 3D practice, one working with digital media, the other working with physical media.

A study of 3D practitioners who have an established material practice and a substantial body of work in digital practice (see Chapter 8, ***Practitioner interviews***) confirmed that this comparative approach is both useful and valid: while aspects of their practice may have changed in the move from the material to the digital medium, their underlying approach has remained the same, and forms the foundation for their digital practice.

Two different stages and contrasting modes of analysis were used in this study. First, a comparative framework was derived from a systematic analysis of the literature discussed in the previous chapter, which describes differences in individual approach in terms of the nature and extent of a dialogue between practitioner and medium. This analysis proposed the formal/concrete axis as an organising principle for differences in approach across a number of levels of practice. In a preliminary analysis, each individual's approach was categorised using this comparative framework, and an assessment made of the distribution of approaches within each group.

The second stage of the study involved both an examination of the collective variation within each group across a number of 'dimensions of difference' which emerged from the data, and a comparison of these dimensions between groups. (The term 'dimensions of difference' refers to distinct observable differences in aspects of practice; taken together these may indicate more fundamental underlying variation between individuals.) The process of identifying these emergent dimensions partly referred back to the framework used in the preliminary analysis, but did not assume that the relationships between these dimensions would follow the inherently 'two-dimensional' structure of this original model. It also allowed for the possibility that other dimensions might emerge.

Comparative framework

In order to develop a comparative framework, it was necessary to undertake a detailed examination of a number of publications which, although they describe various characteristics of individual differences in approach, do not list them in detail and explicitly. The review focused on publications discussed in Chapter 6, (particularly those by Turkle & Papert and Chandler); but also included [Levi-Strauss 1966] and

[Ackermann & Strohecker 2001] as they describe similar differences in approach (and are discussed elsewhere in this thesis). The examination was undertaken to elicit the distinct features of each approach, both the main dimensions of difference already discussed and the more subtle variations observable across different levels and aspects of practice.

This systematic analysis of the literature suggested the formal/concrete axis as an organising principle for differences in approach across a number of levels of practice, and identified a set of around thirty 'indicators' representing those aspects of a practitioner's process that can be examined to determine the nature and extent of the dialogue they experience with the medium (see Table 6). Together, these form a comparative framework which can be used to collectively determine whether a practitioner's overall approach is categorised as 'hard', 'soft' (to use Turkle & Papert's terminology) or somewhere in between.

In this framework, the 'hard' or formal approach is characterised by control and conscious purpose. It has a focus on explicit goals, and the form of the work is predetermined through planning and working with representations. The medium is viewed as a means to an end, and is used as a tool to express an intent. Materials are chosen to suit the overall purpose, and viewed for their formal properties. Risk is minimised, and mistakes viewed as problems. The relationship with objects is objective, formal and distanced, with an approach to thinking characterised by analysis, abstraction and reasoning in terms of rules.

The 'soft' situated, relational approach is characterised by negotiation and a willingness to 'forget yourself' and be open to experience. A tacit aim allows the form of the work to emerge through engagement with the medium. The medium is viewed as interlocutor, with unexpected events viewed as part of the process of negotiation. The practitioner works with the materials to hand, which are viewed for their concrete or tangible properties. The relationship with objects is subjective, concrete and situated, with a contextual approach to thinking characterised by transparency and a mastery of details, learning through interaction, and concrete, bodily and intuitive forms of reasoning.

Although the framework is presented in terms of these two distinct and contrasting approaches, it is recognised that these approaches, and each of the thirty or so dimensions across which they differ, represent two ends of a spectrum. Individual practitioners may appear at one end of the spectrum, or somewhere in between, as is reflected in the design

Indicators	'hard', distanced	'soft', situated
Orientation		
1. goals (how do you know when you've got what you want)	explicit goal	tacit aim
2. direction in work	conscious purpose	open to experience
3. process and product	emphasis on product	equal or greater emphasis on process
4. form and content	separate	developed together
5. constraints, limitations	working to go beyond constraints, freedom of choice	working within constraints, choosing to work within constraints
6. understanding, mastery through...	analysis & abstraction	mastery of detail
7. by...	break down, decompose, analyse	reorganise, rearrange
8. relationship to context	abstract, formal, remote	situated, contextual
Medium		
9. ends and means, 'medium and message'	medium is means to an end, means separate from end	ends become means and vice versa, means becoming end, ends developed through means
10. what is the role of the medium - tool or medium?	expressing, communicating ideas using medium, monologue	developing ideas through dialogue with medium, medium as interlocutor
11. how do you relate to the medium?	acting upon the medium	engaging with the medium, being acted upon
Process	control / distanced	**negotiation** / situated
12. outcome - when you decide this	pre-planned, predetermined goals	unforeseen consequences, discovery, goals emerge through work
13. how is this accomplished, how does this exhibit (process)	planned in advance, premeditated?	collaborative venture with medium, through dialogue with the materials and means of execution, repertoire
14. decisions	pre-planned e.g. through abstractions	keeping options open
Work/outcome/form		
15. organisation, form, structure	imposed, predefined, (premeditated, as in thought about before?)	emergent, arranging, rearranging, playing with ideas, sculpting
16. achieved by	e.g. hierarchy, abstraction	finding 'pattern', 'rhythm', 'form'
17. level of engagement	abstract, with representations, models, metaphorical	working with the medium, literal
18. relationship to details, material	opacity, distancing from details	transparency, keeping in touch with the details
19. dealing with complexity	abstraction e.g. decomposition, design-by-drawing	growing incrementally
20. choice of materials	brought in as required by 'project'	working with what's there, well-known materials, chosen previously, heterogeneous repertoire - not specific to project, brought in as need arises
21. implications of this...		speak through the medium of things
22. use of materials	used for predetermined purpose	used in 'devious' ways, 'truth to materials'?
Attitude to Events		
23. attitude to unexpected effects, surprise, risk	control	"springboards for how to proceed"
24. attitude to mistakes, problems	misstep, to be corrected	essential part of process of negotiation
Ways of relating to materials, objects	distal (distanced)	proximal (close)
25. type of relationship	distant, objective	intimate, 'connecting' with them, subjective
26. boundaries	distancing yourself	immersing yourself, placing yourself psychologically in their 'space', 'down in there'
27. awareness	selfconscious, conscious purpose	unselfconscious, forgetting yourself, 'hear what the material has to say'
28. experience, bodily participation	objects as formal, abstract?	experiencing objects as tangible, sensual and concrete
Ways of seeing objects	formal	concrete
29. attributes	formal properties ('what they are for')	concrete or tangible properties ('what they can do')
30. physicality	as embodying abstract concepts (e.g. sprite – computational object with variables)	as material objects, esp. non-material objects (e.g. sprite – object attributed 'physical' properties – can cover one with another)
31. relationship to context	abstract, in terms of properties, rules	situated, in terms of relationships, with each other
32. transparency	working with concepts, abstract properties, transparent e.g. words being used to express an idea	working with signs, resonances, material e.g. words as textual objects
Ways of thinking		
33. ways of explaining things, tackling problems	in terms of rules	'reasoning from within', bodily thinking, putting yourself in the situation
34. learning about things, understanding things	analytic, dissection, wanting to know how it's supposed to work, learning before interacting with it	through its behaviour, learning through interacting with it
35. what think with	thinking with rules of logic (abstract)	thinking with objects (concrete)
36. ways of understanding	formal, abstract	sensible intuition, perception
37. internal/external	mental	bodily thinking e.g. writing as a way of thinking
	mental revision	*physical revision*
	composition takes place 'internally' then expressed	*writing to think, ideas come through the act of writing*
	internalisation	*externalisation & spatialisation*
Other/Emerging Themes		
38. finding a 'voice'		

Table 6: Comparative framework with 'ideal types' and indicators derived from literature

of the Analysis Sheet (Figure 50), and the results of the preliminary analysis using this sheet (Table 7).

Design of data collection and analysis

Interviews were chosen as the method of data collection because the aspects of practice with which I am concerned involve people's experiences, opinions, and emotions, as well as accounts of their own process. The artefacts they create and work with are integral to this process, but cannot represent the whole process; an approach which uses an analysis of artefacts to gain insight into each individual's approach was unsuitable in this case.

To provide the basis of comparison required between individuals, and within and between groups, an Analysis Sheet was developed from the comparative framework (see Figure 50). A range of choices – strongly 'hard', hard, neutral, soft, or strongly 'soft'- was provided against each indicator. Each subject's interview responses were to be retrospectively categorised and recorded using this sheet from tape (a null response would indicate that no information against that indicator was forthcoming from the interview). A sheet would be completed for each individual, representing their individual 'profile' against the set of indicators. By comparing the completed sheets, it would be possible to compare approaches between individuals and between groups.

Semi-structured interviews were used, to allow questions to be adjusted to suit the different contexts within which they were being asked, or where an interviewee interpreted a question differently than I had intended. The interview schedules were designed in conjunction with the Analysis Sheet to elicit responses that would give insight into each individual's approach. The questions were broadly similar for each of the three interviews, adjusted in response to a review of the outcomes of the previous set of interviews. Copies of the interview schedules are given in Appendix I.

Three sets of interviews were held, once per term (December, March and June), to allow an examination of the development of the students' work and their creative processes over time: this was the first opportunity both groups had had for a full year of self-directed study; it was likely that their working practices as individuals would mature over the year, as previous projects had been of a few weeks duration, and to a brief. (While a number of M.Phil. students had previous established processes and practices in other areas of art and design, this was their first experience of producing a digital animation of this length.)

Each interview lasted between 30-45 minutes, and students were asked, where possible, to bring examples of the artefacts they were producing, for discussion. Photographs of

Interview no. **Group:** M.Phil. / S&J **Date:**

Tapes used:
Questions: (start) (end)

Indicators	'hard', distanced	strong		neutral		strong	'soft', situated	tape ref	quote
Orientation									
1. goals (how do you know when you've got what you want)	explicit goal						tacit aim		
2. direction in work	conscious purpose						open to experience		
3. process and product	emphasis on product						equal or greater emphasis on process		
4. form and content	separate						developed together		
5. constraints, limitations	working to go beyond constraints, freedom of choice						working within constraints, choosing to work within constraints		
6. understanding, mastery through...	analysis & abstraction						mastery of detail		
7. by...	break down, decompose, analyse						reorganise, rearrange		
8. relationship to context	abstract, formal, remote						situated, contextual		
Medium									
9. ends and means, 'medium and message'	medium is means to an end, means separate from end						ends become means and vice versa, means becoming end, ends developed through means		
10. what is the role of the medium - tool or medium?	expressing, communicating ideas using medium, monologue						developing ideas through dialogue with medium, medium as interlocutor		
11. how do you relate to the medium?	acting upon the medium						engaging with the medium, being acted upon		
Process	control / distanced						negotiation / situated		
12. outcome - when you decide this	pre-planned, predetermined goals						unforeseen consequences, discovery, goals emerge through work		
13. how is this accomplished, how does this exhibit (process)	planned in advance, premeditated?						collaborative venture with medium, through dialogue with the materials and means of execution, repertoire		
14. decisions	pre-planned e.g. through abstractions						keeping options open		
Work/outcome/form									
15. organisation, form, structure	imposed, predefined, (premeditated, as in thought about before?)						emergent, arranging, rearranging, playing with ideas, sculpting		
16. achieved by	e.g. hierarchy, abstraction						finding 'pattern', 'rhythm', 'form'		
17. level of engagement	abstract, with representations, models, metaphorical						working with the medium, literal		
18. relationship to details, material	opacity, distancing from details						transparency, keeping in touch with the details		
19. dealing with complexity	abstraction e.g. decomposition, design-by-drawing						growing incrementally		
20. choice of materials	brought in as required by 'project'						working with what's there, well-known materials, chosen previously, heterogeneous repertoire - not specific to project, brought in as need arises		
21. implications of this...							speak through the medium of things		
22. use of materials	used for predetermined purpose						used in 'devious' ways, 'truth to materials'?		
Attitude to Events									
23. attitude to unexpected effects, surprise, risk	control						"springboards for how to proceed"		
24. attitude to mistakes, problems	misstep, to be corrected						essential part of process of negotiation		
Ways of relating to materials, objects	distal (distanced)						proximal (close)		
25. type of relationship	distant, objective						intimate, 'connecting' with them, subjective		
26. boundaries	distancing yourself						immersing yourself, placing yourself psychologically in their 'space', 'down in there'		
27. awareness	selfconscious, conscious purpose						unselfconscious, forgetting yourself, 'hear what the material has to say'		
28. experience, bodily participation	objects as formal, abstract?						experiencing objects as tangible, sensual and concrete		
Ways of seeing objects	formal						concrete		
29. attributes	formal properties ('what they are for')						concrete or tangible properties ('what they can do')		
30. physicality	as embodying abstract concepts (e.g. sprite – computational object with variables)						as material objects, esp. non-material objects (e.g. sprite – object attributed 'physical' properties – can cover one with another)		
31. relationship to context	abstract, in terms of properties, rules						situated, in terms of relationships, with each other		
32. transparency	working with concepts, abstract properties, transparent e.g. words being used to express an idea						working with signs, resonances, material e.g. words as textual objects		
Ways of thinking									
33. ways of explaining things, tackling problems	in terms of rules						'reasoning from within', bodily thinking, putting yourself in the situation		
34. learning about things, understanding things	analytic, dissection, wanting to know how it's supposed to work, learning before interacting with it						through its behaviour, learning through interacting with it		
35. what think with	thinking with rules of logic (abstract)						thinking with objects (concrete)		
36. ways of understanding	formal, abstract						sensible intuition, perception		
37. internal/external	mental						bodily thinking e.g. writing as a way of thinking		
	mental revision						*physical revision*		
	composition takes place 'internally' then expressed						*writing to think, ideas come through the act of writing*		
	internalisation						*externalisation & spatialisation*		
Other/Emerging Themes									
38. finding a 'voice'									

Figure 50: Analysis sheet

artefacts were taken in support of the interviews, but no separate analysis of these was undertaken.

It was unlikely that data for every indicator on the Analysis Sheet would be collected for each subject. One of the strengths of this method is that even if one aspect of the framework or data collected is weaker, there will still be data from the other areas to

support the analysis. Indeed, an interviewee's silence on one aspect may be as significant as another's mention of it:

> *"In studying the nature of mediation, a powerful technique is the search for that which is* excluded *(or 'conspicuous by its absence'), and that which is taken for granted (which goes without saying)"* [Chandler 1995]

A pilot interview was carried out to test the Analysis Sheet, with an M.Phil. student from a previous year. Some small adjustments were made where the interview had clarified distinctions between categories, but otherwise the sheet appeared to work well.

Preliminary analysis

After the first set of interviews was complete, a preliminary analysis of the data was made in line with the original design: using the Analysis Sheet to code each interview directly from tape (an example of a complete Analysis Sheet is given in Appendix J).

A number of difficulties were encountered during this analysis. Some of these arose from the nature of the conceptual framework, which gives an abstracted view of individuals' processes against 'ideal types'. This abstraction is inherent from the way the framework was created: firstly, the indicators were derived from quite different fields of practice; secondly, although the indicators are specific in focus, they must be sufficiently generic in application to accommodate the different areas of practice being studied. There may not be a direct correlation between the concrete manifestation of the approaches in a particular context e.g. preplanning the form of a program using a structured approach of decomposition, hierarchy and black-boxing; and preplanning the form of an animation through storyboarding. Nevertheless, it is the act of preplanning, rather than letting the form emerge, that is of interest in this study.

Because of the abstract nature of the categories, and the richness of the data emerging from the interviews, in certain cases it was difficult to decide to which of two categories data was relevant. In other instances, it was not easy to see in which category data directly relevant to the study should fit: for example, some of the Silversmithing and Jewellery students worked with physical materials when they were designing, but they were using them as a means of manipulating 3D form, rather than working with the material to see what it would do. (This is discussed later in this chapter.)

The initial intention had been to code the interviews directly from tape, but this exacerbated the difficulties encountered. With no written data it was practically impossible, where there was any doubt about suitability of categorisation, to refer back to

decisions made earlier, or view a spectrum of approaches to make comparisons that would give insight into the categorisations.

The richness of the data generated from the interviews exposed the unspecified nature of the spectrum of responses under each category as too subjective. This, combined with the problems identified above – the abstract nature of the categories, and the inability to refer back to data – made it difficult to ensure that similar data were categorised in similar ways between subjects.

In the end, for most participants notes were made from the recording of each interview, and used to code retrospectively against the Analysis Sheet. As a consequence of these difficulties, results from this stage could only be relied upon to give an approximate indication, and an 'abstract' view of approach; nevertheless the results obtained were encouraging. They showed that differences, broadly along the lines of enquiry, exist within both groups and revealed a similar spread of approaches within each group (see Table 7).

	'hard'	not definitive	'soft'
S&J	3	5	3
M.Phil	5	2	4

Table 7: Different approaches within and between groups as revealed through preliminary analysis of the data

The category 'not definitive' indicates that across the range of indicators for which information was obtained for each individual, the overall profile did not clearly belong to either of the main approaches. While some difficulties in categorisation as discussed above may have exacerbated the situation, generally this phenomenon is to be expected when using the concept of 'ideal types':

> *"When we say that hard and soft approaches are ideal types, we signal that individuals will seldom conform to either exactly, and that some will be so far from both that it is impossible to assign a type. In other words our contention is not that the attributes in a cluster are exactly correlated, but that each approach has internal coherency in the way that a stable culture is coherent"* [Turkle & Papert 1990]

These preliminary findings have two main implications for this study: firstly, useful comparison between groups is more likely, as similar approaches appear in both groups, i.e. one group is not heavily skewed towards one approach, and the second heavily skewed towards the other (it is particularly interesting, given that 3D modelling software might appear to favour an explicit approach, that 'soft' approaches appear in this

context); secondly, the broad spectrum of approaches within each group are likely to provide good 'coverage' of the collective picture against which individual approaches can be examined.

Despite the weaknesses in this preliminary analysis, the data emerging from the interviews indicated that there were significant differences between individuals along a number of dimensions, within both groups. For the next stage of analysis, the approach was modified to allow this information emerging from the data to inform the findings: not only to deal with the difficulties I had encountered, but as it became clear that valuable insight into the suitability of the original conceptual model could be obtained from examining where and how the data didn't fit well within the framework.

Analysis of emergent collective variation

To maintain the principles embodied in the method, any modified approach had to enable a collective picture to be built up against which an individual's practice could be viewed; maintain a basis of comparison between individuals, and within and between groups; and allow me not only to work around the original conceptual framework, and comment on its suitability, but also to draw on the detailed information obtained from the interviews. One of the main differences was therefore to work from transcriptions of each interview, as opposed to coding directly from tape.

This revised approach identified the main 'dimensions of difference' emergent from the raw interview data (still focusing on the underlying themes of the original framework, but allowing other relevant themes to emerge). Unlike the preliminary analysis, which focused on the individual, this analysis examined the collective variation within each group, by inspecting the variation of each dimension across individuals within the group. This was established primarily from the first set of interview transcriptions, with additional input from the later sets.

Although the revised approach was different to that originally envisaged, it is valid within a phenomenographic context:

> *"All of the material that has been collected forms a pool of meaning. It contains all that the researcher can hope to find, and the researcher's task is simply to find it. This is achieved by applying the principle of focusing on one aspect of the object and seeking its dimension of variation while holding other aspects frozen. The pool contains two sorts of material: that pertaining to individuals and that pertaining to the collective. It is the same stuff, of course, but it can be viewed from two different perspectives to provide different contexts for isolated statements and expressions relevant to aspects of the objects of research...*

> *One particular aspect of the phenomenon can be selected and inspected across all the subjects, and then another aspect, that to be followed, maybe, by the study of whole interviews to see where the these two aspects lie in the pool relative to the other aspects and the background... This process repeated will lead to vaguely spied structure through and across the data that our researcher/learner can develop, sharpen and return to again and again from first one perspective and then another until there is clarity"* [Marton & Booth 1997]

The next section of the chapter deals with the first of these aspects: the collective variation observed within the two groups.

Dimensions of difference: digital media

Context of study

The M.Phil. in Advanced 2D/3D Motion Graphics is a two year masters course run by the Digital Design Studio at Glasgow School of Art. It takes graduates from a diverse range of backgrounds: past examples have included astrophysics, psychology, literature, product design engineering, mechanical engineering, fine art photography, sculpture and theatre design. In first year, students learn 3D modelling and animation techniques, including lighting and sound. In the second year, the students work on an Individual Programme of Study (IPS), a self-directed research project relating in some way to their first degree. The outcome of this IPS is a short animation, around 3-5 minutes long, and a dissertation. The group participating in this research comprised twelve second-year students working on their IPS.

The course follows standard practice in the animation industry. After the research and conceptual stage, a storyboard is produced: a 2D sequence of 'shots' which forms the basis for subsequent 3D modelling, lighting and texturing, animation, rendering and compositing. In industry, these stages are usually carried out by different people working on the one animation, and the storyboard forms a common point of reference for what will happen, and how long the action will take. It is a planning tool, both in terms of the form of the work, and as a basis for scheduling what needs to be done.

On the M.Phil. course each student does everything, from concept work to final piece of animation, and there is much more scope for individual approaches to emerge. It is within this context of individual practice that my research is based, and where clear differences in approach could be observed within the group. These differences exist across a range of different dimensions, the most significant of which are described below.

Planned or emergent approach?

One of the most striking variations in the group was the role of the storyboard in their process, relating to a preference for a planned approach, where the form of the work is predefined before beginning work in the digital medium, or an emergent approach, where decisions are made as the work progresses.

Producing a storyboard before starting any modelling is recommended practice, and for some students it played a crucial role in their process:

> *"I'll work on the storyboard, work out exactly what I want to include, and that allows you to judge your time limits within the piece as well, 20 seconds for this shot here, 30 seconds for the next shot..."*[9]

The student above produced a visually very detailed storyboard. Some storyboards were less detailed or more 'schematic' – "...not a storyboard in terms of how you see it, necessarily... it's a sequential storyboard rather than by shot or perspective..."[10] - but still a tool used to plan and guide what would happen. Others found that producing a storyboard didn't suit their way of working:

> *"I have noticed other people turning up upstairs with these beautifully drawn storyboards, and I still have lots of pieces of paper with lists on it, and boxes of things... I prefer that, I think it's more flexible... I find it incredibly hard to work to a storyboard, I don't like it, I think it's too restrictive, it really doesn't support the way that I work at all... I prefer leave it more open to interpretation, so I can take that and change it. And I think things have to change."*[11]

One student didn't produce any storyboard, as her abstract piece of work was developed through exploring the effects that could be achieved with the medium:

> *"...there's so little structure to the way I work... I know the basics of what's going to be in it but I can't do a storyboard because the program is so large and you find new effects all the time, you're like, 'oh I'll do this and I'll do that', and that's my approach"*[12]

In my original conceptual framework, I had equated an emergent approach with a 'dialogue with materials', but it has become apparent that this is not an adequate distinction. In this group, two forms of emergent approach appear: one where, although decisions are made as the work progresses, it is more a 'monologue', a dialogue with yourself about a conceptual idea; and one which can indeed be viewed as a dialogue with the digital medium.

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[9] Digital student 2, interview 1
[10] Digital student 6, interview 1
[11] Digital student 5, interview 1
[12] Digital student 7, interview 1

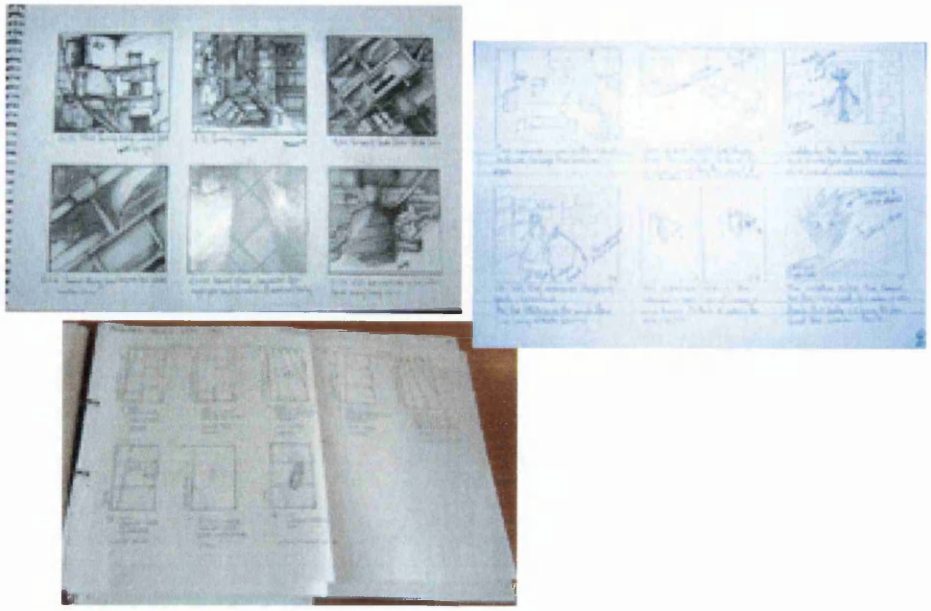

Figure 51: Examples of storyboards

Role of the medium

This distinction between emergent approaches relates to the ways in which the students viewed the role of the digital. Broadly it can be described as a preference for 'speaking with things' or 'speaking though things'. At a conceptual level, there are those who view the medium very much as a means to an end:

> *"I see it as a tool like anything else. The way I look at a pencil and a bit of paper, they're just tools to produce something that's in my head, and I see the computer as the same"*[13]

and those for whom the means become the end:

> *"...rather than using the editing and compositing as a means to an end, to follow a story, I want the compositing and the editing to actually become the end in itself, and through playing around with that, you've got a whole plethora of interpretive possibilities."*[14]

A similar distinction concerns the choice of materials: whether the materials are chosen to suit the design, or whether the design emerges from what materials are available. In the digital case, the medium would seem to a large extent to be predefined, being the software. But variation can be observed in the working processes of this group, for example in individuals' attitudes to the compositing stage of the work. After modelling (building) objects and animating them (giving them movement) within the scene, the

[13] Digital student 10, interview 2
[14] Digital student 6, interview 2

rendering process produces sequences of 2D still images with full colour, texturing, lighting as created. The compositing and editing stages of the process allow you to combine these sequences of still images with other 2D images and sound, and manipulate them in various ways, to form the final animated sequence. The role of this stage varied between students:

> *"...some people have very fixed ideas of what it is that they want to do, and where they want to go, and they know exactly what shots they're gonna use... for them the editing process will be just putting them all together. Whereas I'm interested in the different interpretations you can get through how they're put together... I'm using Maya strictly as a tool, in order to build the elements that I need... Because I am very much more interested in the editing/composing side of it"*[15]

Comparing this comment with the next underlines the difference between 'emergent' approaches. Although in each case the student is playing with the materials at hand to see what effects can be achieved, the above project involves ideas and concepts, a 'dialogue through the medium', while the next student is indeed having a 'dialogue with the medium':

> *"I don't really have a clear idea of a storyboard, I just go and make it... I haven't thought, right, I need to build a room so I need to know this tool, this tool, this tool, I've just went in and thought, right, what can I play with, and what can I produce. And then through each render, each result, I'll assess what else I want to do after that."*[16]

In the 'soft' approach embodied in the framework, where the choice of materials 'determines' the design, the systematic analysis of the literature suggested that this may take various forms: selecting from an existing and project-independent 'repertoire'; 'gathering' materials together, from which the work then emerges; or 'working with what's there'. Elements of the latter two can be seen in the above 'emergent' examples, and 'gathering' in the next, in which a student describes how elements of his approach have transferred from the material to the digital environment:

> *"...I suppose it's the philosophy, the way of thinking that it carries on rather than the actual found things... you can't walk about looking for bits of animation and pick them up and roll them into a new animation, but definitely the way I approach things is to research-wise get all the things I think I need, and then sit down and just get on with it, and put all the bits together, and if it doesn't work like that then take it apart and put it back together another way. That way of doing things definitely carries on."*[17]

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[15] Digital student 6, interview 2

[16] Digital student 7, interview 2

[17] Digital student 3, interview 1

Control and risk

Another dimension of variation is apparent from examining students' attitudes to unexpected events in their work, or the inevitable problems which they encounter in their processes. Although these are different cases (the former open up choice, the latter reduce it) and were examined separately in the study, they broadly relate to a preference for control, or a willingness to be open to 'surprises', or take a different direction in their work. Differences encompassed both the ways in which the students react to things when they occur, and also what 'preventative measures', if any, they take.

One dimension of variation in this context is how much students are willing to do to try and get round the problems they encounter. Some students liked, as far as possible, to have their work as they had intended it to be:

> *"If I've got something in my head that I want to get down then I'll keep chipping away until I get it... And I don't scrimp, or take short cuts or just miss things out, because I can't do it... if I can't do something, I'll sit and figure out how to do it"*[18]

Some were content to solve the problem if they could, but if not, to take a slightly different direction in the work. For others, while planning their work was important, they were open to changing their work in response to unexpected events if the outcome was better.

Another dimension is the measures, if any, students took to ensure that unexpected events or problems did not arise in the first place. These ranged from consulting with tutors before starting to ensure what they wanted to do was possible, and the optimum way of achieving it; to trying to "foresee as many technical shortcomings" by learning to use the tools that they anticipated they were going to need, "So I know quite quickly if I can do it that way and if I can't then I'll find another way to do it".[19]

Others were happy to play and experiment with the tools while they were producing the work to see what effects they could get. For one student, unexpected events formed the whole basis of her work:

> *"somebody'll introduce you to a tool, and you'll start playing about with it... to get certain effects, and you'll think, 'oh, that looks pretty good', and then you'll combine it with another tool and then everything just starts going"*[20]

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[18] Digital student 10, interview 3
[19] Digital student 10, interview 2
[20] Digital student 7, interview 1

Ways of relating to objects

Other differences reveal aspects of a student's preference for a close or distant relationship with the objects they work with. Unlike the differences in approach already described, some of these differences become explicit only when they become apparent to the student: for example when they experience difficulties with the software, or express preferences for using one technique over another. The opposite viewpoint is rarely expressed by the interviewees, but can be inferred from the lack of explicit reference, and revealed by examining the collective variation across the group.

The following example illustrates one student's approach to learning the software. In their second, self-directed year of independent study, a predominant way that students do this is by reading manuals, running software tutorials, buying specialist books, or getting help from the Internet or one another. However some prefer to work much more directly with the software, learning through interacting with it to see what it will do (as distinct from experimenting with the software to test their understanding of theoretical principles):

> *"I should actually sit down with tutorials and the books, and say right, how does this tool, this manipulator or this modelling thing, how does it like to be treated, how does it like to be used, why does it do that when I press this? But I tend to just jump in there and go, well I want this shape, I'll pull that and see if that works, it's a bit more trial and error... I don't really understand how it works, I just know that it works so, I use it because trial and error's got me there."*[21]

These different approaches are in line with those identified by Turkle & Papert: 'learning by interaction' and 'learning through understanding'. The above example also illustrates both a distinction in the ways which the students 'saw' things – formally, as 'what they are for', or concretely, as 'what they can do'; and a subjective, as opposed to objective, relationship with the software.

Some students were driven by a conscious purpose in realising their work: "Same way as drawing, if you put a line on a bit of paper then you should really have a reason why it's there. And if you don't then it shouldn't be there."[22]. Others were more willing to forget themselves, and become immersed in the work:

> *"I always try and get really involved in a project, in terms of it becomes something I'm thinking about a lot of the time. And what I like about that is you're not being too careful about where it's going or how you're going to do it, you just get lost in it... every now and then something turns out really well, and totally unexpected from how*

[21] Digital student 3, interview 1
[22] Digital student 10, interview 2

you expected it to turn out... it seems like you've got this thing from nowhere, just like, 'wow, what's that?', I like that."[23]

While these characteristics relate to a 'mental' closeness or distance, another group of characteristics relate to an almost 'physical' closeness. These are frequently mentioned in students' comparisons of physical and digital media, and appear to comprise a number of distinct elements. Although these are very closely related (particularly when dealing with physical objects), for the purposes of my research, which aims to dissociate ways of working and knowing from their physical context, they are worth identifying individually. They include: being able to manipulate things directly; immediacy and responsiveness; 'physicality' of objects; physical, hands-on interaction; and tactile appreciation and sensation.

A number of students expressed preference for, or ease of working with, different software packages or physical objects, by the ability to manipulate things directly. Many found the 3D modelling software distancing, and themselves frustrated, by the often laborious processes required to do things. An aspect closely related to this is the immediacy and responsiveness of the software – in Maya particularly the time between 'cause' and 'effect' can be anything but instantaneous, and this was definitely a drawback for a number of students, who liked to get immediate feedback:

"the sheer time that it takes to do things in Maya, and you do just want to grab the computer and just push and pull and squish and then go, 'Right, that's what I meant' but you can't do that."[24]

This was one reason why some students preferred the editing and compositing stage:

"When you work in the compositing (software)... you get kind of instantaneous results, and you can build layer upon layer upon layer, and then take it all off again, delete as much as you go along as you put on. Whereas in Maya, you have to wait, 24 hours till it's done its render, until you can even see the effects of what you've done... When it's actually animating, you can't even tell that till it's rendered and then you could find that you've just wasted three days. And I find that very very frustrating, whereas in the compositing side of it, it's a much quicker result, and I feel much more comfortable using it"[25]

Other students found problems when manipulating the digital materials didn't 'make sense' in a physical way:

"... you can't get your hands in there... it doesn't work the way you would think, 'oh I'm going to do this and therefore I should just do that'... you're forced to go through

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[23] Digital student 3, interview 1

[24] Digital student 6, interview 2

[25] Digital student 6, interview 2

steps to achieve something, which are really unnatural if you work with your hands a lot, it just doesn't make any sense why you should have to do that..."[26]

A theme running through all of the above is the lack of physical, 'hands-on' interaction', but this does not preclude a sense of tactile awareness and appreciation. While software in general is quite different to working with physical objects, some students were conscious of a sense of tactility and the enjoyment of working with materials in this digital context, although,

"...it's hard work, and especially using Maya, it just gets so frustrating. But the actual, seeing something happen and seeing the things that you want, or even happy accidents perhaps, or just experimenting with it... what used to be the actual tactile touching of materials and just the enjoyment in that respect, you still have through the computer, 3D. But I think you have to go through a real pain to get there... There's much more planning, there's so many calculations that you have to put in..."[27]

Relationship between thinking and doing

One dimension of variation which appears to run through and across the data on many levels, is a preference for 'internal' or 'external' ways of working. Some students could clearly visualise their work in their 'mind's eye': for them, thinking and doing appeared to be separate, and they used the medium to express an idea that was already clear in their mind: as one student described it,

"it's like a film you have in your head, like you've already seen it on the television and you're remembering it."[28]

For others, ideas emerged through working with external media:

"I'm not the type of person that can sit down with a piece of paper and sketch a character, or an environment, I have to have an area that I can look at and say well, I quite like this area of this building, this windowsill here and this doorway... That's the way I'm driven more than anything, a lot of going about with digital cameras, taking photographs and stealing doorways here and there... that's how I can compile my work... I've never been the type of person that can just produce an idea out of their head."[29]

Summary

In the group of students working with the digital medium a number of dimensions of variation can be observed in different aspects of practice. These include a preference for a planned or emergent approach; a preference for control, or a willingness to take risks; those who see the medium as a means to an end, and those for whom the means become

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[26] Digital student 1, interview 2
[27] Digital student 5, interview 1
[28] Digital student 1, interview 2
[29] Digital student 2, interview 1

the end; distance or closeness in relating to the artefacts they create and work with; those for whom thinking and doing are separate, and others for whom thinking happens through doing.

Dimensions of difference: physical media

Context of study

The second group of students who took part in this study were eleven final-year B.A. (Hons.) students on the Silversmithing and Jewellery course at Glasgow School of Art. This course accommodates a broad range of students, from those who want to focus on design for industry to those whose aim is to become studio jewellers with their own workshop.

While the course is largely focused on the use of (particularly precious) metals, and the skills and techniques necessary to work with them, it embraces the broad range of materials and techniques used in contemporary jewellery and silversmithing, including wood, plastics, and found objects (as can be seen in the work of the students in this study). The 'preciousness' of the objects produced does not derive solely from the inherent value of the materials from which they are made, but from the unique skills and approach of each designer-maker.

The course combines a foundation of technical and practical skills with strong design and critical elements. This ensures that those wanting to focus on design have a solid grounding in material knowledge, while the design content provides a rigorous basis for exploring ideas to those whose natural inclination is to the making aspects of the discipline. In Second Year, students are given a programme of projects predominantly geared towards acquiring a range of basic technical skills, with appropriate elements of drawing and design. Third Year is structured around a programme of design projects (including external competitions), some of which are then made; there are also opportunities for learning additional techniques including enamelling, lathe work and acrylics through specialist workshops. At the end of Third Year/beginning of Fourth Year each student proposes an individual programme of study for their final year of self-directed practice towards producing a body of work for the degree show (a gallery exhibition of work) at the end of the year. For degree assessment, each student is expected to have, as well as the final body of work, supporting material including research, sketchbooks, technical samples, and presentation drawings (rendered

representations of pieces as they will look when finished, used to convey designs to a client, for example).

The course includes both design and making aspects, conducted in the design studio and in the workshop, and while there is certainly no prescribed approach for final year students, the model 'process' underpinning the course structure is 'design then make'. This approach has a strong practical basis in this field. In design for production, 'designer' and 'maker' are usually different people, therefore the design has to be largely worked out before it is passed to a craftsperson to make. (Although the craftsperson will be given a fully specified design to make, there will usually be elements between this and the realisation of the design which remain unspecified (intentionally or unintentionally), leaving scope for the craftsperson to exercise their skill in approaching the making in ways most appropriate to successful realisation of the piece.) If designing to commission, it will be necessary for the customer to agree the design at least to a certain extent before making commences (unless you are very well-established and people are prepared to accept whatever you produce!). If you are working with expensive or precious materials, knowing exactly how much you will need, and how you are going to make the object before starting, helps avoid costly mistakes.

Within this overall design and make process, there are a range of typical elements that may be included:

- research (e.g. gathering source material/technical sampling)
- design exploration/brainstorming (generating a number of ideas)
- design development (developing a design idea in more detail)
- technical specification of design (fully specifying a design for making)
- presentation of design (a rendered representation of a finished piece, usually before the piece is made)
- final piece

Many of the design stages above are typically carried out through drawing, often in a sketchbook or series of sketchbooks, but they may also, or alternatively, be achieved through the use of physical materials: samples, mockups, models, and prototypes.

Individual approaches to practice

Students in their final year work to an individual programme of study, agreed with tutors at the beginning of the year. The process and production of work is each student's own responsibility and, as for the M.Phil. group, this allows individual approaches to emerge.

Many of the students interviewed felt they were finally able to find *their* way of doing things, as this year gave them the opportunity to let their own processes develop and mature. In previous years each project had been to a brief, over a relatively short period of time, and with specified outcomes. While the students were glad to have this opportunity, it was, for some, quite a daunting experience.

Many of the students in the group were quite adamant that there wasn't a 'right' way of going about things, in contrast with a perceived ideal 'design process' that was taught within the structure of the course. The students themselves identified different approaches within the group, mainly along the lines of whether individuals worked predominantly in the studio, or in the workshop. Certainly in my experience as a student on the course some years previously, there seemed to be quite clear differences between individuals' approaches to producing the body of work for the Degree Show: those who were design-led, and those whose work was driven by, and based around, the exploration of particular techniques and processes.

Relationship between design studio and workshop activities

Variation concerning the relationship between studio work and working at the workbench could be seen in this group of students. Yet as became clear on more detailed examination, a superficial distinction between those who primarily design in the studio and those who primarily 'make' at the bench, or between those who are design-led and those whose work is based around particular techniques, misses more subtle variations in students' processes.

The nature of the relationship between these two activities included the extent of each activity; the integration of these activities (how much they influence one another), and the direction of influence between them (which influences which). Some students liked to keep them separate, quite distinct activities; for others there was a closer relationship between them, where students would work in their sketchbook while working in the workshop.

My initial categorisations of approach from the interviews, involving the above three elements, related to where the design or 'form' of the piece of work appeared primarily to take place:

- design primarily in sketchbook, then make
- design primarily in sketchbook, refine through 3D drawing, then make
- design primarily in sketchbook, informed by technical sampling at bench

  - technical sampling at the beginning of the year, then working within those techniques/material constraints
  - technical sampling as required throughout for pieces
- design evolves between sketchbook and workbench
- design primarily through working at bench, then recorded in sketchbook
- design primarily through working with materials ('making')

This spectrum reveals how for many students in the group, although working at the bench played a more significant role in their processes than simply to make up a fully specified design, their use of materials in each case was different, and certainly not all equivalent to my earlier categorisation of 'make-as-design' or 'negotiation with materials'.

Closer examination showed that the roles of drawing and materials were not the same for each student, and revealed more subtle variations, which are discussed below.

The 'sketchbook'

In my original distinctions about the relationship between working in the studio, and working at the bench, one aspect was the 'direction of influence' between studio and workbench. In the traditional 'design then make' process, a design would be worked up through sketchbook work/drawing, then made. For a number of students in the group, this appeared to be inverted: either the sketchbook/drawing was used to record ideas as they occurred at the bench; or more extreme, some students used the sketchbook 'after the fact' to record work that had been done at the bench. The latter in particular was seen as in contradiction to the expected approach: students talked about being 'found out' in this aspect of their work.

This may partly be due to students' perceptions of 'the sketchbook', and their relationship with it, which varied within the group. Some students considered the sketchbook a very important part of their work; some said they didn't find working in a sketchbook particularly useful themselves, but did it because it was required; and others didn't feel 'at ease' with their sketchbook, saying that they viewed it as primarily for other people, or that they didn't engage with it:

> *"I think often, I see the sketchbook as for someone else. I don't know if it's just because I'm studying just now, and I really feel like this is what's got to tell people what I'm doing, rather than me using it- 'Cause I almost feel it's got to communicate to other people rather than just to me."*[30]

[30] Material student 1, interview 1

Figure 52: Excerpts from students' sketchbooks

While sketchbooks may be an integral part of many designers' working process, in this context they also form an important element of assessment for the degree: a student is expected to maintain sketchbooks during their process, not only as a means of developing the work, but in a significant sense to illustrate this development to tutors and assessors. Many of the students were very aware that their sketchbooks were not 'for their eyes only', and for some, this appeared to influence their relationship with it. Some students

talked about 'producing' a sketchbook, almost as something they must be seen to have, rather than because they found it useful in their own processes. Some felt that it had to have a certain quality of drawing in it, or a certain 'look' to it. The student quoted above used separate sheets for the rough drawings which she found useful, and then copied these into the sketchbook in a more 'finished' version. In contrast to this, another student who very much enjoyed working in her sketchbook, and who used it to stimulate her own thinking and ideas, felt that this effort was looked upon somewhat askance by others in the group:

> *"I love designing, and I will sit and design for hours, and I will sit and draw for hours... I think maybe I'm different because of the amount of design work I do, and sketchbook work. I think I'm the only one that enjoys it (laugh). I always get scoffed at because of my sketchbook work that I do. Everyone's like, 'no, I don't agree with that, I think, you know sketchbooks are just books that-' 'Cause I try and make mine interesting for myself so I stimulate myself when I'm looking at them, so I think people think it's a bit of a show."*[31]

The nature of sketchbooks is personal and individual. Sketchbooks can be, and within the group were, used for a number of different purposes including collecting source, logging technical samples, brainstorming (both words and drawing), writing, design development, technical notes, 'to do' lists, collage, finalising design ideas, and more. A student may use general sketchbooks, keep a sketchbook for each activity, or use a separate sketchbook for each individual piece. They can range from notebooks, bound loose leaf pages, to books of samples, or books of source (see Figure 52).

A student's perception of, and relationship with, their sketchbooks may be therefore quite different to their relationship with drawing. A student's use (or non-use) of sketchbooks can give insight into ways in which they organise their work, and the relationship between different elements of their work. It has not been possible to pursue this aspect in the current study, but it could form an important part of any future research in this area.

Use of drawing

Drawing was used for a range of different activities within the students' processes, and with a number of different purposes: as a means of recording, 'ideating', analysis, and communication and presentation to others.

Types of drawings do not fit exclusively into these categories: for example a designer may use technical drawings to work out how something will function, but they are also

[31] Material student 2, interview 1

used to communicate the details of a design to others. Also, people may use the same types of drawing for different purposes.

In this study, drawing was used for generating ideas, through brainstorming and other techniques: some students found this aspect particularly useful when they 'got stuck', to get going again.

A significant use of drawing, in this group, was for recording ideas: often rough sketches to note things down quickly. For some students this was very important for 'externalising' ideas: 'drawing down' ideas, "get down everything that goes on in my head"[32], "getting things out of my head"[33]. Others used drawing to capture ideas that arose at the workbench.

Drawing was used to explore and develop ideas, through investigating shapes and forms, for example, and stimulating further exploration, as described by the student above who commented on her comparatively greater use of sketchbook activity.

An important use for drawing, even among those students who worked a lot with materials in the design phase, was as an analytical tool: to work out aspects of a design or piece, or work through problems. One student whose designs arose to a large extent from combining physical elements, described how she used drawing as a 'thinking tool' in this respect. While most students in this group had little need to produce conventional technical specifications for pieces, some students did use drawing to work out detailed technical aspects of their pieces (Figure 53).

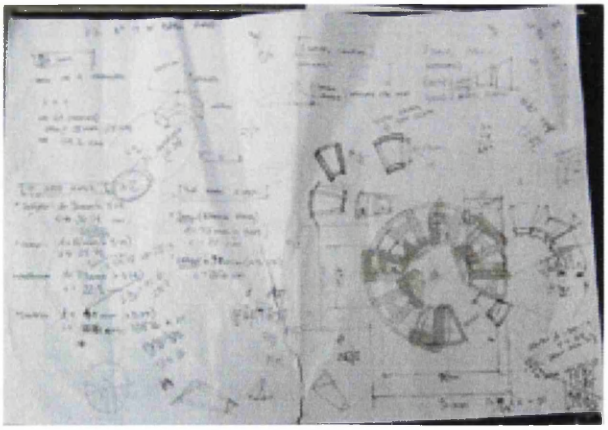

Figure 53: Example of technical drawing

[32] Material student 5, interview 1
[33] Material student 10, interview 1

Drawing is not solely a tool or medium for design, but also has a role in communicating ideas to other people. This may be formally, through presentation drawings (or in certain cases, technical drawings), or more informally, through sketches and design drawings. In the educational context of this study, both these elements are important. This role of sketchbooks has been discussed above, but presentation drawings also form an important part of the work that is assessed for the degree: students are expected to produce a number of presentation drawings illustrating designs for future pieces (Figure 54); this activity proved particularly challenging for some students for whom ideas emerged through working with materials.

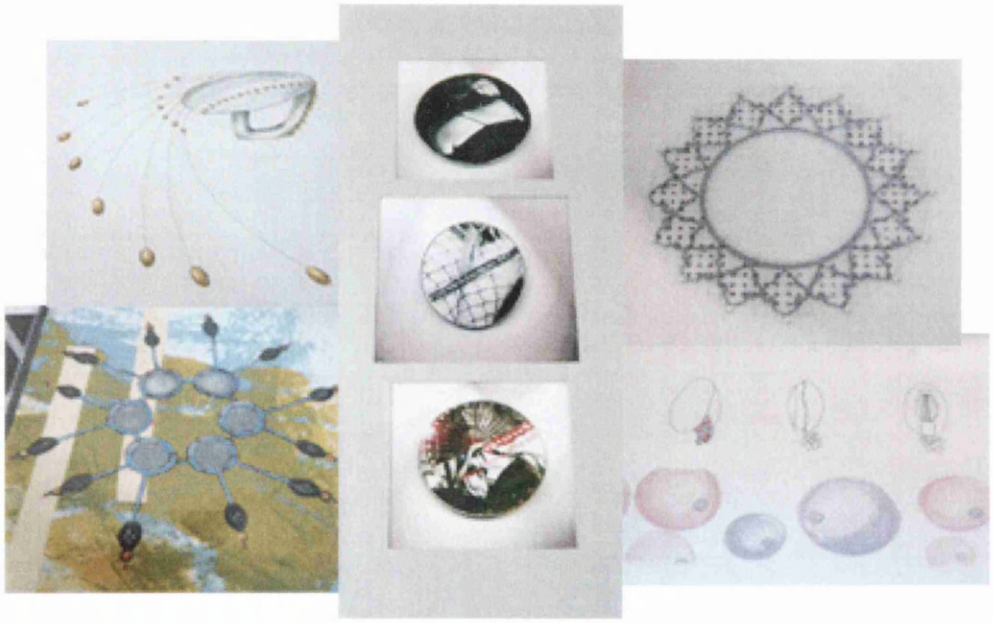

Figure 54: Presentation drawings using a range of different techniques (hand drawn, collage, digital)

Use of materials

Students used materials for a range of purposes and activities other than to make up a fully specified design. I have identified a number of terms to distinguish different uses of materials (see Table 8); these are described more fully in Appendix K. Some of these terms are derived directly from the interviewees; others I have defined to distinguish between two superficially similar uses. Where appropriate, I have used my definition rather than an interviewee's to maintain consistency between individuals, as participants used different terms to mean the same thing, or the same term to mean different things.

technical sampling, technical samples	producing (often small) samples to test materials, find out their capabilities, try out techniques, textures, finishes etc.
3D sketching	'sketching' directly in 3D with materials to generate or explore ideas
3D drawing	using physical materials to visualise or realise ideas in 3D
physical model/mockup	a physical model to test aspects of a design to see practically how it will work
physical element	a physical element or component which is, or represents, part of an actual piece
prototype	a physical working replica of a final piece

Table 8: Definitions of uses of materials

While these uses of materials could be clearly discerned in students' descriptions of their working processes, in practice the distinction between them is not always clear-cut. Students worked with materials in ways which combine two (or more) of the above uses, as can be seen in the following examples.

One student for whom a lot of the final design of pieces happened at the bench through arranging and rearranging physical elements, as her work developed, incorporated her technical sampling with the creating of design elements to form a library on which she could then draw:

> *"I do a lot of sampling in metal. And the little samples that I've got are actually quite complete in themselves. And I quite like to finish something off and go, right, and then I've got it there as a reference and I can use it again if I want, and if I don't, then I've not spent a whole week making a brooch in that style... I've spent an hour making a little sample that's in a library that if I want to I can go back and use it... And I do that... if I'm designing, I go right, I like this shape, and I'll take that technique, or that colour that I've used, or those stones that I've used, and then apply that to that. And so I'd kinda bring them together..."*[34]

Another student who liked to work very directly with the materials effectively combined the activities of technical sampling, 3D sketching and prototyping in the development of her pieces:

> *"...with things like this, the colours are good but the texture is good so then I will just experiment with that until I come up with something which I'm like, 'ooh, that would be really nice in the finished piece', or I can combine elements like the colour and the form. It's just things that to me is important about all my samples, I will then pop into one final piece."*[35]
>
> *"...the samples I use as a sketch. I'll begin to that and I'll put that at the side, and I'll go and focus with like this is precisely how I'm gonna make this final piece. And just sit down and make it."*[36]

[34] Material student 10, interview 3

[35] Material student 4, interview 1

[36] Material student 4, interview 1

Figure 55: Variety of samples, including some mounted for display in the Degree Show

Sometimes these 'samples' (which were in some ways more like prototypes) became final pieces:

> *"sometimes I'll have a piece that I can't recreate again, like either I don't have the materials or I just carry on working in it as a sample and then it will just finally come to being a final piece."*[37]

The following student's description of her working processes combines elements of 3D sketching, 3D drawing and modelling to achieve her goals:

[37] Material student 4, interview 1

> *"I think it's important that I actually try and not just draw down what I'm doing, but actually see if it works visually and three dimensionally, because it's amazing how, when it looks like something on a page, when you actually make it up it can change completely. And obviously using the fabric and the metal together... I need to figure out ways of attaching the fabric to the metal, ways in which the fabric can become unattached from the metal, from the practical side of cleaning... So I'm trying to consider it from all angles, and I think that's why I definitely need to make up the mock-ups to see whether this connects well to that... And obviously fabric's got a life of its own, what I can't draw down with fabric, I can't- so I need to actually draw with the fabric directly, and the metal, and then use that information to perhaps draw down technical, so that's why I do it that way"*[38]

The same activity may have a different role within each individual's process: in this group, for example, some students used technical sampling at the beginning of the body of work, to 'scope out' a process or technique that would be used as the basis for all their pieces within the Degree Show. Once the student had perfected the technique or process, or at least achieved a level of confidence in working with it, they then designed the subsequent pieces within this scope. In other cases technical sampling was done as needed for a piece, as with one student who had decided to make a body of work based on the theme of brooches, where each piece was designed around a different narrative work. The materials, techniques and processes for each one were largely determined by the concept and design of the piece; the technical sampling was thus focused on a single piece, and to achieve particular ends.

The ways in which individual students use materials, or the emphasis on different uses within their process, may also change during the year.

Recognising the difference between these uses of materials is helpful in distinguishing between those who were 'making' – working directly with materials at the bench to create a piece – and those who, as revealed through further discussion, were actually using materials as a design medium: working at the bench seemed initially to be very important in one student's processes; however in later interviews it became clear that while ideas might be generated at the bench, they did not affect the piece she was working on:

> *"I go to the bench with my technical drawing, and if anything else comes out of that- for instance, my units that I've got, I noticed that they made patterns within themselves, so I recorded that and photographed it at the bench. And it's something that I've put in to go revisit but, I do not deviate from what I initially went in to do,*

[38] Material student 5, interview 1

because I've found in the past that when I do, I then get confused and frustrated by it. So if I go in, I'm very focused with what I'm doing with my drawing."[39]

Drawing or materials?

A student's choice of drawing or working with physical materials may depend on a number of factors, relating to levels of confidence in each type of medium; practical reasons for choosing on or the other; or reflecting a more fundamental relationship with materials.

Some students felt less confident at drawing than others, particularly as a mechanism for visualising ideas that were quite clear in their minds; others were less confident at the bench. These feelings were more marked at the beginning of the year: by the end, many of the students had become more confident in both these aspects.

In some situations drawing was perceived as less useful than working with materials, for example when trying to render complex material structures such as wire mesh or French knitting; or for exploring and understanding movement within pieces, or how they will feel. It is necessary to work with materials to investigate their properties, as in technical sampling. It can also be beneficial where you want to understand the actual making process, such as in a prototype. Some students found that designing with materials was better to "see if it works visually and three dimensionally"[40].

While these are largely practical reasons, some students appeared to have a more fundamental need to work with materials. These ranged from those for whom a '3D sketch conveys the feeling of a piece', for whom objects have a 'presence', or substance lacking in a 2D drawing, to those who play with physical elements to design pieces (the term 'play' has no derogatory overtones, but reflects the relatively unconstrained and experimental nature of this process), or for whom ideas for designs come through working with materials:

"I've definitely got to work with things. I've got to have them and play about with them before things will come. Sometimes I can sit down and draw it, and make it, but it really doesn't do anything for me. I feel I've got to have it"[41]

The students' preferences for different media for different processes may relate to a number of aspects of their approach, discussed below: to what extent the design is

[39] Material student 11, interview 3
[40] Material student 5, interview 1
[41] Material student 4, interview 1

preplanned before making commences, or emerges after making has begun; the perceived role of the materials within each student's process; the extent to which an emergent approach can be related to a 'dialogue with the medium', or, as in the case of some M.Phil. students, whether it is more a 'dialogue through the medium'; a preference for control or a willingness to be open to unexpected events in the process; and whether idea generation or development is done largely 'internally', with media used to record this process, or happens rather through external means.

Planned or emergent?

This closer examination of the different ways in which they are used reveals the important and varied roles that materials play in all the students' processes. In this group, there was only one student who appeared to design primarily though sketchbook work and then make; a number of other students who designed primarily in their sketchbooks used 3D drawing or sampling to inform their design work. Interestingly, the first student was working with a particular technique, and as time pressures developed through the year and her confidence in working with materials grew, the balance of design activity moved towards the bench. For other students, the two activities were more integrated. Nevertheless, distinctions can be drawn within the group between those students for whom the design is largely preplanned before the final piece is made (whether through drawing or using physical materials as a 'design' medium), or whether the form of the piece emerges throughout the making process, with the design not fixed before making is started. The following student worked closely between her sketchbook and at the bench to develop the designs for her pieces, but,

> *"on the whole, the samples and the models and the drawings go towards what then is a finished piece. So I would model-make or model up in the workshop with metal or whatever, and I'd do my drawings and I'd sometimes do technical drawings, but ultimately when I go to start the finished piece, that is the finished piece"*[42]

This examination also revealed what appeared to be different types of emergent approach. In the first, elements of a piece are constructed, and then the final form of the piece emerges through arrangement and rearrangement of these pieces. This 'conversation' is largely concerned with shape, form and function, rather than the properties of the materials. The second type of emergent approach is typified by a more direct approach to working with the materials, and the exploration of the properties of the materials themselves as part of the making process (as opposed to in a 'sampling' phase earlier on

[42] Material student 5, interview 1

in the process). These differences appear to relate to the extent to which an emergent approach can be seen as a dialogue with yourself *through* the medium, or a dialogue *with* the medium, which concerns the role of the medium within the process.

Role of the medium

One student, for whom working with elements at the bench seemed to play a significant part in her process, nevertheless made it clear that,

> *"It's not so much that the materials give me it. Well I suppose they do, but when I'm making something in the workshop, I get other ideas from it, from the shapes, it's not necessarily like how the silver functions."*[43]

Another student, who had a very strong relationship with the materials, relied much more on what happened with the materials:

> *"More engage with it to see what can happen because- I think, from that, if you let a material do what it wants to do it can throw up some good surprises that can then help you to see it in a different way and use it in a different way. Which I think is very important, which you would miss if you just went, it's got to do this and it's got to do it now. You would miss that whole sort of process of it pinging exploding in some way or- like differing itself. ... a lot of my pieces are just by, 'oh, it's happened, but I really like the way that it has done, so I'll utilise that in a piece."*[44]

Choice of materials

A related difference that could be observed concerns the extent to which the materials are chosen to suit a particular design, or whether the design is determined by the materials which are available.

Some students selected the materials to suit a design or a conceptual idea – "rather than designing to the material"[45] - where materials may be chosen for their physical, visual or evocative qualities:

> *"[the materials] convey a lot about the lyrics that I'm looking at as well, and making particular sense of a word or something, that the other materials couldn't. You've always got to try though, just to see which would work- it's got to have the strongest impact for you, how it matches with what you're trying to say"*[46]

For other students, the design was influenced (to a greater or lesser degree) by the materials. This occurred at different levels of process.

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[43] Material student 11, interview 1
[44] Material student 4, interview 3
[45] Material student 11, interview 1
[46] Material student 8, interview 1

Repertoire or palette

A number of students based a body of work around particular processes or techniques. Perfecting these, and finding out the capabilities of the materials, was a very important part of their work: they spent a lot of time at the beginning of the year sampling and testing the technique and materials to see how far they could push it. However, for some of these students, after the period of refining a particular process or technique was over, pieces were generally designed before being made:

> *"it's trial and error... you just have to see what works and what doesn't work so it's a case of producing loads and loads of samples and when I eventually find what does work, then it will be a design-based thing"*[47]

One student had a very large collection of materials which played a central role in her work:

> *"I have lots of components that I'll just merge together. I have a room at home, it's covered with bags, poly-pockets of everything I've been collecting, and I will go through it and say 'that goes with that, that goes with that, I'll create this'... that's the main way I work."*[48]

An interviewee from my earlier research had described the large collection of beads she worked with as a 'palette'. This term resonated strongly with the student above:

> *"Yeah, precisely, that is precisely it... I try and colour coordinate them or keep all the pieces together but in different coloured packets... because colour is very important so I do always sort of categorise things colour-wise, and see how that works together."*[49]

This material 'palette' seemed to differ from the 'repertoire' of techniques and processes in the sense that while the materials were selected by the student, unlike the repertoire they were not *defined* by the student.

Working directly with materials

For other students, the design was determined by the materials in a more direct fashion, specific to each piece. This again manifested itself in two different ways.

Some students created and collected physical 'elements' or 'components' for the work and played about with them to create the final piece or design (Figure 56). These elements appeared to have two different roles: either 'samples', which the student would work with to create the form of the piece, and then make it in the final materials; or actual

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[47] Material student 3, interview 1
[48] Material student 4, interview 1
[49] Material student 4, interview 1

Figure 56: Elements

finished components, which would be made up into a final piece. (I have not included in this category those students who generated ideas while working with elements at the bench, but recorded them for later use, i.e. the form of the current piece did not change through what happened at the bench.) For these students, although some work was done in the sketchbooks, there was a strong sense that the form of the work came from working with these material elements.

> *"I think I do more play about and start to think about how they could go together but then I don't just throw it together, I do do some sketches to see what I could do with it. But it is more sampling, definitely"*[50]

Other students seemed to work more directly with the materials to evolve the design of a piece. For the student who had the 'palette' of materials, the form of each piece seemed to arise very directly from working with these materials:

> *"I approach things in a very sort of 'into the deep end', I'll start making a thing, and just really- It depends, I get a lot of different inspirations from other things but usually I will just go straight into a piece if I'm making a particular piece that I want to do, sketch it quickly and just get the materials going"*[51]

Although she describes items in her palette as 'components', they are 'selected' and less finished than the physical elements which are largely 'predefined' or premade by the students. This suggests a similar difference to the repertoire/palette level above, with its distinction between having been made or selected.

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[50] Material student 7, interview 1

[51] Material student 4, interview 1

Difference upon difference

Running through these examples of two different 'levels' of working with materials – producing a body of work within a repertoire of processes and techniques or a palette of materials, and working directly with physical elements or materials to produce a particular piece – are a number of other differences which have already been discussed above: the extent to which the design is preplanned before making, or whether making commences before the design is finalised; and the extent to which an emergent approach can be seen as a dialogue with the medium, or through the medium. A related difference concerns the nature of each student's relationship with the medium.

Relationship with medium

Within the group, students characterised their relationship with the medium in different ways. For some, they were very much "the boss":

> *"I'm quite strict to what I've got in my head, I'm quite strict to what I've got on paper... I tell it what to do (laughs). As far as I can, I manipulate it, as opposed to- there's people upstairs who will very much work according to what the metal does or according to what happens, it's that kind of exciting, perhaps not quite sure what's gonna happen but we'll give it a go. That comes in occasionally with me but because I'm very clean with certain shapes or forms, it tends to be me asking it to do something, and if it doesn't work then I'll try it again to achieve the same end product"*[52]

This is not to say that they weren't sensitive to materials: rather, that once a design had been completed, they pursued that. Other students were more open to change their design if something happened while they were making it:

> *"...you have the idea in your head, and you go to do it, but while you're doing it, the material's doing something else, so that then changes what you set out to do..."*[53]

Although this dimension may relate to a preference for a planned or emergent approach, those are preferred ways of working; this aspect concerns a preference for control, or a willingness to be open to unexpected events in the process.

Internal or external?

One interesting distinction is the use of drawing/materials to develop ideas, or to record/realise ideas arrived at by some other means.

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[52] Material student 5, interview 1

[53] Material student 7, interview 1

Some students used their sketchbooks to record work done at the bench 'after the fact', but the term 'record' was also used in the sense of "draw down everything that goes on in my head". A number of students gave the strong impression that much of the design work was happening internally, which they would then 'draw down' or 'record', as opposed to the sense that the ideas came through drawing. One student, when first interviewed, was aware of drawbacks with this ability, and was making a conscious effort to take more account of what was happening in her sketchbook, and what was happening at the bench:

> *"an awful lot, I have preconceived ideas of- you know when your brain conjures up this notion or this finished piece before you've even drawn anything down, then I'll almost be working towards that, instead of observing what's going on in the paper, what's going on in my drawings, or what's going on at the workbench"*[54]

Interestingly, when interviewed subsequently, she had discovered that she found it more successful to realise her ideas in three dimensions first, then record them on paper:

> *"I can sit there and quite happily go through the motions of a page in a sketchbook in my head... I can sit and I can rotate things in my brain and I can see things from every different angle. And actually when I draw it down, it loses something that was up here, and actually I think I'm now better making it three-dimensionally, and then recording that on paper, and recording the bits that haven't gone wrong.*[55]

In contrast, another student seemed initially to work in very 'external' ways in her sketchbook. She photocopied drawings and photographs, cutting them up and rearranging the elements to see what design ideas would result.

I had originally thought that a preference for this way of working might indicate that the student did not have the ability to clearly visualise designs 'internally', and so used an external process. But for this student at least, that was not the case; her approach concerned her relationship with drawing:

> *"The drawing doesn't particularly come naturally to me. When I go to finalise the idea, I do it on the technical drawing. If I have rough sketches, it's done very roughly in a small sketchbook... But apart from that, most of it is actually done in my head. And I think that's where, as I say, I did struggle with the drawing because it wasn't something I did naturally. And the kind of drawing that the department wanted me to do, wasn't natural to me, and I did far more of the development process - like trying to figure out exactly how I was going to make it - in my head, rather than drawing it. I suppose I've had to do the drawing part, more than I probably would do if I didn't have to do it. And then I would just go straight to the technical drawing board probably. Although, because I was looking at fragmenting the circle, I've used it just*

[54] Material student 5, interview 1
[55] Material student 5, interview 3

as a tool to experiment with pattern and things like that. Which you can't do freehand, because obviously it's not precise enough."[56]

Her approach also relates to other notions of what 'drawing' can be:

"In my second last sketchbook, it was working a lot with photocopied patterns. And it was deconstructing them... I think that reflects the training I had doing my portfolio, when we were taught that drawing wasn't just with a pencil, drawing was using scissors... I think that's really came back through my work in the last year, that I will just sit down and kinda cut things and remake them. And it kinda reflects the work, because, I've started to deconstruct the circle and then reconstruct it, same with pattern, you know. ...so, that's still quite a big part."[57]

This example illustrates why it is necessary to examine carefully the ways in which media are being used within a student's practice.

Another student's processes seemed more externally driven: she described the focus of her work as "the source material and the materials". Her description of her relationship with her source material was interesting, and may give additional insight into her approach. For her source materials, she chose "things which are inspiring to me, things I think that will relate to what I'm doing". A particular technique she used was to work into photocopies of visual source material,

"just picking out elements in it which is the most interesting to me, like this, it looks as if it could be beads, and then how I can translate that into how I'm working, like how I can French Knit it or how it would look if it was French Knitted, and colours..."[58]

The idea of 'translating' the ideas from the source using materials and processes she had decided to use came through very strongly. As her work developed, while the influence of the source was still strong, a lot of the pieces were derived from the materials:

"At the very beginning I was trying to find lots of visual research, but then once I started working with materials that just took on into it's own, and all my sketchbooks and everything went very much on the back burner. While I just started continually using like material and 3D sketches."[59]

Summary

In this group of students working with physical media, a number of dimensions of variation can be observed in different aspects of practice. These include the roles of drawing and materials within each student's practice; a preference for a planned or emergent approach; the extent to which the materials are chosen to suit a particular

[56] Material student 11, interview 3
[57] Material student 11, interview 3
[58] Material student 4, interview 1
[59] Material student 4, interview 3

design, or whether the design is determined by the materials which are available; their different relationships with the medium; and whether idea generation or development is done largely 'internally', or achieved through external means.

Comparison between groups

The previous two sections of this chapter discussed differences in approach that could be observed between the students within each of the two groups participating in this study. This part of the chapter demonstrates that similar differences in approach exist within each group, and that a comparison between similar approaches within two environments, physical and digital, has value in clarifying aspects of approach, and offering insights that arise from the differences between the two media.

Strong similarities exist in both groups: these relate both to a number of 'dimensions of difference' concerning various aspects of the students' approach to their work or relationship with the medium, and to other more general aspects concerning design processes and the role of artefacts and media within these.

There were no points on which the groups varied widely, although there were instances where a comparison between similar approaches in each group clarified aspects of approach which might have been misinterpreted; elicited multiple phenomena which might have been misperceived as one; or brought things to light which were emphasised more in one group than the other, where they might have gone unnoticed.

'Dimensions of difference'

Planned or emergent

Within both groups, differences could be observed between those students who liked to predefine the form of the work before starting to make it, and those who were happy for the form of the work to emerge during the process. However, closer examination revealed further differences in each case.

In the M.Phil. students who preferred a 'planned' approach, there were differences in the extent to which the visual appearance of the work (as opposed to its narrative structure, for example) was determined before starting to build it. Some students prepared a visually detailed storyboard; others prepared what one termed a 'sequential storyboard', planned in terms of what was going to happen, but not visually detailed (see Figure 51).

In both groups, more fundamental differences appear to exist between the two different types of emergent approach observed, relating to the role of the medium. For some students, the emergent nature of the work is related to working directly with the medium, and an exploration of its properties (a dialogue *with* the medium). For others the emergent nature of the work is related rather to the conceptual idea or design (what could be described as a dialogue *through* the medium).

In the latter case there seems to be a further difference between (for example in the digital context) a dialogue with an emerging idea – "jumping into the void"[60] - and (in both physical and digital contexts) arranging and rearranging partially predefined elements to achieve a final piece; nevertheless the emphasis is on the 'design' as distinct from the medium.

Role of medium

This distinction between the role of the medium can be observed on two levels. At the conceptual level, there are those who view the medium very much as a tool, or a means to an end; their emphasis is on what they are trying to achieve through the work whether design, concept or message. Others engage with the medium, and work with the effects that arise through 'playing about' with what the medium can do.

Choice of materials

A similar distinction, but at a different level, concerns the choice of materials; whether the materials are chosen to suit the design, or whether the design is determined by what materials are available.

In the group of students working with physical media, some students selected materials to suit a design or conceptual idea: materials might be chosen for their physical, visual, or evocative qualities. For other students, the materials appeared to have a greater influence on the design. However, on closer examination, again further differences could be discerned within this latter case. These relate to the level of process at which this occurs - at the level of practice, or for each individual piece - and how the material constraints arise.

[60] Digital student 11, interview 1

At a 'practice' level, some students worked within a *repertoire* of skills or processes, while another student worked also within a *palette* of materials. The main distinction between these seemed to be that while the former was largely *defined* by the student, the latter was *selected.*

At the level of the piece of work or artefact, some students built elements of a piece, then arranged and rearranged them to achieve the final form of the work. For others, the piece largely emerged from working directly with the materials, and from what the materials could do. Again, the distinction between these seems to relate to how much the physical materials being worked with had been 'predefined' by the student.

Similar differences can also be observed in the group of students working with digital media. Although the medium is largely defined as the software package that's available, the observations concerning the use of a 'repertoire' or 'palette' may, on reflection, relate to differences between the 'digital' students' approaches to using and learning techniques or elements within the software. Some students chose processes and techniques according to what they were wanting to achieve ('chosen to suit the design', above). Others learnt a broad range of techniques in case they might need them, and incorporated them into their work as appropriate. A comment made by a number of students during the interviews (mostly about *other* students) was that some of the group appeared largely to use techniques with which they were already familiar through their previous year of study.

Similar differences to those observed at 'piece' level within the S&J students were also evident in this group. Some students used the compositing and editing stage of the process to put shots together according to the predefined plan. Others built elements using the modelling software, then used compositing and editing to experiment and explore different interpretations ('arranging and rearranging' elements). Another student worked even more directly with the software: the effects achieved through playing with the digital medium itself determined the direction of the work.

Control or risk

Whereas a planned or emergent approach reflects preferred ways of working, this aspect deals more with the students preference for control, or a willingness to be open to unexpected events in the process. Differences in this dimension could be observed within both groups.

In the M.Phil. group I had considered three different aspects: reaction to unexpected events; attitude to problems; and 'preventative measures'. In the analysis of the S&J group, I hadn't become explicitly aware of the types of 'preventative measures' such as observed in the M.Phil. group; however these could be reflected in the use of sampling, or of building prototypes, in the processes of some S&J students.

Ways of relating to objects

In the group of students working with digital media I had identified a number of differences revealing aspects of a preference for a close or distant relationship with objects. These appeared in two different contexts: a 'mental' closeness or distance, and another group of characteristics related to an almost 'physical' closeness. I had observed that some of these differences became explicit only when they became apparent to the student: for example when they experienced difficulties with the software, or expressed preferences for using one technique over another. The opposite viewpoint was rarely expressed by the interviewees, but can be inferred from the lack of explicit reference, and revealed by examining the collective variation across the group.

For the students working in the digital medium, a number of aspects of 'mental' closeness or distance could be observed: learning the software through manuals or by interacting with it; having a subjective or objective relationship with the software; seeing elements of the software in terms of 'what they can do'(concrete) or 'what they are for' (formal); and being driven by conscious awareness, or forgetting themselves and becoming immersed in their work. Although these aspects didn't emerge as obviously in the group of students working with physical media, elements of these differences can be seen in the ways in which some students explore and stretch the possibilities of their materials.

In the digital group, a number of students made comments relating to 'physical' attributes of working with the medium (being able to manipulate things directly, immediacy and responsiveness, the physicality of objects, and physical 'hands-on' interaction) - largely concerning their lack of experience of these characteristics in the digital medium. Comments along these lines were not as obvious in the S&J group, probably because the students were actually working with physical materials. However, similar characteristics can be observed in some students' preferences for using physical materials over drawing in the development of their ideas (as opposed to solely a preference for working in three dimensions rather than two).

This reveals the benefits of a comparison between digital and physical environments: it is useful to view this 'dimension' through the prism of the digital medium, as it helps to split the different aspects of 'working with physical materials' into constituent parts. Although in the one case a comparison is being made between digital and physical media, and in the other between drawing and materials, some of the underlying reasons for choosing one over the other may be similar.

Internal or external

For this 'dimension of difference', the elements of process that I'd identified as constituting an 'internal' or 'external' approach were slightly different in each group. In the M.Phil. group, I'd identified an 'internal' approach as having a number of aspects across different levels of practice. Some students could clearly visualise their work in their 'mind's eye': for them, thinking and doing appeared to be separate, and they used the medium to express an idea that was already clear in their mind. For some S&J students media was used to record ideas generated internally, parts of the development process were done 'in my head', and many commented on being able to mentally visualise objects quite clearly.

A number of students in both groups commented that they could see objects, or sequences of events "like a movie"[61], quite clearly in their heads. In contrast there were two students, one in each group, who particularly seemed to develop their ideas in an 'external' manner, in 2D via collage (Figure 57). I'd originally linked what seemed to be

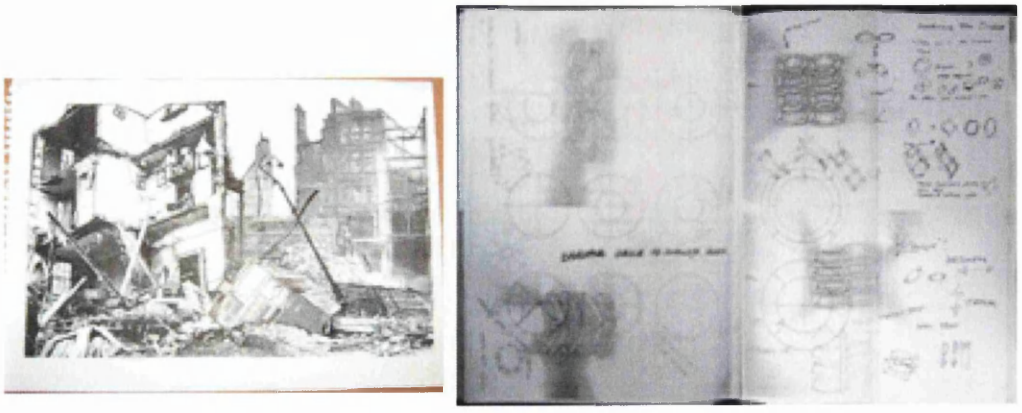

Figure 57: Working with photocopy collage (left) M.Phil. student, (right) S&J student

[61] Digital student 1, interview 2

this preference for working externally with an inability to mentally visualise objects, as the M.Phil. student had commented that she wasn't able to come up with an 'idea' straight out of her head. However, as discussed earlier in the chapter, the S&J student was able to visualise objects quite clearly in her head, and appeared to use collage techniques for other reasons. It cannot therefore be assumed that an apparent preference for working with external media necessarily equates to an inability to visualise ideas mentally in three dimensions.

However, there is an interesting comparison between the description which the above M.Phil. student gave of her process at this stage as 'compiling' her work from external sources ("stealing doorways here and there"[62]), and the description by another S&J student, whose ideas emerged from working with source material and materials, of 'translating' ideas from the source using the materials and processes in her 'palette'. In both these cases - 'compiling' work from external elements, or 'translating' source material, there is a strong sense that the students are working externally. (This has resonances with the 'choice of materials' dimensions, above, and the distinction there between 'selecting' and 'defining'.)

Despite these variations, there appear to be differences between students for whom idea generation or development is done largely 'internally', with media used to record this process, and those who generate or develop their ideas using external means.

It is also important to note that an 'external' approach doesn't necessarily equate to an emergent approach, as the M.Phil. student above who worked with collages in the design stage of her piece planned her work carefully before starting work in the modelling software.

Design processes, and role of artefacts/media within these

In addition to these 'dimensions of difference', other similarities could be observed between the two groups. These related more generally to design processes, and to the role of artefacts/media within these processes.

For both disciplines represented in this study, in 'industry' design and making are often done by separate groups of people. This leads to an (ostensibly) 'design then make' process. When one person is doing everything, as is the case with these students,

[62] Digital student 2, interview 1

individual differences in approach spanning the whole process can emerge. A number of S&J students particularly commented quite strongly that there wasn't 'a' design process. The experience of some students in both groups was that they were doing things because of the requirements of the course, rather than because it was useful to them. With the M.Phil. students these comments largely related to the storyboard; for the S&J students, most of these comments centred around the role of the sketchbook.

One of the valuable lessons learned from this study was differentiating the variety of ways in which students use the media with which they work. Particularly within the group of S&J students, it revealed the important distinction between those students who originally appeared to be what I have termed 'making' – working directly with materials at the bench to create a piece – but who, as revealed through further discussion, were actually using materials as a medium for design. Although it may not be possible to equate the use of physical materials in this way directly to using Maya (the 3D modelling and animation software) as a design tool, some students in the M.Phil. group did use 'animatics' when developing their work – simplified 'block' models to represent characters of elements of a scene to allow them to test movement, timing, lighting and camera positions within a scene. In a broader context, it highlights the fact that the same medium may be used in different ways and for quite different purposes by individuals, and that it is therefore necessary to examine the relationship between design practitioners and media carefully.

Conclusions

To recap, the aims of this comparative study between two groups of students, one working with 3D physical media and the other with 3D digital media, were: firstly, to establish whether differences in approach, relating to the nature and extent of a dialogue between practitioner and medium, could be observed within each group; and secondly, to establish whether similar differences could be observed within both groups.

In order to address these questions, this study focused on examining those aspects of practice which relate to the nature and extent of a dialogue between practitioner and medium. In the first stage of this study, a comparative framework was derived from the literature, taking the formal/concrete axis as an organising principle for differences in approach across a number of levels of practice; it comprised a set of around thirty 'indicators' representing those aspects of a practitioner's process that can be examined to determine the nature and extent of the dialogue they experience with the medium and

collectively determine whether their overall approach is categorised as 'hard', 'soft' or not definitive. In a preliminary analysis of the first set of interview data, each individual's approach was categorised using this framework, and an assessment made of the distribution of the different approaches within each group. Certain limitations of this analysis mean that it can only be relied upon to give a broad indication, nevertheless different approaches, broadly in line with those in the framework, could be observed within both groups, with a similar spread of approaches within each group.

The second part of the study - based largely on the first set of interview transcriptions, but with input from later sets - involved both an examination of the collective variation within each group across a number of 'dimensions of difference' which emerged from the data, and a comparison of these emergent dimensions between groups. One of the limitations of this second stage of analysis is that while it identifies differences in approach that could be observed, along certain dimensions, within the group, it lacks the formal connection between these dimensions within each individual's practice to allow a rigorous comparison between individuals across all the 'dimensions' of their approach (further analysis of the data will be required for this to be possible). It is also not possible to make a direct comparison between these results and the results from the preliminary analysis which categorised individual approaches as 'hard, 'soft' or 'not definitive'. However, despite these limitations, a number of observations can still be made.

In both groups, a number of dimensions of variation can be observed which appear to be in line with the original framework, relating to a 'hard' or 'soft' approach. These include a preference for a planned or emergent approach; a preference for control, or a willingness to take risks; those who see the medium as a means to an end, and those for whom the means become the end; the extent to which the materials are chosen to suit a particular design, or whether the design is determined by the materials which are available; their different relationships with the medium, including distance or closeness in relating to the artefacts they create and work with; those whose idea generation or development is done largely 'internally', or those who achieve it through external means. The dimensions emerging from the groups therefore seem to be broadly in line with those embodied in the conceptual framework. However, how these different dimensions logically relate to one another within an individual's approach does not appear to be completely described by the two-dimensional nature of the framework. (Although this second stage of analysis focused on the collective variation within each group, there are

relationships between dimensions that can be observed within certain individuals' practice which are not consistent with the framework.)

In the 'soft' approach embodied in the conceptual framework, I had equated an emergent approach to a 'dialogue *with* the medium'; however instances could be observed where an emergent approach could rather be characterised as a dialogue with oneself *through* the medium (in this case the differences relate to whether the emergence relates to the conceptual idea or design, or an exploration of the properties of the medium). Another dimension which is not adequately explained by the original framework relates to the choice of materials. In the framework, this dimension broadly distinguishes between whether the materials are chosen to suit the design, or whether the design is determined by what materials are available. On closer examination, again further differences could be discerned within this spectrum, relating to the nature of the material constraints.

Without a more formal means of comparing the relationships between dimensions within each individual's practice it is not possible to determine, at this stage, whether these differences in approach simply represent different positions on the existing 'hard'/'soft' spectrum, or indicate two wholly different spectra of approach, one at the level of representation, and one at the level of the artefact (this is discussed further in Chapter 9, ***Discussion***). However, findings from the Practitioner Interviews discussed in the next chapter may offer additional insight. Comparisons between practitioners who had what at first appeared to be quite similar approaches, in terms of the original analytical framework, revealed distinct and significant differences relating to the role of the medium in each practitioner's practice. These interviews indicate that even between practitioners who appear to share a close relationship with the medium, this relationship may not be the same.

8. Practitioner interviews

Chapter 6, ***Concepts of dialogue in design*** proposed that significant differences exist between individuals in their approach to creative practice which can broadly be described in terms of the nature and extent of a dialogue between practitioner and medium. Further analysis suggested the formal/concrete axis as an organising principle for these differences in approach across a number of levels of practice and encompassing a number of 'dimensions of difference'.

Chapter 7, ***Comparative study*** demonstrated that differences along these lines could be observed in the working practices of two groups of student 3D design practitioners (one working with digital media, the other working with physical media). However, it revealed that differences between practitioners could be observed which could not be fully explained by this 'two-dimensional' organising principle. Findings from the study discussed in this chapter offer additional insight into differences between individuals relating to the role of the medium in their practice.

This chapter describes an interview study of three 3D practitioners who have an established material practice, and a substantial body of work in digital practice. By drawing comparisons between each practitioner's approach to material and digital practice it aimed to gain insight into key elements of their relationships with the medium they use and the artefacts they create. A primary aim of this study was to determine whether, in support of the principle of comparing material and digital practice which underpins the method chosen for this thesis, a practitioner's approach is consistent across media. The emphasis of the investigation therefore had been within each individual's approach. However, during the study it became clear that important insight could be gained from looking at differences between individuals. Comparisons between practitioners who had what at first appeared to be quite similar approaches, in terms of the original analytical framework, revealed distinct and significant differences relating to the role of the medium in each practitioner's practice. These differences may help to explain the results obtained in the Comparative Study; this is discussed in Chapter 9, ***Discussion***. This study of advanced practitioners complements the relatively early developmental stage of the students in the Comparative Study. The interviews also

provided an opportunity for issues to be raised that are important, but which might not be immediately obvious in the two 'single' environment elements of the Comparative Study.

Verifying the basis of comparison

One of the main principles underpinning the method chosen for this research is that insight can be obtained from comparing phenomena which are similar-but-different. In this thesis that is primarily achieved through comparisons between material and digital practice, either between individuals working in each of the environments (as in the Comparative Study) or within one individual's practice (as in this study).

In order for these comparisons to be valid and useful (particularly between similar approaches in different groups), it has to be demonstrated that a practitioner's approach is consistent across media. If, for example, there was a significant difference in approach between a practitioner's material practice and their digital practice, then it would not be possible to say which effects may be due to differences in approach, and which may be due to working with the different media. It would still be possible to compare similar approaches within different groups, and see how each type of approach manifested itself in each type of environment, but it would not support the thesis, as it would not be possible to claim that there are underlying differences in the way that individual practitioners relate to the medium they use.

Also, for this principle to be useful, insights into practitioners' processes must be gained from this comparison, i.e. the approach remains the same, but aspects of it are foregrounded by the differences between material and digital media.

This study verifies both elements of this principle: that a practitioner's approach is consistent across media; and that insights into their approach can be gained from examining similarities and differences that arise from the differences between the two types of media.

Design of study

Participants

My original intention had been to keep the areas of practice for this study as similar as possible to the groups proposed for the Comparative Study, and therefore that the 3D

practitioners concerned would be designer-makers/applied artists now working in digital practice. However, it soon became apparent that, while a growing number of designer-makers are using computer systems within material practice, very few are working in a digital medium, particularly in the UK. I therefore decided to broaden the search to include sculptors now working in a digital medium.

I had originally thought that this variety of backgrounds would make some elements of direct comparison between these practitioners more difficult, as they not only use different digital media but have backgrounds in different material practice (although it gives a broader view of the ways in which practitioners view and engage with digital media, complementing the Comparative Study which has a narrower focus in terms of the material and digital media being used). However, as noted above, during the study it became clear that important insights were to be gained from looking at differences between individual practitioners in terms of their approach to the medium and its role in their practice. These aspects are largely independent of the medium (particularly as this study demonstrates that the characteristics of a medium are not absolute, rather they are defined through a practitioner's relationship with it) and therefore a comparison between practitioners on this level is more straightforward.

Interview design

Each practitioner was interviewed to examine how their experience, perceptions, skills and working processes transferred from the material to the digital environment. The main aim of these interviews was to examine similarities and differences in their working practices across the two environments, therefore gaining insight into key elements of their relationships with the medium they use and the artefacts they create. (These might have explicitly come to the practitioners' attention through their move from material to digital practice, or be things that they may not be aware of, but which can be inferred from their accounts of practice or revealed by the types of comparison made during this study.) In particular, I was interested in how they view the digital medium, how they engage with it, and how their material practice relates to their digital practice. I was also keen to identify insights they had obtained into their own practice in moving from material to digital, and the differences they highlight between the two working environments. There are a number of levels at which this 'foregrounding' or 'distancing' between media may take place, giving insight into the practitioner's general practice,

approach, and relationship with the medium, or the concerns, content or theme of their work.

A semi-structured design was used for the interviews, recognising that while there were particular aspects that I wanted to explore, some of the most important information was likely to emerge from the discussion with the practitioners. A copy of the interview schedule is given in Appendix L. In the event, the schedule acted as an aide-memoire during a broad discussion of practice, to ensure that all areas of interest were covered, rather than being rigidly followed question by question. Each practitioner was given the opportunity to review the excerpts from the transcriptions quoted in this chapter, to clarify points or tidy up phraseology, as they felt appropriate.

Analysis

A two-stage analysis was made of the interview data, in both cases examining themes that emerged from the data, but within the broad theoretical framework discussed in Chapter 6, ***Concepts of dialogue in design***. Firstly, a comparison was made between each individual's digital practice and their material practice, to characterise their approach in each. Secondly, a comparison was made between practitioners, focusing on aspects of their digital practice, to identify any differences that could be observed between individuals in terms of their relationship with the medium and its role in their practice.

The practitioners

The three practitioners interviewed in this study come from a range of 3D practice. Practitioner A (PractA) is a maker with a background in textiles, now working with 3D computer graphics as a medium. Practitioner B (PractB) is a sculptor with a background in installation, now using a combination of immersive digital environments and real space as his medium. Practitioner C (PractC) is a sculptor, working in what he terms the 'cyber environment', using a 3D modelling package as his medium, with a range of digital and material outcomes.

Practitioner A

PractA's practice-based Ph.D. enquiry marked the move away from her established practice in constructed textiles to the use of 3D computer graphics (including motion

capture) as a medium. This move was driven primarily by limitations she experienced in pursuing her material practice.

> *"I felt that I hadn't yet achieved all that I wanted from my work, and there was so much more to pursue, particularly in terms of the expression of movement within the pieces, the presence of the body within the work. I was still really fighting to simultaneously incorporate so many different elements in the 'making' of any one piece. The material process that had brought me to this point and defined my practice and my palette, if you like, was very time consuming. Each piece took about three to six months solid time to produce. Each composed of very finely pleated forms, a by-product of an intricate three-dimensionally structured, tie-dye process. Resulting work was really quite fragile, which also made it difficult to exhibit as a three dimensional form, let alone define in a performative sense. The work on stage would have perished. Kinetics was an inherent characteristic of each piece and I needed to explore new ways of presenting and exhibiting the work as well as furthering development of the work itself..."*

Unable to explore the kinetic potential of the work - "the characteristics in the body of this... the working of it, the happening of it, that inside-outedness of it, that sort of fourth dimension in it, the thing that you can't see, but it has?" - or the movement of the body within the work; concerned with becoming stagnant; and frustrated by being limited in the number of ideas she could pursue while still maintaining the quality of the work, PractA moved towards digital practice. She knew visually and aesthetically what she wanted to achieve, but at that point had no idea of the 'palette' of tools she would end up using.

Initial exploratory work in two-dimensions, using software such as Flame and AfterEffects to manipulate video, started to reveal the potential of digital media, but PractA began to realise that to originate work, as opposed to working from existing source, it would be necessary to move to the medium of 3D computer graphics. At that stage in their development – "pre 'Toy Story' and 'Bugs Life'" - 3D computer graphics did not have the tools that users of today's high end packages such as Alias's *Maya* take for granted. For a maker with little experience of computers, let alone 3D computer graphics and modelling, to be faced with such a move was daunting: nevertheless, PractA knew that it was the only way in which she would be able to achieve what she wanted.

Although it took time and considerable personal endeavour, PractA has now achieved fluency in what she describes as the 'language' of the medium of 3D computer graphics; she now has a palette which allows her to produce work of the quality and aesthetic she requires. Collaboration with a dancer in the motion capture element of the work, and a computer graphics operator, has allowed her to explore dynamic elements and themes

Figure 58(a): "Transcience" 1987-1990
Reproduced by kind permission of the artist.
Photography Pierre Guillemin
Performer Jaqueline Duncan

Figure 58 (b): "Kinetic" 1991-1994
Reproduced by kind permission of the artist.
Photography Shannon Tofts

Figure 59: "A'Dressing" 1996-1998
Reproduced by kind permission of the artist.
Performer Emily Bruni. Assisted by Mill Film, Soho, London
Supported by The Arts Council of Great Britain, Channel 4

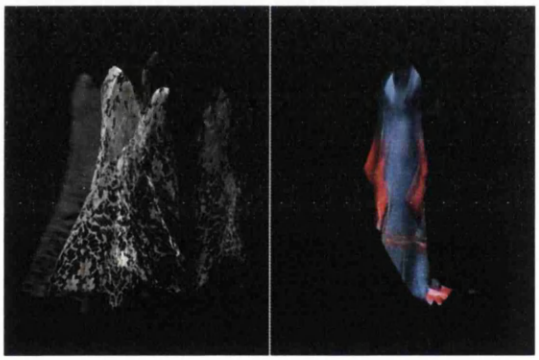

Figure 60: "Portrayal" 1998-2000
Reproduced by kind permission of the artist.
3D CG Mike Dawson, Performer/Choreographer Ruth Gibson. Supported by Vicon

Figure 61: "Potential Beauty" 2002-2003
Reproduced by kind permission of the artist.
3D CG Mike Dawson, Performer/Choreography Ruth Gibson. Supported by AHRB, Vicon

within the work relating to "identity through movement narrative", the communicative aspects of the body moving within a garment:

> *"A visual conversation or dialogue is evolving in the work, identities are explored through the motion capture. Kinetic reactions between body and cloth are manipulated using absent and present forms in digital space. There are many potential subtexts linked to the movement of material, cloth, fabric which can be drawn out in 'performance'... viewed in dress in its every day form or function, its presence, walking down a street... there's something more to it than meets the eye. Clothing can be very communicative and evocative, defining identities... an example being the enduring image of Marilyn Monroe holding her dress down around her knees, in an attempt to stop it from flying up around her body as she is 'apparently' caught out by an air duct... The digital arena proffers scope for different forms of visual play, which challenge perceptions formed by our experience of 'physical' spatial scenarios, however visual subtlety to this play is key. 'Special effects' are easy to use and all too readily recognisable, this is where the ability to 'craft' is of value."*

A major advantage of the move to digital practice is the ability to explore a number of projects simultaneously, "to really pursue the ideas as they come":

> *"...core technology and tooling that we have developed can be used to support a number of different projects simultaneously, within a range of contexts. And that simply wasn't possible, in my previous physical practice. The process remains time consuming, however this is rapidly changing as technology evolves and will inevitably become more intuitive. It is the perception that working processes are instantaneous because the computer is now the predominant tool, but I view it less as a means of speeding up a process, more as a means to facilitate what wouldn't otherwise be possible. It's amazing the difference in viewpoint I now have, evolving new ways of thinking, new concepts for a variety of outcomes, thinking about different audiences. My perspective has shifted, there are almost too many possibilities - an established 'language' crucially assists in retaining a discerning focus. Although very much informed by working with physical material, digital media has broadened my practice both in terms of approach and application... research and in contrast work that is purely creative."*

Finally, and importantly, it enables PractA to produce work that it wouldn't be possible to make any other way.

For the other two practitioners in the study, the driving force behind their move to digital practice was less the constraints of material practice, more a growing realisation of the potential of the digital as a medium.

Practitioner B

PractB is a sculptor with a background in installation: his material practice concerned the relationship between an installation and its environment, the viewer's relationship with the installation, and their experience of space. Earlier computers left PractB with an impression of how long it took to do even simple things. Although latterly he had begun to think about using computers in his work, the move to digital practice was not triggered until he saw and experienced work that fellow artists were doing in a school workshop, where they had used CAD to design large installation pieces: "when I saw their work, it just suddenly struck me that there was something to be done here...".

Initially inspired by an experience of 'Osmose', an immersive digital environment by Char Davies, PractB began working with immersive virtual reality, and exploring the emergent qualities of digital media. This practice was transformed by the realisation that digital environments could be dynamic:

> *"...I don't know why it hadn't struck me, but I just started thinking 'bloody hell, nothing has to be static... it's absolutely fluid what you can do with this stuff'."*

Figure 62: (installation)
Reproduced by kind permission of the artist

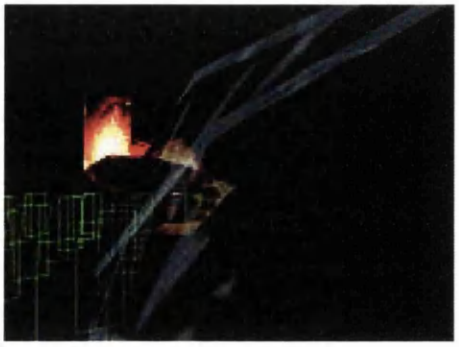

Figure 63: "Intersculpt", 2001 (immersive environment). Reproduced by kind permission of the artist

Figure 64: (interactive/emergent behaviours)
Reproduced by kind permission of the artist

Figure 65: "Maelstrom" (multi-user interactive environment – tracking and projection)
Reproduced by kind permission of the artist

His initial work used fully immersive digital environments, viewed through head mounted displays, which responded to the viewer's position; these allowed him to explore the relationship between physical and virtual space, and provided new insight into his previous themes of the viewer's experience of space:

> *"What was tremendously interesting about this whole process is how you actually started to see your environments through somebody else's eyes, because you could put it through onto a monitor, you could see how people reacted... You are seeing through their eyes, and how they dwell in particular places and so on. So that was quite fascinating."*

Combining these themes with an interest in the emergent complex behaviours of simple systems has led to his more recent work exploring dynamic real time interaction with digital environments. In his current work a combination of tracking and projection systems allows the digital and physical environments to merge: viewer-participants interact with and influence the behaviour of digital 'systems' by moving in physical space; their movement through the space acts as the interface to the digital environment, the 'cause' resulting in the effects in the dynamic digital environment:

> *"I'd always tended to think about things in relatively static terms, in spatial terms, and suddenly the notion of actually dealing with things to do with time, dynamic form, kind of things like that... when I showed you that stuff to do with the particles and the flow and stuff like that, that's all it's moving towards now in some senses, there's a kind of richness that can come from that dynamic aspect of the work."*

PractB's work with immersive digital environments, particularly his more recent work with tracking and projection systems in interactive digital environments, has allowed him to extend the themes from his material practice relating to space, and the body's relationship to space, in new and unforeseen ways.

Practitioner C

PractC is a sculptor whose practice concerns the nature of three-dimensional form and is characterised by a subjective approach which has run through much of his work since the beginning:

> *"I was fascinated by producing objects the like of which one hadn't quite seen before. In themselves they were then kind of problematic, and although I couldn't articulate it then, and possibly didn't quite fully understand what I was dealing with, in some ways, really I guess I was questioning the whole nature of representation and symbolism. And somehow, from those very early beginnings of revealing a possibility to explore the physical world, without a known outcome as such other than the object would somehow be finished to your satisfaction, whatever that means."*

Early experiences of computers left PractC with initial reservations as to the value of using the digital as a medium; however he did use a computer as a tool for 3D drawing, to allow him to visualise and plan large pieces of sculpture. It was seeing television documentaries in the late 1970s/early 1980s, just when 3D computer graphics was emerging, that triggered a move towards using the digital as a medium rather than solely a tool: he recalls "being just spontaneously excited about those possibilities initially".

PractC produces his forms through working directly with 3D modelling software (3D Studio Max) as his medium. Taking the torus geometric primitive as his starting point, he engages with it directly as one might a physical medium, manipulating parameters and modifiers in a speculative way, exploring the possibilities inherent within the mathematical and geometric properties of the form to discover three-dimensional forms which are geometrically complex, although they can be deceptively 'simple' visually. This approach "makes possible entities that I don't think that I could conceive of by any other means". This is an important feature of his work, and one which links to the subjective approach linking both his digital practice and much of his previous material practice:

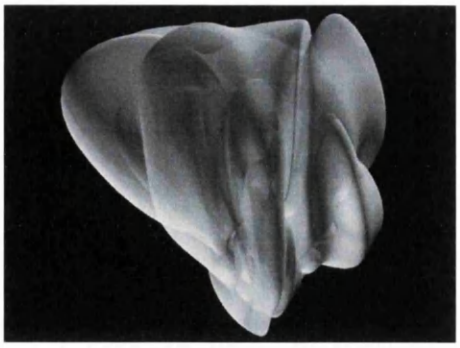

Figure 66: "Dayton 01" (cyber object)
Reproduced by kind permission of the artist

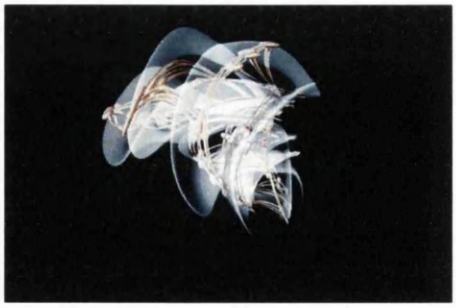

Figure 67: "Y-13-1" (large format print)
Reproduced by kind permission of the artist

Figure 68: "Shoal", side view (rapid prototype)
Reproduced by kind permission of the artist

Figure 69: "Geo_03" (bronze cast)
Reproduced by kind permission of the artist

> *"I want to see the like of which I've never seen before, and to respond to that, to try and glean from it some kind of understanding. At whatever level, I mean whatever understanding is, and for what that might mean."*

The move to what PractC terms the "cyber environment" has allowed him to extend his material practice in a number of ways, in particular by allowing him to discover/create 'new orders of object', forms that he could not have produced in the physical environment, with any other two- or three-dimensional media: "for me it offers, in my own discrete discipline, tremendous possibility in terms of potential exploration". PractC's claim to a 'new order of object' arises from the critical dependence of these objects, and their aesthetic, on the 'cyber environment' and from the ability to "encounter the unexpected" within this environment generated by his spontaneous explorations within the software, through direct manipulation of geometric primitives.

> *"That facilitates something the like of which we've not had before, therefore I think I'd be prepared to call it the potential for a new order of object. If you produce a milk bottle with a 3D modelling application on a stereolithography machine then that's patently not the case, but if you produce an object the like of which hasn't been really possible, then I think it's fair to say that there is an element of paradigm shift happening within that."*

PractC's move to digital practice has also allowed him to explore new forms of output – new ways of 'manifesting' the cyber objects, including large format high quality prints,

'cyberkinetics' (moving forms like animations), integral images (a form of autostereoscopic 3D image[63]), rapid prototypes, and bronze pieces cast from rapid prototypes. This mix of digital and physical outcomes has led him to explore, more deliberately, the relationship between the two environments on a conceptual as well as practical level:

> *"...the reflections on the surface of the burnished bronze are exploring the virtual in the actual... So with the highly burnished bronze ones, I'm bringing it up to a mirror finish so that it reflects itself within itself, and that then develops a certain kind of visual ambiguity. One's not able to quite determine what's real and what's reflected. What's real and what's virtual within the composition. Now, that's a very deliberate application of the material in a peculiar sort of a way to generate an effect. I'm also going to give it a black patina tomorrow to emphasise the extremities of the 'actual' form and not the reflection within the form..."*

For PractC, the possibilities of the cyber environment and the associated technologies he uses are tremendously exciting, and offer new ways of looking at the world:

> *"...at the moment it's a little bit like how it must have felt hanging around those cafes by Sacre Coeur, just after the turn of the century when all these exciting artists were kicking around these new ideas of modern art to do with Cubism or Fauvism or whatever- Breaking the mould really in some senses, trying to find other ways through which we can understand ourselves and the world that we live in."*

The digital medium

As can be seen from these examples, the term 'digital medium' covers a broad range of systems and technologies. However all the practitioners interviewed stressed that they were not working in a 'virtual' medium. For PractA, this is because the term 'virtual' (as in 'virtual reality') implies simulation rather than origination. Although her work is informed by her previous practice and aesthetic, she is concerned with using the medium of 3D computer graphics to originate work, not merely to simulate real materials. For PractB, the term 'virtual' is not appropriate partly because of its connotations in the philosophical context that underpins his work, but also because he is not using the medium to represent the world, but rather as "a way of rethinking the world". His work draws on the 'sensible' qualities of the experience in both immersive digital environments and his more recent work which combines digital and physical environments, which are real qualities, and real experiences. PractC has similar

[63] See Appendix B, ***Visualisation and interaction in 3D*** for an explanation of autostereoscopic displays

concerns, as the term 'virtual' implies a non-reality, but "the cyber... it's there, you can see it, you can interact with it, it's certainly real".

This emphasis on origination rather than simulation emphasises a crucial element of each practitioner's experience discussed above: their digital practice has allowed them to push the boundaries of their practice in ways that would not otherwise be possible, and to pursue work, themes, and objects that exploit the unique possibilities of the digital as a medium.

Approach

The desire to use the digital medium to originate rather than simulate is reflected in the approach each practitioner takes to the digital medium, whether it be 3D computer graphics, immersive virtual environments, or 3D modelling software. In each case this approach to the medium is in line with (and largely arises from) the approach they used in the physical environment. All of them are questioning the medium, pushing its boundaries, 'finding its edges', and crucially, using the qualities it can possess as a medium, not as a tool for simulating reality. This type of approach is frequently in contrast to ways that these media have traditionally been used, or are being used by other creative practitioners, and often results in the digital medium being used in ways other than for which it was intended, or beyond that for which it was designed.

The following sections describe each practitioner's own way of characterising their approach to the digital medium.

Practitioner A

PractA regards 3D computer graphics not as a means of simulating reality, rather as a medium for origination. Her distinctive approach to this medium – to engage with it, push it, and understand it as a medium - derives from her background as a maker, with its characteristic 'inquiry about materials'.

> *"I think that's what makers particularly have, those that work specifically with material and are really inquiring... an ability to question the aesthetic of the material and how it's perceived, how it's used..."*

For PractA, this approach to the digital medium is driven by an extensive experience of material practice and knowledge of materials, not with the aim of simulating reality, but

because it gives her 'questions and an enquiry', aesthetic parameters within a medium which in itself has very few boundaries.

> *"There are certain elements I'm exploring which are defined by an established knowledge of material. I'm not interested in attempting to simulate this knowledge or convey how it was previously used, however it does provide me with questions, levels of enquiry, aesthetic benchmarks, which guide me through the software, defining certain routes that I don't think I would consider pursuing or otherwise find."*

This approach to 3D computer graphics leads PractA to push the medium in many aspects far beyond what the computer graphics industry needs or is doing, not just in terms of the 3D computer graphics software, but also in the movement and motion capture.

> *"we're pushing use of the technology to a particular level informed or inspired by earlier 'physical' process and its effect, which to some extent sets the key challenges relating to the medium. Particularly in terms of altering perception towards it as its potential, is I feel, little understood on some levels."*

This non-conventional use of the medium arises both from her experience of material practice – the 'questions and enquiry' she describes which lead her to challenge the tools – but also from the unusual circumstances in which she learned to use the software. Provided with the opportunity to use the high-end computer graphics software 'out-of-hours' in a post-production company, PractA taught herself to use the medium. Whilst very difficult at the time, this 'liberated' her to engage with the software as a medium in her own way, rather than being taught 'the' way. While beneficial in many ways, one drawback of this approach was that, as she hadn't learnt the conventional 'language', communication with industry users of the software was difficult.

> *"I wasn't learning software in a way that would be used in a commercial environment, I wasn't learning 'their' language. Left to my own devices, I found my own methods and would be asked about my process 'oh, did you do that using this 'path', that 'effect''... And I actually wouldn't really know what they were talking about, because I hadn't been taught use of the software in that [way]. I wasn't using a lot of the software processes that they were using, which were often specific 'special effects' predominant in advertising at the time, I very much defined my own way, so... in fact, I had no means of retelling the process to operators if I wanted to. In some respects this was an advantage. I suppose in true research terms, it could be argued that this was maybe the wrong way to go about it, there are many reasons why I chose to work this way but just in terms of liberating myself from evolving convention in terms of software use, in order to develop use of the medium, this particular one being quite cumbersome, I felt to work intuitively was the right thing to do."*

These two aspects – bringing what PractA terms an aesthetic 'vocabulary' from her material practice, and learning the software outwith industry conventions – result in a very different perspective to 3D computer graphics to those within the industry who have

learned to use the software as a tool, tending to accept that 'that's the way it works', rather than challenging why it works that way. Today's high end 3D computer graphics packages, such as Alias's *Maya,* are large and complex pieces of software which if you don't have reason to explore (e.g. from knowing what's possible with other materials), then you probably won't:

> *"Generally a computer graphic operator has learnt how to work with software in a certain way, you can improve on that working process with use and with some relevant elements of programming. But the operator isn't necessarily the sort of person that sits and really questions the construction or capability of the software or its interface for example, just as they are unlikely to have an idea about materials, the 'surface' of an object, visual perception of a material and what this communicates to the viewer. I suppose the connections that I'm making are because I work from a totally different premise. If 3D software packages were rewritten from the perspective of the maker, jeweller, glassmaker or painter for example, I'm sure it would be possible to devise a very different, more intuitive interface or working environment, so that the digital working process were more accessible and interesting to a broader sector. However most of these tools have been developed with very different industries in mind."*

Even within the arts, PractA's approach of engaging with the digital as a medium is very different to that of many practitioners who emphasise conceptual concerns:

> *"...few practitioners/artists connect with the digital media in a material sense. Most explore digital media from a conceptual perspective working with the mechanics of the medium and its creative potential through the web, live interaction, using tools in terms of location, communication, audience etc... As a maker there are of course conceptual considerations, the working process however is predominantly driven from an overall aesthetic premise of engaging with material. In discussion with a writer from a digital magazine there was great curiosity expressed regarding the 'craft' issue in digital terms as an emerging practice and how digital media, in this context, is being aesthetically challenged..."*

The approach which PractA uses has been particularly important in enabling what might normally be perceived as software-imposed limitations or restrictions on the work to lead to new ways of achieving things, and new directions within the work:

> *"Early on, working with 3D software in particular, it was essential to bypass what appeared to be enormous technical and aesthetic limitations, compared to established 'physical' process... to access new levels or 'mind spaces' to work/think within. This directive generated such interesting results, that in the form of an acknowledged approach, I would add it to the 'palette'. Consequently there are working methods currently in development which I'm convinced would never have evolved had we not had those restrictions early on. What could be perceived as 'restrictions', to what's normally known. There is value in being challenged by the medium as well being in a position to challenge the medium, work against or beyond convention, this opens new doors, particularly in the digital realm which on many levels is still uncharted territory... It is important to view the software as a medium, a 'material' that is malleable with the capacity to function beyond perceived understanding... in this case established knowledge is useful."*

Practitioner B

PractB's approach to the digital medium is also based on principles from his material practice: to question the material, find out its limits and exploit those limits; what he describes as 'truth to materials'. Within the context of his work with immersive virtual environments, while there may be no physical materials involved, nevertheless there are aspects of materiality within the medium:

> *"obviously you might question the notion of material, so you might talk more in terms of sensuous qualities or a sensibility of digital media. But the point I'm in now, I'd really apply the same term to material things as much as things that derive from digital sources. D'you see the generic way in which I'm trying to use that notion of truth to materials?"*

He continues to explore the themes from his material practice, enhanced by the possibilities offered by the digital medium. Despite the differences in the two types of media, PractB finds that his enquiry in terms of space, and the viewer-participant's experience of space, is not that distant from his material practice:

> *"...those sorts of events, I'm looking to involve people with them within installation environments, but now I've obviously got the power of a dynamic system to play with those things. And it's not the same as film, because you can involve the body. And in that sense it's very sculptural, for want of a better term. I don't see it as being removed from the stuff that I used to do- it's just slightly different and so I work with it slightly differently, but it doesn't mean to say that the underlying principles of say, something roughly described as a truth to materials doesn't lie behind it."*

He is not concerned with using the digital medium to reproduce the physical world, rather he aims to explore "those emergent qualities that come from it, the dynamism that's involved in all of those sorts of things. Those are all absolutely real qualities that you're working with". He is particularly interested in exploiting unintended effects, or characteristics of the environment that might conventionally be perceived as problems or limitations. He describes an example from his practice, where 'performance limitations' led to a new area of work:

> *"...do you remember when the streaming video format first came out? You'd get these incredibly compressed files... When it's blown up, like I had my daughter, and bits of her dissolve in and out of the background. And like that notion I was talking about a body, and the coherence of a body. You've suddenly got this being played out visually. It's not a representation, or anything literal, but just this quality of these things going on within an image. And that's actually quite low-tech. It was designed in order to punt video across at low data rates. And it's like, look at that, look what you can do with these very simple means... You start realising, well, there are simple means of doing things."*

This approach, making use of what PractB describes as 'minimal means', often produces work which is simple and elegant, qualities PractB admires in this area of practice.

> *"...this is where I think the type of work that I'm doing wants to be heading, very kind of minimal qualities, to do with light, where the richness of the piece comes out of the quality of the things that emerge, the dynamic aspects of the system."*

He finds his approach contrasts with the 'won't it be good when' attitude of many practitioners towards digital media:

> *"...in terms of aspirations, like we want all this super-real stuff... won't it be good when we can have digital objects which behave like physical objects and stuff like that... You miss out on all the interesting stuff that can be done there and then, because it's always about aspiration. And that seems to me always the danger of it, and that's particularly I think one of the aspects to do with that notion of a digital ghetto, is that people get tied into those aspirations, and it's always tomorrow when it's gonna be better, and they miss out on the very stuff that I'm talking about notions of truth to materials, about what this stuff can do. All the things which informed them as an artist, are suddenly sshh cut free, because you're looking to tomorrow, you know. Like it's gonna be better, it's gonna do this, it's gonna do that."*

Practitioner C

PractC takes a similar stance to PractA and PractB: he is not using his chosen digital medium as a means of simulating the 'real' world', or of representing objects which have been predetermined, but is engaging with it as a material, playing with it to see what forms and effects emerge. A speculative, exploratory approach is fundamental to PractC's digital practice and, as discussed above, relates back to much of his material practice. Key to this approach is his very direct, immediate, spontaneous, free, intuitive, and playful way of working with the software:

> *"I've got nothing in particular in mind as an outcome. I could, in the next few minutes produce what I considered the best piece of work that I've ever produced, or I might not, you know. And all I do is I just fiddle with the dials (laugh) and watch what happens, you know. So, it's very much a sort of suck it and see."*

Unlike the conventional use of 3D modelling software, PractC is not treating the geometric primitives within the software as abstract entities, mathematical representations of physical or imagined forms, but as material to be worked with, manipulating the primitives and modifiers in the software to explore the possibilities within this medium:

> *"I go to my software, I pick extended primitives, I pick a torus knot, and I generate a torus knot... Now, one of the wonderful things about a torus knot, is you can actually affect its P and Q factors to change the numbers of windings. Now, to be able to do that in real time... You know, that just happens to be 17.25 by 8.5, windings this way and that way that causes the various segments within the torus to align in this particular way. If I increase the number of segments... that's giving us something*

else. Now, that last one was kind of curious... But just look. I mean, this is where I'm using it as a material."

The ability to work with the 3D modelling software this way is supported both by an interface which, while it may be relatively complex in the context of building models of predetermined objects, supports this style of working - "it's not hard, you know, isn't difficult to actually interface with the software" - and by having a computer system with sufficient processing power to respond quickly enough:

"The tremendous facility now that's afforded with real time graphics... allows you that possibility to interact with it in a very immediate and spontaneous way. And because I'm working directly, it helps the flow of that direct, reciprocal thing that's happening between me, and what I'm doing."

Central to PractC's approach is the desire to encounter the unexpected within the medium. This leads him to not only use the 3D modelling software in ways not normally considered, but to push this medium to its limits and extend its possibilities as a creative material:

"After working with it for four years, I realised if you went into the negative, it squeezed it this way instead of that way. And that for me was a little discovery that, whoever wrote this software didn't expect someone like me coming along and distorting it to the extent that I do."

PractC's experience of engaging with the cyber environment is one of excitement, discovery and wonder, but so far it is shared by few sculptors:

"It's an adventure, for me, really and I'm really truly amazed that there are so few of us who have actually engaged with that cyber environment. You can almost count on one hand the number of serious sculptors in the world who are using this technology. But of course some of them are using it and not telling us. 'Cause I can spot it, in some artists, that aren't saying how they're arriving at the forms that they're producing. Fairly major artists, and I can see the traits of the computer aesthetic. I can see the computer aesthetic in the work, because I know the generic tools that are there to manipulate the medium."

While PractC's approach is certainly speculative and exploratory, as will be discussed more fully later it should not be misconstrued as arbitrary.

"It's pushing my art form to its edges, and I guess that's what's always fascinated me about what I've been doing, whether it's in fact with a bag of clay, a lump of wood or the cyber environment"

Role of medium in practice

From the above descriptions, it is clear that the three practitioners' approaches are broadly similar: they are all actively engaging with the medium, and using its inherent qualities, rather than using it to represent or simulate reality; they are all exploring the

digital medium in very different ways from its conventional use; and what might normally be considered limitations actively contribute towards their developing practice.

Yet although there are strong similarities, there are also differences. Some of these arise from the different digital media that are being used, or because the practitioners, in a sense, are all looking at the digital medium differently because of where they've come from. Yet there are more fundamental differences than this between practitioners, which concern the role of the medium within their practice, and relate to whether their approach could be characterised as a dialogue *with* or *through* the medium, and whether the medium is closely identified with the 'self', or viewed as 'other'.

Practitioner A

PractA describes her relationship with the medium, and its role in her practice, using strong metaphors of language. Her approach to each medium she uses – questioning it, understanding it – is related to the idea of becoming familiar with it as a language: how it works, what its characteristics are, what you can do with it, what you can say with it. Part of learning a language is learning or becoming familiar with its vocabularies – those elements of it that give it meaning, flavour, and nuance (in a sense as distinct from grammar, which gives it its structure):

> *"Direct contact with physical materials enforces intuitive enquiry, driven by the hand and eye, directly manipulating the media, which takes in or assesses the cause and effect, i.e. the vocabulary of the material in any one particular set of hands."*

Each medium yields different vocabularies: in PractA's digital practice these arise not only from the 3D computer graphics software, but also from collaborating with a dancer whose movements are made available to the digital environment through motion capture:

> *"...how the pieces are driven by human movement is key. The 'choreography' has been considered in a very different way to how it would evolve performatively, it has to respond to the capabilities of the software for example. There have been limitations, which have proffered a new vocabulary of movement, affecting the 'cloth' form in unusual ways kinetically. Different participants provide different movement and indeed identities through the gesture and 'characteristics' that are apparent when placed within the digital garment form. The contribution this element makes is one that I have only begun to explore."*

This aspect of language is to a large extent defined by the person using it. Choice of vocabulary is one of the ways in which, as individuals, we each make language our own. Another aspect of language defined in relationship to the individual is the notion of 'voice', a term that PractA uses in describing her practice. Far more than style or

technique, 'voice' relates to personal, individual expression. While 'language' and 'vocabulary' are defined in terms of a medium, this aspect of practice runs through and across media:

> *"...the sensibility that one has as a maker, a consistently recognisable 'voice' that evolves during one's practice, a fluid line of connection between all you produce over time... Makers', painters', sculptors' work is generally identifiable regardless of the medium or variety of media employed in pursuit of their practice..."*

Another metaphor PractA uses for the medium in her practice is that of the painter's palette:

> *"...as I accumulate and define processes, tools, concepts, aesthetic values, I tend to define these collectively as a 'palette'. I do feel literally as if there is a palette to hand filled with a range of gooey squishy colours, splurged and being mixed, the paint colours slowly changing as they become mixed. With the digital medium, I wonder if this is to counteract what is in fact quite a rigid interface, have I used the term and the visual that it conjures up to dupe myself into believing that the environment I currently engage with is more fluid than it in fact is? Or is the visual metaphor in fact a more fundamental and flexible bridge to what would otherwise be a rather rigid working environment?"*

Similarly to the notion of 'vocabulary', a painter's palette is defined in its relationship with the painter; a painter selects a palette from a much wider range of paints at their disposal. PractA's development of her 'palette' within the medium of 3D computer graphics is informed by her previous material practice, not because she is concerned with simulation, rather because it gives her what she describes as 'questions and an aesthetic enquiry' in her exploration of the software. For many people who approach the software without such "an enormous bank of knowledge that makes something", the experience can be bewildering.

> *"...the working parameters of function and possibility within certain 3D software can be vast. Without experience of the tool and an objective, engaging with the medium can be overwhelming, it's not really possible to imagine the potential depth of the tool."*

The metaphors of language PractA uses when talking about her relationship with the medium, and its role in her practice, might convey a strong impression that PractA has 'something to say'. Yet her process is not driven by an explicit aim or a predetermined outcome, but is tacit and organic, where the work evolves:

> *"It is hard to explain an essentially tacit process. I have a passion for the work, particularly the elements that I have less control over, such as the movement, which will contribute more and more in the future to the narrative of a piece... That becomes a focal point to producing the work, guided by a fine line of what 'feels' 'right' or 'wrong' which defines much of the 'making'."*

In PractA's approach, a close relationship between the practitioner and the medium is very important to the development of the work. This can be seen from this description of her process:

> *"There's an element of beauty in the work... beauty is a very a subjective term and philosophically loaded but the pieces do have this quality on completion, although it is not something I consciously aim to achieve... And I think that's not only the tacit knowledge issue, for me it's also the tacit aim. I'm not sure if I can really define this, it is complex and further complicated by combinations of physical and digital languages that may be misinterpreted, perhaps require redefining. Ultimately I think I initially work very organically, playing with the medium, pushing and pulling at it almost in a very physical way until the journey is clear, driven usually by the 'feeling' described earlier of what is 'right'... Guided by form, colour, movement, structure and the effect of this combination of elements... The work belies perception of the medium 'computer graphic animation', which is generally driven by a commercial aesthetic... This wasn't necessarily an aim but it is interesting to have an effect on a medium and how it is perceived."*

Although 3D computer graphics software has an interface which invites descriptions such as 'grey', 'linear', 'rigid' and 'boring', which contrast starkly with the above description of her process, nevertheless PractA found that through familiarity with the medium, and with her "prior knowledge" of the "fine line of what 'feels' 'right' or 'wrong'" from her material practice, she did achieved a sense of 'immersion' ("when you really forget all of those menus") characteristic of a maker's relationship with their materials, with this medium.

> *"Again, I think that is also due to my prior experience of physical material... I know instinctively what I'm looking to achieve, driven by a 'feeling' and 'effect', which comes through familiarity of the medium."*

Practitioner B

PractB's relationship with his chosen digital medium appears to be qualitatively different from PractA's. PractA sees her relationship with the medium in terms of language, making it almost part of herself. In PractB's work and practice, the medium's role is to reflect back our ways of seeing, ways of thinking, ways of experiencing, to make us aware of our unconscious assumptions about the world. In this way PractB appears to relate to it as something 'other', a means of doing "interesting things" and of "rethinking the world".

This role which PractB ascribes to the digital medium, or more broadly new technology, has two aspects, one outward-looking and one inward-looking. Firstly, it enables him to challenge the viewer-participant's assumptions about the world; secondly, he believes it must challenge the nature of an artist's practice. Both of these aspects relate to the

indefinite nature of digital media – their ability to be many things - which allow them to be used in very different ways, and for very different purposes. A digital medium can be used in a representational or simulatory sense: a practitioner may want to use it to represent reality, or to be able to work with it in the same ways that they would work with physical materials. Alternatively, it can be used in the way that PractB approaches it, exploring and exploiting its inherent qualities and limitations, very much in the spirit of 'truth to materials'.

In the first of these approaches - the desire to simulate reality through representation, or through devising systems whereby it is possible to work with digital media in the same ways as we can with physical media - the digital medium embodies our assumptions about how we see, experience and relate to the world. In the second of these roles, it has the potential to reveal our assumptions about the world, and to allow us to rethink our experience of and relationship with the world. Virtual environments, for example, can allow you to experience things it would not be possible to experience in the physical world such as the ability to move through objects that appear to be solid.

> *"If you play with that quality of being able to pass through things, it becomes quite physical. You almost feel things when you move through. It's probably some interesting bit of psychology going on there to do with assumptions, but it's interesting that you disrupt the assumption by being able to pass through it, and so it becomes a physical quality anyway. So the notion of reality and stuff like that's not really an issue, because the quality of the experience is still real, and it's assumptions which are being overturned. I think often that's what good practice does, is it challenges one's assumptions about the world. And that's what's interesting about using these dynamic systems, you can look at things in other ways..."*

Much of PractB's practice concerns our embodied relationship with and experience of space, and with the world. Disrupting these "habitual relationships" with the world (such as playing with our experiences of absence and presence, above, where absence is made physical) allows PractB to reveal and challenge our assumptions about it, providing us with new ways of looking at the world:

> *"You look at some of the interesting assumptions that are made about qualities of experience, and tinker with that. That's why I think this thing about challenging assumptions is interesting as well, because so many of those habitual assumptions stop us seeing the world. And you think about major experiences in your life, it's normally when those assumptions are overturned and you see the world in a new light."*

PractB has found this true in his own practice with digital media:

> *"I'm far more interested in some ways in what's going on with it, than I ever was before. That's doing myself down, I was very interested in it before, but- I can't quite put my finger on how to describe it, but it seems to reveal more of the world than my*

work used to. I think my work used to reveal more of my assumptions, whereas this stuff seems to be fundamentally about questioning assumptions and trying to really push beyond habitual relationships."

He has reservations regarding practice which views digital technology as a solution to existing problems or concerns, rather than as a medium in its own right. Whereas PractB is exploring the possibilities inherent within digital media to question assumptions,

"... they've got a set of assumptions and strategies that work in one particular field, and they are expecting to move them across to another, and to do things quicker, to do things slicker, all those sorts of things using digital means."

PractB's view of the role of the digital medium is quite different:

"I've had some students who've come in and they've thought that new technology is the solution to their problems, whereas actually, it's the thing that precipitates the crisis, because they've got to examine the core of their practice and how that relates to this technology, rather than being a package of solutions which solve their problems. So it's not a bolt-on. People think it's something that's gonna bolt on and change things or speed things up. It's actually something I think which needs to radically challenge assumptions and transfigure things in that way."

In comparison with PractA, PractB's process does not seem to be quite so closely related to his relationship with the medium - there seems to be less explicit focus on process, more on content, or 'intent' - but he does nevertheless have a process in which the medium is allowed to play a important role: firstly in the sense of 'truth to materials', where he is exploring and exploiting the inherent qualities and limitations of the medium; secondly, where he is developing work which uses the emergent qualities of dynamic systems, where complex behaviours can arise from interactions between individual items with simple behaviours; and thirdly, where although he has certain objectives in mind for the work, he is open to risk and discovery during the process. This can be seen in his description of his process of developing code, which he likens to his previous experiences with carving. Software packages tend not to address this well, because they are 'risk averse', which is one of the reasons PractB likes the coding process:

"if we go back to the thing about carving, you'd be down there, you'd be doing your carving and what have you, and then you'd want to assess your work, so what do you do? You stand back and you look at it. So when you think about running code or writing code, there are certain objectives you have in mind when you're writing the code, and you want to look at what it does, so you run the code. It's not as if the two are so intimately bound that you cannot separate them. Do you see what I mean? There is some distance between the activity. And when you get used to working with code, you're getting an idea of what's gonna happen with something, and how things ought to feel, you know? There's a certain degree of experimentation. Much in the same way as when you're kind of going to bend a piece of steel or you've got to split a piece of stone or you're gonna do this or you wanna do that, you don't know exactly

what results are gonna occur. And part of the joy is actually doing it, and seeing what does result. Now, that's what's frustrating I think about a lot of packages, is that because they want to reduce the risk involved with certain things, and they want to take away the effort involved with certain things, you get very predictable results. So you can look at some student's work say, and say, they've used this PhotoShop filter or they've used that PhotoShop filter, or there was a lot of criticism about the generic feel of a lot of sculpture that would have been developed out of CAD."

Practitioner C

For all three practitioners interviewed, the medium plays a significant role in their processes, yet its role in PractC's practice is again subtly different from PractA and PractB. PractA's relationship with the medium is one of language; PractB's one of challenging assumptions. But PractC is very definite that he 'doesn't have anything to say'. He describes his process as speculative and disinterested: he's not asking questions, or looking for answers. Rather,

"I've always seen myself really more concerned with the business of exploration and discovery. Rather than representation, interpretation, or translation. Those things involve, somehow language very much more, and language is something that bothers me. Maybe it bothers me initially because I'm dyslexic and I have a mistrust of words, I have just as much a mistrust of numbers as I have of words because somehow you can do anything you like with them. Perhaps you can do anything you like with all media, it's somehow, I guess trying to get beyond that to make some kind of connection with something that for me goes very deep - it's somehow beyond language."

This defines the medium as 'other' rather more markedly than PractB. In his subjective explorations of the medium, with its emphasis on discovery rather than invention ("you don't have to invent what you discover, you simply find it in the world. Whereas to invent it you would probably need to have a purpose, some question to resolve in some way"), realisation rather than recognition, PractC sees himself not as looking for something specific, but responding to things he sees, not giving meaning through creating objects, but deriving meaning from the objects he finds and brings into being through his explorations. This sense is particularly strong where he describes his pursuit of 'objects the like of which haven't been seen before', and the notion that they are somehow waiting to be found:

"...it's just really the joy of coming across something you're pretty convinced hasn't been encountered by anybody else before, and just simply saying 'Look at what I've found. Make of it what you will'."

This position is reinforced by his reluctance to predetermine the outcome, rather exploring the potential of the material, to "relieve myself of a certain responsibility for making choices". PractC is happy to work within and explore the possibilities of things

that other people have determined, and in this respect, likens working with this digital medium to working with found material in the physical world.

> *"...I treat [3D Studio Max] in the same way as I would treat a piece of found material in the world. Because I don't want the responsibility to pre-determine. I don't mind working with pre-determinates that others have specified, and within that exploring possibilities, but I don't feel that I want to take the responsibility and add something to that... it just perhaps brings something into the equation that I don't actually require, and it would be cumbersome if I had to justify the inclusion of something in particular, rather than perhaps choosing from what's already there"*

This 'otherness' of the medium, together with his speculative, exploratory and responsive approach, defines the reciprocal relationship between him and the medium which is fundamental to his practice, and to the form of the work which is, in a sense, not created but 'realised': "wrestled into being" through working with the medium. This distances his practice from the criticism of being purely introspective and self-indulgent:

> *"However, whilst it might be seen by many as some sort of masturbatory type activity, some sort of self-satisfaction, I maintain that that's not the case, because masturbation's a completely introspective activity. What I'm involved with here has an external element which is to do with a reciprocal exchange, interaction between me and the medium. And, through exploring that, it's revealing to me, often the unexpected."*

His spontaneous way of working, supported by the responsiveness of this particular digital medium, allows him to generate many iterations or explorations from which the work evolves. Like PractA and PractB, often it is when the medium 'breaks down' in a conventional sense that interesting possibilities are revealed. But perhaps more than for either PractA or PractB, the medium plays an immediate and crucial part in PractC's practice. The torus geometric primitive within the software provides him with a foundation, a secure starting point from which he is free to explore. His work is realised through direct interaction with this medium, and is the result of what he finds there:

> *"I know, although I've not seen it, that there's a great deal more waiting for me in there, as it occurs within that spontaneous act of engaging with it, very much in some senses a playful kind of a way. Sometimes at the end of a fruitless evening of struggling away modelling, I just grab a bunch of vertices in an object and delete them to see what happens, and sometimes that serendipity aspect throws up something really quite unexpected, that invariably isn't quite acceptable. You need often to tweak it to bring it in within the bounds of your own sensibility."*

Of all three practitioners, PractC's approach is the most open-ended. Both PractA and PractB have an objective in mind, albeit tacit, whereas PractC's approach is defined around the ability to reveal the unexpected.

> *"I have a design on the notion of producing another form the like of which I haven't seen before, by the end of the day or by tomorrow or next week or however long it*

takes, there is a desire to want to encounter something there. But I can't for the life of me see what it is, it's not like I have a vision."

But while his approach is speculative and exploratory, it is not arbitrary: "Whilst on the one hand the immediacy and the spontaneity of possibility within the cyber environment makes it easy, at the same time that makes it very difficult, because anything won't do". As what 'will or will not do' has not been explicitly predefined, PractC's process is one of ongoing evaluation – "taking stock" throughout the creation of a piece of work – not against specific criteria, but guided by a sensibility of what is 'right', the resolution of what PractC describes as 'cognitive tension'.

"And yet there's something about it that's niggling, that I guess is certainly what Peckham refers to as cognitive tension. And it's not until you relieve that tension that you're somehow in receipt of an understanding of the meaning of what it is... You somehow feel that it's not right. What's not right about it then? You know, what is it about it? And that goes beyond logic for me..."

Related to this sense of going 'beyond logic' are tacit ways of knowing associated with making practice, the 'thinking with your hands':

"it's not an automatic, involuntary activity like an instinctive response to something is - it's considered. You squeeze it this way, you squeeze it that way, you look at what you've got. You then assimilate what you've got and you determine a further outcome beyond that in some way..."

Underlying this sensibility is PractC's requirement for coherence in the pieces he produces: "that coherence indicates to me that I've included all the bits that are necessary to it and not included aspects of information that are irrelevant to it". As his work concerns the exploration of three-dimensional form, it is the form that must satisfy his criteria of coherence within the piece. In his digital practice, working with the 'generic primitive' (currently the torus form), provides him with "the coherence of a logic", even when he produces forms that, produced by other means, would not meet his criteria: aspects that would be arbitrary in other circumstances are the result of his manipulation of the underlying mathematics and geometry of the objects, and are therefore acceptable:

"What I find absolutely fascinating is, how the geometries behave in the cyber environment... {discussing example} I'm fascinated by it, because, if I were carving this or modelling it, I wouldn't put that bit there, and I certainly wouldn't have put this subtle little element of form here. Or maybe this change in plane here... Because it would be arbitrary. I might choose to, say, put another bump on there, but what for? I couldn't do it- Unless I had good reason. By good reason I mean if it made sense, I mean if it felt right, I could put one there, but I wouldn't have put these bits where they are, is what I'm saying. [And do you think you're happy with where they are, because it's true to the geometry?] Absolutely. It makes a sense."

The realisation of a digital object into physical form, through rapid prototyping and casting in bronze, adds a requirement for coherence on that level as well, adding another element to the work.

Comparing material and digital practice

From this examination of the working processes of these three practitioners it is clear that, in all cases, their approach to the medium in their digital practice is in line with (and largely derives from) the approach they used with physical materials. This is not to imply that they use similar techniques in both media, but that their overall approach to the medium is consistent across both.

One of the principles underpinning the method for this study, and the thesis research overall, was that insights could be drawn from the comparison between the practitioners' material and digital practice. These might have explicitly come to the practitioners' attention through their move from material to digital practice, or be things that they may not have been aware of, but which can be inferred from their accounts of practice, or revealed by the types of comparison made during this study.

My original rationale for this element of the study, as described in Chapter 4, ***Difference as a means of enquiry*** was based on the perceived similarities and differences between the two environments. It proposed firstly that in many respects the indeterminate nature of the digital medium (its ability to be many things to many people) would make it an ideal environment for delving deeper into the nature of this relationship, by examining the ways in which people choose to use it; secondly, that because it typically is viewed as being less immediately intuitive to use, this should bring to the foreground aspects of practice which might otherwise remain unseen; and thirdly, through this comparison, it would be possible to dissociate some of the ways in which design practitioners work from the physical artefacts that they use, and to gain insight into ways of working and knowing that are not embodied in the material context of the real world (although the significance of *a* context is recognised).

While the comparison between material and digital has undoubtedly borne fruit, findings from this study suggest that it is necessary to examine more closely the assumptions behind this rationale, regarding the nature of the media.

The nature of material and digital media

Characteristics conventionally attributed to the digital medium (or at least those attributes which may be most immediately apparent) are immateriality; intangibility; the need to work to a large extent with abstract, formal representations; working at a distance from the 'real' world; and freedom from material constraints. For example, digital media such as 3D computer modelling and animation software require, at least on first examination, users to be very explicit when creating objects, working with geometric representations and operations. Material practice, on the other hand, is frequently regarded as 'hands on'; rooted in physical materials; with a concrete and intuitive approach marked by a close relationship with the materials.

However, the descriptions of the working processes of the three practitioners above indicate that a medium's characteristics cannot be derived from the medium in isolation but are, and must be, defined in relationship to the practitioner. For example, geometric primitives in 3D modelling software are normally regarded as abstract entities, but PractC treats them like materials, albeit with mathematical rather than physical properties, manipulating them in a direct, spontaneous and intuitive way. This way of approaching the software is possible because he is not using the medium as a representation of 'real' objects, rather he is working with the qualities of the medium as they reveal themselves through exploration. Despite requiring considerable effort to achieve sufficient familiarity with the medium, PractA is now able to experience an 'immersive' feeling with the computer graphics software she uses, even though it has an interface which is very rigid and linear.

Both PractB and PractC regard the experiences within the digital environment as real. For PractB, digital environments have sensible, sensuous qualities, and the experiences you have in them are perfectly real, albeit ones which challenge your habitual experiences of the world. In PractC's case the cyber environment, while 'virtual', is still real; he now sees little difference in ways of working between physical and digital media:

> *"I've worked with it for so long now that it's difficult to really identify too much difference in ways of working between, say, taking a bag of clay and pushing it around in a disinterested way, or taking a torus in the cyber environment and pushing that around. The difference is in the difference, because physical materials behave in the way that they do, depending on what you do to them I guess, how you interact with them."*

It is possible therefore to work with digital media in ways usually attributed much more to physical media, so the conventional ways of regarding digital media may seem inadequate. Nevertheless there are differences between the two types of medium which give insight into the practitioners' working processes. Indeed, in the cases examined in this study, it is each practitioner's very act of approaching the two media in the same way, and the implications which this has had, which has yielded the most insight.

'Foregrounding'

There are a number of levels at which this 'foregrounding' or 'distancing' between media may take place, giving insight into the practitioner's general practice, approach, and relationship with the medium; or the concerns, content or theme of their work. Table 9 lists elements of foregrounding that have been examined within this study. Many of these have been discussed earlier in this chapter.

One area not previously discussed in great detail is the degree to which elements of their practice have, or have not been transferred between media (as distinct from their actual approach, which was broadly consistent across media). Perhaps the most striking aspect of this is that not being able to be physically 'hands on' with the medium, nor working with physical materials, doesn't appear to be a big drawback. For PractA, there are certainly elements of her material practice she doesn't miss:

> *"....'don't you miss the fabric, or feeling of material in your hands?' is a common question. In actually working the material physically, the fabric would be wet or in the process of being dyed or stitched.... the physical nature of which I didn't particularly enjoy ... My hands were often in agony using a repetitive fine stitching process, sitting or kneeling to make work affected knees and back over many years... however I enjoyed the anticipation of the result and the effect of experiencing the final work..... In terms of the process, the cause and effect of physical process is ingrained in my mind and somehow readily transfers itself to the digital experience, contributing to an immersive state..."*

Although the medium still plays an important part in PractB's process, it plays a less predominant role in his digital practice than previously:

> *"I still like working with materials, and it seems to be something that comes quite naturally when I need to, but it's not the be all and end all it used to be."*

Touch was an important part of PractB's process when carving, but in his digital practice the lack of touch isn't an issue. Moreover, he feels that trying to emulate that aspect of work for interacting with digital media, as in systems which allow you to 'sculpt' digital clay using a force-feedback stylus, can be problematic:

Medium	Differences and similarities identified by the practitioner between the two types of media
Work	Differences and similarities in the nature of the work produced by the practitioner in each environment
Approach	Differences which the practitioner noticed in their approach between medium Anything the practitioner finds difficult to achieve in the digital medium that, because they nevertheless struggle to do it, may be considered important to their practice (this does not imply that things which are easy are not important, but it could be argued that things would not be done which were difficult and not important) Alternatively, things which the practitioner finds easier, and things that were not possible before that are now important to their work
Practice	The degree to which elements of practice are transferred between media Elements from material practice that deliberately or unconsciously were brought into digital practice because the practitioner found them lacking in the digital environment Elements from material practice that deliberately or unconsciously were 'left behind', because the practitioner found they didn't want/need/miss them in the digital environment
Other	Observations made by the practitioner about ways that other people work in the digital environment Other aspects of practice that have been brought to the practitioner's attention by an aspect of the medium More general insights the practitioner has received from their move to digital practice

Table 9: Elements of 'foregrounding' in this study

"...when you carve a particular form, at a certain point I'd stop using my eyes quite so much and use my hand, so you'd pass your hand over a form and feel where the irregularities were as far as the shape you were trying to achieve was concerned, mark it up as a guide to the eye when you were then using the tool. And also what would happen is the tool gives you a hell of a lot of information by touch through it. Now this is the frustrating thing for a lot of sculptors who come to this stuff, is that it won't give you any of that information. So something like the [haptic stylus clay modelling] system is trying to emulate that, but what's problematic about it, is of course you've got a series of servo motors, and it's like a series of magnets and so what does it feel like? It feels like putting two north poles of magnet's together when you get the resistance, you know? Its- what's this? And then of course you want to put your hand over something, and you can't."

PractC has no particular desire to work with his hands in the digital environment, although he does enjoy it. His experience as a sculptor has made him familiar with mechanical processes, and for him, working with the software is, in a sense, a mechanical process.

"I don't know that I have any great desire to want to work with my hands as such. Although I do enjoy, and have always enjoyed, working with my hands. When I slice my trees up I use a chainsaw. You know, you don't actually take it apart with your hands, you use a machine to do it. Mechanical processes are something that I'm quite familiar with as a sculptor. I guess to some extent computer graphics is another sort of a mechanical process, but, it makes possible entities that I don't think that I could conceive of by any other means."

In terms of those aspects of material practice that have been brought to the digital medium, PractA in particular emphasises the importance to her digital practice of her prior making knowledge and her extensive bank of experience, not with the intention of simulating this work, but in terms of informing her enquiry of the medium. All three practitioners are using the digital medium to extend the aesthetic and conceptual concerns from their material practice, and push the boundaries of their practice in ways that would not otherwise be possible.

Conclusions

For each practitioner interviewed in this study, their approach to the medium is in line with (and largely arises from) the approach they used in the physical environment demonstrating that, at least for these practitioners, their overall approach is consistent across media, therefore the basis of comparing approaches between physical and digital material appears to be sound.

The three practitioners' approaches are broadly similar. In terms of the original framework all three exhibit elements of the 'soft' approach: a focus on exploration or tacit aims rather than explicit goals; an openness to unexpected possibilities; the importance of the medium in their practice and their approach to it - actively engaging with the medium, and using its inherent qualities, rather than using it to represent or simulate reality; exploiting unpredictability and unexpected effects; and using the medium in ways other than for which it is intended, or beyond that for which it was 'designed'; exploring the digital medium in very different ways from its conventional use; and what might normally be considered limitations actively contributing towards their developing practice. Yet a more detailed examination revealed distinct and significant differences between what at first appeared to be quite similar approaches, concerning the role of the medium within each practitioner's practice, and relating to whether their approach could be characterised as a dialogue *with* or *through* the medium, and whether the medium was closely identified with the 'self', or viewed as 'other'. These subtle yet significant differences between practitioners confirm that in the investigation of a practitioner's approach to and relationship with their medium it is necessary to examine carefully a number of different aspects.

The comparison between material and digital environments revealed interesting aspects of this relationship that might otherwise be overlooked. It also revealed the degree to

which elements of their practice have, or have not been transferred between media (as distinct from their actual approach, which was broadly consistent across media). For these practitioners, the lack of being physically 'hands on' with the medium or working with physical materials was not significant; other things, such as achieving a sense of 'immersion' characteristic of a maker's relationship with their materials, were more important. The practitioners worked with digital media in ways usually attributed much more to physical media, emphasising the limitations of some conventional conceptions of digital media. Comparisons between practitioners showed that what one practitioner highlights as differences between the physical and digital media they are using may be quite different from what another practitioner would be aware of. These latter points lead to one of the most important conclusions to be drawn from this study: that the characteristics of a medium are not absolute, resulting from notional inherent properties, rather they are defined through a practitioner's relationship with the medium.

The conclusions from this study complement the findings from the earlier studies, confirming aspects of and providing additional insight into the nature of the relationship between practitioner and medium. The next chapter, ***Discussion***, draws together the results from the various studies within the thesis. It argues that important underlying differences exist between individual design practitioners, concerning their relationship with the medium with which they work, and its role in their practice. However, it concludes that while elements of these differences in approach can indeed be mapped directly to a formal/concrete axis, others cannot, and proposes avenues for further exploration.

9. Discussion

This thesis has examined the nature of individual differences in approach to design practice, in terms of a practitioner's relationship with the medium with which they work, and its role in their practice. This enquiry has been situated within the context of developing future digital environments for creative practice.

It has used methods and instruments designed to elicit information on differences: between individuals, between theoretical positions, and between other phenomena. It has defined and explored the territory of research through reviews of the literature (both contextual and theoretical); a systematic analysis of literature to derive a comparative framework as the basis of empirical work; and empirical studies, mostly interviews, but also set tasks and observation.

It has drawn on literature on creative processes from other disciplines (writing and computer programming/epistemology) and the results of three empirical studies which examined in detail the creative practices of students and professional practitioners working with three-dimensional media, both material and digital, to demonstrate that important underlying differences exist between individual design practitioners, concerning their relationship with the medium with which they work, and its role in their practice.

It has argued that these differences are more significant than variation arising from each designer's personal style, unique experience, or working context; rather they represent wholly different approaches to design, elements of which relate to the nature and extent of a dialogue between practitioner and medium. However, it concludes that while aspects of these differences in approach can be mapped to a formal/concrete axis, this does not account for all the variation which can be observed.

This chapter places the research and its findings within their wider critical and practical context. It examines the findings from the different elements of the research, draws a number of conclusions about the nature of the relationship between practitioner and medium, and more particularly about differences between individuals concerning their relationships with the medium and its role in their practice, and proposes avenues for further investigation.

If the following discussion reflects the frustration occasionally experienced when trying to disentangle the different threads within this research, I hope it also illustrates the insight which can be gained from comparisons across different fields.

Critical and practical context of the research

Comparative disciplines

This research has drawn on three very different fields of practice in the development of its thesis: 3D material/digital design practice, writing, and programming. It has shown that, while the fields may be different, studies in each reveal a similar range in the underlying approaches taken by individual practitioners. Although writing and computer programming may at first appear to be quite different fields to 3D design practice, there are a number of reasons why they are appropriate for this comparative role. My research concerns the entire design-make process; I am interested in examining cases in which individuals undertake the whole process, partly because this is a situation in which individual differences in approach emerge. Writing and programming share a similar 'design and make' context. Writing in particular provides a good comparative discipline, because there are studies in both writing and design which propose not only similar models of the creative process and the relationship between practitioners and artefacts (or similar explanations of differences between individuals), but each has a range of similarly different models of the creative process. The diversity of commentary on differences in approach adds to the strength to the argument: if similar differences in approach appear in two disciplines, it adds weight to the probability that they will appear in a third. A comparison between descriptions of these differences in approach in diverse fields allows one to illuminate another, adding clarification, or highlighting aspects which may not be immediately obvious. Further use of this type of comparison is made later in this chapter to gain additional insights into the structure of relationships between the various dimensions of difference that can be observed in individuals' practice.

Writing and computer programming are useful and appropriate fields for comparison for other reasons. Most people who read this thesis will have some experience of writing (whether as 'planners' or 'discoverers'...), forming a point of common understanding. They are both disciplines in which the 'planner' approach has often been viewed and taught as the 'right' approach (particularly in computer programming). However, there are programmers such as Casey Reas who describes software as "a medium", and "each programming language as a material with unique affordances and constraints" [Reas

2004]. Part of the motivation behind this research is to identify those aspects which should be considered in the design of the next generation of digital media, therefore the discussion of differences in another digital context is of interest.

Defining 'difference'

Readers may respond to this thesis by saying, 'of course people are different and do things differently', but I would suggest that our ideas about individuality between design practitioners (or indeed any creative practitioners) are often rather undifferentiated. Some may relate more to personal style - the unique quality which makes it possible to recognise work as belonging to a particular practitioner - rather than to quite different approaches; in a class of student practitioners, for example, it quickly becomes possible for class members to identify each other's work (the reader is referred to a discussion of the use of the term 'style' in Chapter 1, p. 9). Art and design education emphasises the importance of developing this individuality of expression – a unique 'voice'. These notions of difference relate to Schön's model of design, where he recognises the uniqueness of each individual's practice, but the differences he discusses arise from the personal and situational context within which the practitioner is working - their unique 'design world'- rather than wholly different approaches to design, reflecting different relationships between individual design practitioners and the artefacts and media they work with within their creative practice.

Other readers may argue that, 'of course we know there are differences', citing comparisons between design and craft, between those who work analytically and those who work intuitively, between 'thinking' and 'doing' (like Hoban's descriptions of Muskrat and Manny Rat in the ***Prologue***). However, while people may agree that these different approaches exist, they may not have considered more deeply why people would use these different approaches, or what it actually is that causes them to be different. They may assume that the fundamental differences between these ways of working and knowing are embedded in the physical context of the real world. They may therefore confuse approach and context, and classify a practitioner as a 'designer' or 'maker' because of the type of work they're doing, or the context in which they're working. However, Chapter 6, ***Concepts of dialogue in design***, illustrates that practitioners in quite different fields can also experience a close relationship with their medium, whether that medium be software or language. The Practitioner Interviews in Chapter 8 indicate that even between practitioners who appear to share a close relationship with the medium, this relationship may not be the same, as the role of the medium in their practice may be

different. An examination of approaches within the group of students working with physical media revealed the important distinction between those students who originally appeared to be what I would originally have termed 'making' – working directly with materials at the bench to create a piece – but who, as revealed through further discussion, were actually using materials more as a medium for design.

Most significantly, this research suggests that the relationship between practitioner and medium encompasses ways of working and knowing which can be dissociated from the material context of the real world, and brought into new spheres of practice.

Some studies discussed in Chapter 3, ***Artefacts and the design process*** explored the relationship between differences in designers' processes and the quality of the outcome: this research makes no link between choice of approach and quality of output, but shares the stance of Turkle & Papert who observed that computer programs produced by bricoleur-style programmers could be just as elegantly structured as those produced by 'conventional' programmers, but that the process used to arrive at them was different.

> *"...the differences between planners and bricoleurs is not in quality of product, it is in the* process *of creating it."* [Turkle & Papert 1991]

This research has focused solely on differences between individuals regardless of gender. Although Turkle & Papert found that there may be some gender differences in preferred approach, these were not absolute:

> *"...the elements of each cluster ['hard' and 'soft'] are not invariably associated with each other; still less are they invariably associated with gender. But in our observations of people learning to program we have found an association between gender and approach to programming. When people are free to explore programming without preconceptions about the 'right' way to do it, more women use soft approaches and more men hard approaches, although many men are alienated from the dominant engineering style and many women work creatively within it."* [Turkle & Papert 1991]

For this stage of research, my main interest has been in identifying individual differences that can be observed in groups of design practitioners, rather than linking these to gender. In the Artefact Study where all the participants were female, differences in approach could still be observed. In the Comparative Study, where one group was all female and the other was mixed, similar differences in approach could be observed within each group, and neither seemed to be skewed heavily in one direction. (Indeed, my expectation before these studies would have been that any skew would have been towards the 'hard' approach in the digital environment, and a 'soft' approach in the physical environment, resulting from the commonly perceived differences between the two environments.) The fact that differences in approach appeared within all-female contexts

might have certain implications in the broader context of this research. However, within the existing limitations of the analysis as regards the comparison of individual approaches, and as the gender 'dimension' within the data has not yet been explored, it is not possible to comment further at this stage.

Attitudes towards the digital as a medium

The broad contextual motivation for this research is to bring a deeper understanding of the working processes of creative practitioners to the development of future digital environments for creative practice. The research has revealed a number of attitudes towards the role of computer systems in creative practice.

While discussing her use of Alias's industry standard 3D modelling and animation software, one of the students in the digital group in the Comparative Study, who had previously worked with physical media, commented:

"...you can't take a tea bag into Maya. It doesn't go in!"[64]

This light-hearted remark encapsulates many reservations that practitioners may have about the digital as a medium: its immateriality, its intangibility, its distance from the real world. For those used to working in material practice, a dialogue with the digital medium might seem a remote possibility. It may be difficult to envisage using the same approaches to digital media as you would with material media, or appear that your range of approaches is more limited; yet interviews with practitioners working with different types of digital media show that while the processes and techniques may be different, their approach to the digital medium is in line with, and largely derives from, the approach they used with physical media. PractC, for example, now sees little difference in his ways of working between physical media and digital media.

PractB described how, in his experience, some practitioners come to computer systems within creative practice with an expectation of making the process easier, or to solve problems in their practice. Linked to this approach is a tendency to focus on the current perceived limitations of the technology in terms of comparing it to physical materials: the 'won't it be good when...' scenario. He sees this viewpoint as problematic, as it precludes practitioners from exploring the possibilities inherent within the medium. This reflects the contrast between the view of the digital as a tool to simulate reality, or as a medium in its own right with unique properties to be explored. It also emphasises a point

[64] Digital student 1, interview 1

which will be familiar to those working with physical media, but may be less obvious to readers from other fields, that a medium may be used both as an abstraction/ representation of another one, or for its own sake.

The spectrum of approaches which can be observed in the group of students working with digital media is similar to that visible in the group of students working with physical media, suggesting that although some students do not find the digital medium as intuitive as working with physical media it does afford a broad variety of ways of working. These may not be the *same* ways of working, but it is this aspect that is of particular interest; how ways of working and knowing can be dissociated from the material context of the real world, and brought into new spheres of practice.

Design processes and creativity

In the ***Introduction***, I explained that this research is not concerned with what might be termed 'design processes' (e.g. the patterns of and relationships between analysis, synthesis and evaluation, or divergent and convergent thinking in a practitioner's process), or 'creative cognition'. Although these aspects may be an element of the individual differences in which I am interested, they are not the territory of this research.

This distinction may shed light on some observations that I had made in the Artefact Study: firstly, a number of students' approaches changed depending on which exercise they were doing, particularly if they were recalling things from memory; secondly, while a number of students expressed preferences for ways of working in the various exercises within the study, these could not necessarily be correlated to preferences for ways of working in their design processes. One student moved from a more narrative approach to a brainstorming technique, while another moved from a narrative approach to making lists. Another student appeared to change approach quite markedly between the 'responsive' exercises and the design exercise in the Words study, because she 'was designing'. There may be a number of reasons for this: for example in the 'responsive' exercises the students were being asked to use the different types of media to respond to something – an object, a person, a memory – whereas in the design exercise, they were creating something new.

These differences with an individual's responses could be seen as contradicting my conclusion from the Practitioner Interviews that a practitioner's approach is consistent across media, yet the two things are actually quite distinct: in the Practitioner Interviews, I was comparing the same activity in two different contexts, physical and digital; in the

example from the Artefact Study, I was examining different activities in the same context. In another case the student commented that she normally did use words to an extent in designing, but had not found in the Words design exercise that it had sparked off any ideas: this may have been because 'words' were playing a different role in the workshop context, or being used in isolation.

In the context of this research it is to be expected that practitioners will use media in different ways depending on what they are doing: using a computer system to design an object is quite different from using it as a medium, for example. In Sharples & Pemberton's study of writers discussed in Chapter 6, ***Concepts of dialogue in design*** they frame the writing process as a sequence of steps (not necessarily linear) through different external symbolic representations which facilitate different cognitive processes. In the ***Comparative study*** (Chapter 7) it is apparent that students use different media for different stages of the process.

Even though the two observations are therefore not contradictory, it is worth emphasising that you can't make assumptions that the way someone will use a medium in one type of activity will be the same way as in another type of activity. This does not preclude the fact that individuals may use different media for the same activity, or engage in entirely different activities, which is the concern of this research.

The Artefact Study does not provide enough evidence to make clear exactly what the relationship is between the ways in which an individual might use a medium for a particular activity, and how they might relate to it (e.g. in the Artefact Study where participants appeared to have a subjective or objective approach to the items they were responding to, or whether the physical materials were foregrounded or backgrounded in their responses). The comparative framework derived from the literature includes indicators which appear to address both aspects, such as a planned or emergent approach to work, and people's ways of 'seeing' or relating to objects; however, it does not examine in detail the patterns of activities such as analysis/synthesis/evaluation that might normally be considered as 'designing'.

It is therefore worth making the distinction in this research between the term 'approach', which concerns the practitioner's relationship with the medium, as distinct from the term 'process', which concerns these different activities.

Summary of main conclusions

The characteristics of a medium are not absolute

The previous section suggested that an individual practitioner may use the same medium differently for different activities. This section proposes that the characteristics of a medium are tied even more closely to each individual practitioner.

One of the most important conclusions that can be drawn from this research is that the characteristics of a medium are not absolute, resulting from notional inherent properties, rather they are defined through a practitioner's relationship with the medium. (This is different to Brereton's observation that "the problem context derives what attributes of an object people notice and in which ways they try to use an object" [Brereton & McGarry 2000]: I'm claiming that for different people even in the same context, the characteristics of a medium would be different.) This conclusion is supported by findings from all four studies in this research.

In the Artefact Study, the range of artefacts that were produced by the group of students within each exercise suggests that individuals used the same 'type' of artefact quite differently. The apparent taking of a subjective or objective approach towards source objects, and the ways in which the material aspects of the medium seemed to be foregrounded for some students, also suggests that the characteristics of an object or medium which are important to one individual may be quite different to another.

While this is not as strong a position as saying that the characteristics of a medium are defined through a practitioner's relationship with it, Turkle & Papert bring this closer in their description of the different ways in which the students they studied related to the objects they worked with: 'hards' see them formally, as what they are for, while 'softs' see them concretely, as what they can do.

Similarly different approaches and ways of relating to the medium could be observed within the group of students in the Comparative Study who were all working with the same (albeit large and complex) digital medium. While some students viewed the medium as a means to an end, others engaged with the medium, and worked with the effects that arose through experimenting with what the medium could do. Similar differences can be observed in the different approaches to learning the software that could be observed within the group: those who preferred to learn what tools were for before using them, and those who played with the software to see what it could do. Although

the group of students working in the physical environment were using different media, processes and techniques, the approach of many students in exploring their chosen medium to develop a repertoire of processes and techniques, some quite different from ways in which the medium might conventionally be worked, also supports this premise.

From the descriptions of the working processes of the three practitioners interviewed (see Chapter 8), it becomes clear that a medium's characteristics cannot be derived from the medium in isolation, but are, and must be, defined in relationship to the practitioner. In these cases the 'conventional' characteristics of digital media are not necessarily those used or experienced by the practitioners: for example, geometric primitives in 3D modelling software are normally regarded as abstract entities, but PractC treats them like materials, albeit with mathematical rather than physical properties, manipulating them in a direct, spontaneous and intuitive way. This way of approaching the software is possible because he is not using the medium as a representation of 'real' objects, rather he is working with the qualities of the medium as they reveal themselves through exploration. This approach is similar for all three practitioners: they are questioning the medium, engaging with it - using the qualities it possesses as a medium, 'finding its edges', exploiting its limits, using unintended effects, rather than as a tool for simulating reality - each within the context of their own practice. This type of approach is not conventional, and results in the digital medium being used in ways other than for which it is intended, or beyond that for which it was 'designed'. The point that the characteristics of a medium must be defined in relationship to the practitioner is reinforced in that what one practitioner highlights as differences between the physical and digital media they are using may be quite different from another's experience. PractA's use of metaphors such as 'vocabulary' and 'palette' when describing her relationship with the medium, emphasises the close identification between some practitioners and the media they use.

Individuals relate in similar ways to different media

The previous two sections have proposed (a) that an individual practitioner may use the same medium differently for different activities, and (b) that a medium's characteristics are not absolute: they cannot be derived from the medium in isolation, but are, and must be, defined in relationship to the practitioner. This section argues that an individual practitioner will relate to/approach different media in similar ways.

The tentative findings from the Artefact Study, where differences observed within the collective data included a subjective or objective approach to objects, or where for some

students, materials in all the exercises seemed to be 'foregrounded' (i.e. whether the exercise used words, markmaking or materials), suggest that individuals may approach different 'types' of artefact or medium (1D/2D/3D) in similar ways. However, a direct and rigorous comparison between individuals' approaches to the different media would require further analysis of this data. Although some students in this study expressed a preference for working with one type of medium over another, this does not preclude the fact that they may approach both media in the same way.

In the Comparative Study comments from some of the students working with the digital medium who had previously worked with a physical medium, also support the argument. One remarked that for him, although the medium was different, the "philosophy, the way of thinking" carries on. For another student who had been used to gathering physical objects for her work, although that wasn't possible in the digital medium she found an alternative way of achieving a similar approach:

> *"...every single texture symbolised something, like the fact that she had a jumper on that had stripes that looked a bit like a fence, or barbed wire - she was divorced from reality... So, you know, I got it in there. But in a completely new different way, as in it wasn't the actual things, it was symbols of things, instead."*[65]

In the Comparative Study some students in both groups expressed preferences for working in three dimensions as opposed to two, as this allowed them to more successfully express ideas they could already see clearly in their heads. One student described how,

> *"I have it all in my head and I'm not so good in doing a storyboard because, I have a picture of the cameras, I have a picture of the movements of the characters but, when I'm doing a storyboard I (find?) like limited in the 2D paper, so I prefer to take it to the 3D..."*[66]

However, this does not necessarily imply that individuals might relate in different ways to different media, particularly as in the cases above the two-dimensional medium was being used as a design medium, rather than the medium within which the work was being produced.

From the examination of the working processes of the three practitioners described in Chapter 8 it is clear that, in all cases, their approach to the medium in their digital practice is in line with, and largely derives from, the approach they used in the physical environment. This is not to imply that they use similar techniques and processes in both environments (the media are different, after all!), but that their overall approach to the

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[65] Digital student 1, interview 3
[66] Digital student 4, interview 1

medium is consistent across both. As described above, all of them were questioning the medium, pushing its boundaries, 'finding its edges', and crucially, using the qualities it can possess as a medium, not as a tool for simulating reality.

While this is certainly true for the three practitioners that I interviewed for this study, for all those interviewed the materials played an important role in their practice and they had what could be classified as a 'close' relationship with the media they used (although the roles and relationships still differed in a number of respects). However, given that practitioners who see a medium as a tool to be used to achieve a particular end might tend to have a more objective approach to a medium in any case, it could be argued that their approach is less likely to change as a result of a change in medium. This is supported by a comment from one of the students in the Comparative Study about the software he was using:

> *"I see it as a tool like anything else. The way I look at a pencil and a bit of paper, they're just tools to produce something that's in my head, and I see the computer as the same"*[67]

It might be argued that the three practitioners interviewed have chosen media which can be approached in this way i.e. they might take a quite different approach with other media. Yet PractA's description of her initial frustrations in getting to grips with the software she was using shows the struggle she went through to achieve this type of relationship with the medium, and would argue against the position that difficulties in using one approach with a particular medium would result in a change in approach. It could be true that practitioners see potential in some media that they wouldn't see in others, but they might nevertheless approach them in the same way.

There are differences between individuals in the ways that they relate to the media with which they work

While the previous sections have focused on clarifying aspects of the relationship between a practitioner and the medium with which they work, this section discusses the differences in this relationship which can be observed between individual practitioners.

Initial enquiries concerning practitioners' preferences for working in two or three dimensions to generate design ideas [Chapter 5] suggested more fundamental differences between individuals in their relationship with the medium with which they work, relating to their relationship to the medium and its role in their practice; in particular, they

[67] Digital student 10, interview 2

identified differences concerning a subjective or objective way of relating to objects; whether materials played a foreground or background role; and the extent to which a design was expressed in or derived through working with the medium.

Although little design literature has examined individual differences of this nature [Chapter 3], there exist studies of writers and student programmers which discuss variation in individual approach which resonated strongly with what I had observed in previous research, and with the tentative ideas emerging from these early enquiries. They discuss individual differences which can broadly be described in terms of the nature and extent of a dialogue between practitioner and medium [Chapter 6].

A systematic analysis of this literature suggested the formal/concrete axis as organising principle for differences in approach, across disciplines and different levels of practice [Chapter 7]. This analysis was used to derive an analytical framework based on the notion of 'ideal types': two distinct approaches – 'hard' and 'soft' - representing each end of a spectrum (see p. 130 and Table 6 p. 131 for more detailed descriptions of each approach). The framework is therefore two-dimensional, categorising individuals as one of (or neither i.e. somewhere on the spectrum between) two approaches, which are expressed through a number of different characteristics or 'dimensions of difference', where the internal coherence of each approach is reflected in the logical relationships between these dimensions of difference.

Taking this framework as the basis of enquiry, an investigation was made into whether similar differences in approach could be observed between two groups of student 3D practitioners, one working with physical media, one with digital media [Chapter 7]. A comparison between individuals across all aspects of their approach, using the framework, suggested that differences, broadly along the lines proposed, existed within each group, with a similar spread of approaches in both groups.

However, an examination of the collective variation within each group revealed relationships between different dimensions within certain individuals' practice which were not consistent with the original framework. It identified differences within the *collective* variation along the lines of the framework: a preference for a planned or emergent approach; a preference for control, or a willingness to take risks; those who see the medium as a means to an end, and those for whom the means become the end; the extent to which the materials are chosen to suit a particular design, or whether the design is determined by the materials which are available; their different relationships with the

medium, including distance or closeness in relating to the artefacts they create and work with; those whose idea generation or development is done largely 'internally', or those who achieve it through external means. However, how these different dimensions logically related to one another within an *individual's* approach did not appear to be completely described by the two-dimensional nature of the framework.

In particular it identified instances where an emergent approach did not equate to a 'dialogue *with* the medium', as inferred by the original framework; rather it could be described as a dialogue *through* the medium' where the emergence relates to the conceptual idea or design, rather than an exploration of the properties of the medium.

Another related dimension which is not adequately explained by the original framework concerns the 'choice of materials'. In the framework, this dimension broadly distinguished between whether the materials are chosen to suit the design, or whether the design is determined by what materials are available. On closer examination, further variation could be discerned within this spectrum, relating to at what level of process and how 'material' constraints arise. At a 'practice' level, some students worked within a *repertoire* of skills or processes, while others worked also within a *palette* of existing materials. At the level of the piece of work or artefact, some students built elements of a piece, then arranged and rearranged them to achieve the final form of the work. There were also cases where students were working with elements which had already been defined (like found objects), but which they had selected rather than defined themselves. For others, the piece largely emerged from working directly with the medium, and from what the medium can do. The main distinction appeared to be whether the 'materials' and elements were *defined* or *selected* by the student.

A further decoupling of dimensions arises from the observation that an 'external' approach did not necessarily equate to an emergent approach.

Without a more formal means of comparing the relationships between dimensions within each individual's practice (see p. 171) it is not possible to determine, at this stage, whether these differences in approach simply represent different positions on the existing 'hard'/'soft' spectrum, or indicate two wholly different spectra of approach, one at the level of representation, and one at the level of the artefact.

The interviews with practitioners [Chapter 8] also revealed differences between approaches which would be classed as similar in terms of the original framework. All three exhibit elements of the 'soft' approach: a focus on exploration or tacit aims rather

than explicit goals; an openness to unexpected possibilities; the importance of the medium in their practice and their approach to it - actively engaging with the medium, and using its inherent qualities, rather than using it to represent or simulate reality; exploiting unpredictability and unexpected effects; and using the medium in ways other than for which it is intended, or beyond that for which it was 'designed'; exploring the digital medium in very different ways from its conventional use; and what might normally be considered limitations actively contributing towards their developing practice. Yet a more detailed examination revealed distinct and significant differences between practitioners, concerning the role of the medium within each practitioner's practice.

PractA describes her relationship with the medium, and its role in her practice, using strong metaphors of language. Her approach to each medium she uses – questioning it, understanding it – is related to the idea of becoming familiar with it as a language: how it works, what its characteristics are, what you can do with it, what you can say with it. In PractB's work and practice, the medium's role appears to be to reflect back our ways of seeing, ways of thinking, ways of experiencing, to make us aware of our unconscious assumptions about the world. PractB's relationship with his chosen digital medium therefore appears to be qualitatively different from PractA's: PractA sees her relationship with the medium in terms of language, making it almost part of herself; PractB seems to relate to it as something 'other', a means of doing 'interesting things' and of 'rethinking the world'. The role of the medium in PractC's practice is again subtly different from PractA and PractB. PractA's relationship with the medium is one of language; PractB's one of challenging assumptions. But PractC is very definite that he 'doesn't have anything to say', he's not asking questions. Rather, he describes his process as speculative and disinterested, about "exploration and discovery". This defines the medium as 'other' rather more markedly than PractB. In his subjective explorations of the medium, with their emphasis on discovery rather than invention, realising rather than recognising, PractC sees himself not as looking for something specific, but responding to things he sees, not giving meaning through creating objects, but deriving meaning from the objects he finds and brings into being through his explorations.

PractA's process is closely related to her relationship with the medium: a tacit, organic approach, 'playing and pushing', in which the work evolves, guided by a sensibility, what she describes as a journey drive by a feeling. In PractB's practice the process seems to be less closely related to his relationship with the medium - there seems to be less explicit

focus on process, more on content, or 'intent' - but he does nevertheless have a process in which the medium is allowed to play a important role. Perhaps more than for either PractA or PractB, the medium plays an immediate and crucial part in PractC's practice. This 'otherness' of the medium, together with his speculative, exploratory and responsive approach, defines the reciprocal relationship between him and the medium which is fundamental to his practice, and to the form of the work which is, in a sense, not created but 'realised': 'wrestled into being' through working with the medium.

Although there are similarities between these approaches, as described above, nevertheless they seem to be qualitatively different. Drawing comparisons between PractA and PractC in particular, this relates to whether the medium is closely identified with 'self', or viewed as 'other'; whether the process is 'purposeful', where the work evolves through questions/enquiry driven by a tacit aim, or 'disinterested', where the work arises through speculative exploration and discovery through a reciprocal relationship with the medium; whether the process could be described as a dialogue *through* or *with* the medium.

These studies demonstrate that important underlying differences exist between individual design practitioners, concerning their relationship with the medium with which they work, and its role in their practice. However, while elements of these differences in approach are described by the original framework, with its formal/concrete axis, others are not.

Do the findings of the research support the thesis?

This section examines in more detail whether the findings of the research support the thesis:

> *that individual practitioners experience different relationships with the artefacts they create and work with in their processes, and that elements of these differences can be attributed to the nature and extent of a dialogue between designer and media*

As discussed in the previous section, while the 'dimensions of variation' within the data are largely in agreement with those in the framework, the data diverges from the framework in terms of the 'structure of variation', i.e. how these dimensions relate to one another within an individual's practice. (Although the analysis of the data presented here does not permit the formal connection between these dimensions within each individual's practice to allow a rigorous comparison between individuals across all the 'dimensions'

of their approach, an examination of selected dimensions with certain individuals' approach reveals aspects which diverge from the original framework.)

There appear to be two main ways in which the data diverge from the original framework: firstly, where individuals have both 'hard' and 'soft' elements in their approach (e.g. where a student appeared to have an 'external' approach, yet the form of the work was predetermined before it was made); and secondly, where the approaches as defined by the framework do not accommodate all the variation that can be observed.

Although Turkle & Papert categorised their 'hard' and 'soft' ideal types in terms of clusters in which an individual's style of organising work and their relationship with objects are closely related, this does not exclude the possibility of finding examples where they are not:

> *"Empirically, we sometimes find each aspect of soft mastery – bricolage as a style of organization and closeness to the object – without the presence of the other. In particular, one finds people who are planners but who enjoy a close relationship with concrete objects (and who experience computational objects this way)."* [Turkle & Papert 1991]

In some cases, Turkle & Papert argue that this does not reflect the individual's underlying preference, rather it is an approach adopted to operate within a particular situation.

> *"But although closeness to objects favours contextual and associational styles of work, it does not exclude the possibility of using a hierarchical one. Planning is not always an expression of personal style. It can be acquired as a skill, sometimes because it is needed to get a job done, sometimes as a façade to hide rather than express individuality."* [Turkle & Papert 1991]

Turkle & Papert's description of such cases suggests a more fundamental adjustment than simply an automatic change in approach to suit whatever situation an individual is working in:

> *"Some bricoleurs respond to the dominant ethos of the computer culture by entering into an inauthentic relationship with the computer. This can lead to a paradoxical reaction: frustrated bricoleurs appear at first sight to be extremely rigid planners... When denied a chance to do their 'real thinking', they turn to rules that do not require them to think at all."* [Turkle & Papert 1990]

From the examination of the data presented here, it is not possible to state whether or not 'crossovers' between hard or soft approaches in this research are primarily the result of personal preference or 'imposed' choice. In the case of the student who appeared have an external approach (working with collage in the early stages of the process) yet predetermined the form of her work through storyboarding, although she commented that it is accepted practice,

> *"...everybody says you must have a storyboard, work and stick to your storyboard, so it has to be quite a rigid structure I imagine, that you need to get it down the line at the start, and try and stick to it..."*[68]

there was no strong sense that she was struggling against a process that was being imposed upon her:

> *"...I have to have it down in 2D, which sounds odd if you're working in 3D to have to have it down in 2D straight away but it's just the normal working practice. But I have seen people going straight to computer, which seems very odd for me... I can't imagine coming up with an idea and not being able to sit down with a paper and pen and take it as far as I can go before even approaching the computer."*[69]

However, a closer examination of all the data would be required to say whether this was the norm, or the exception.

Examples where the framework does not accommodate all the variation that can be observed (particularly within the 'soft' approach) could be seen in both the Comparative Study and the Practitioner Interviews, and concerned the following aspects:

- *emergent approach*: differences relating to whether the emergence relates to the conceptual idea or design, or an exploration of the properties of the medium
- *choice of materials*: differences (both at the level of the process, and the level of the piece) relating to whether material constraints are *defined* (repertoire of techniques and processes; physical elements) or *selected* (palette of materials; components or materials) by the practitioner
- in terms of the overall role of the medium, whether it is viewed in terms of 'self' (e.g. language, vocabulary) or as 'other'
- where the practitioner is working with the medium, whether this is guided by a tacit aim ('a journey driven by a feeling'), or is exploratory and speculative

Some of these differences may be, or be similar to, dimensions that already exist within the framework, for example working with ideas or working with the medium; a focus on goals or discovery; acting upon or engaging with the medium. The difference here is that the relationship between them is not as defined in the original framework.

The main question is whether they simply represent different positions on the spectrum between the 'hard' and 'soft' approaches, as in Figure 70, or are indications of an entirely different relationship between various dimensions within the original framework (i.e. an alternative 'structure of variation' to its current two dimensional nature).

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[68]Digital student 2, interview 1
[69]Digital student 2, interview 1

hard	form of work predetermined through planning
	form of work partially predetermined through creating elements of the piece then playing with them to achieve the final form
soft	form of the work left entirely open and achieved through working directly with the medium

Figure 70: 'Hard' – 'Soft' spectrum

While the example above may solve the 'predetermined' dimension, it does not allow for a distinction between whether the emergence concerns the 'idea' (as would be the case with the predetermined elements) or the properties of the medium (the third case, above). In the Practitioner Interviews, the comparison of PractA and PractC's practice suggests that there may be alternative approaches within the third case in the above example.

A number of the observed divergences from the original framework can be placed in the relationship illustrated in Figure 71. It is quite possible that an individual might use elements from both columns in their work (for example one student in the S&J group used physical elements she had created as well as objects such as pearls, etc.), and another student who had a huge collection of materials from which she selected to use within her pieces, also was using a particular technique within her work; nevertheless it is likely that an individual might tend towards one or other of the columns.

	Relates to self / 'defined'	**Relates to medium / 'selected'**
Overall relationship to medium	as a 'language', identified with self	as 'other'
'Choice of materials' (material constraints) at process level	*'repertoire' of processes and techniques	*palette of materials
Partially defined elements	elements created by practitioner	components selected by practitioner
Working directly with the medium	using a 'language'	speculative exploration and discovery

* PractA's use of the term 'palette' is related more closely to the term 'repertoire' used in the discussion of the Comparative Study

Figure 71: self-medium

Although similar differences within the planned approach are not as obvious, there are aspects of certain individuals' approach which might be characterised in similar ways (see Figure 72).

	Relates to self / 'defined'	Relates to medium / 'selected'
Form of work predetermined	through drawing and sketching	through the use of collage, working with objects

Figure 72: Form of work

Rather than signifying an 'additional' dimension within both the 'hard' and 'soft' approach, these observations suggest that there may be a spectrum of approaches (similar in nature to the planned/emergent spectrum) which appear in each of these two different contexts. This would therefore support the idea of an entirely different relationship between the various dimensions within the original framework, as yet to be determined. One interpretation is that the two poles in the table above – 'relates to self' and 'relates to medium' – are actually a more accurate description of the 'internal' and 'external' dimension, or perhaps a separate but related element within it.

Without further analysis of the data, it is not profitable to speculate on what the actual structure of variation might be, or indeed whether within the entirety of the data these divergences might be less significant. However, they do suggest that the original two-dimensional structure of the framework is not adequate to explain all the differences in approach that can be observed within the data.

Regardless of whether the framework completely explains the diversity that can be observed within the data, it is clear from the findings of the various studies that individual differences in approach can be observed between individual practitioners; that aspects of these differences do concern a practitioner's relationship with the medium; and that elements of these differences can be attributed to the nature and extent of a dialogue with the medium. The studies therefore do support the original thesis:

> *that individual practitioners experience different relationships with the artefacts they create and work with in their processes, and that elements of these differences can be attributed to the nature and extent of a dialogue between designer and media*

However, they also suggest that there may be additional elements which contribute to individual differences in approach, and that these and the variety of ways in which practitioners relate to the media with which they work require to be more fully explored.

Effectiveness of the research method chosen

The combination of theory-driven inquiry and the examination of themes which emerge from the data is one of the strengths of this research, and is in keeping with the overall

spirit of using the examination of difference as a means of inquiry. Rather than being viewed as a problem, the identification of a gap between these two elements is a positive basis for further research. The comparison between these two aspects of this research has allowed deeper insight into the phenomenon than would be achieved through each alone.

Much research tends to one of two different approaches: begin with a theory which is then tested by running experiments (while this approach allows you to test elements of the theory, it does not enable insights to emerge from the data); or take a purely emergent approach which focuses on themes that emerge from the data (and only later consider how it fits with the theory). Chapter 4, ***Difference as a means of enquiry*** describes how design research which takes the former approach, and which assumes that there is a single design method to be discovered, has been blind to individual differences in design practice. A combined approach, such as that adopted for this research, provides some safeguards against either extreme. Although the method used for this thesis is not entirely emergent, it nevertheless has many characteristics of a Grounded Theory approach: it uses the literature as data (developing the theoretical framework in Chapter 7); comparison within the data is fundamental to the process (as described in Chapter 4, ***Difference as a means of enquiry***); and its ultimate aim is to find the theory which best fits the data.

In disciplines where a combined approach (examining what emerges from the data in opposition to the theory) is common practice it is quite normal to have a gap: when there are strong top-down and bottom-up elements to a body of research there are many reasons why the results from each won't match completely.

In this research there are at least three possible explanations as to why the data do not fit the framework: firstly, incorrect interpretation of the literature from which the framework was derived which, had it been interpreted correctly, would have fully explained the data (i.e. a structural problem); secondly, the difference in environment, i.e. 3D creative practice as opposed to writing or programming (i.e. an interdisciplinary difference); thirdly, the literature from which the model was derived does not provide an adequate explanation (i.e. a theoretical problem). The analysis reported here cannot make this decision. However, of the three explanations given above, an interdisciplinary difference is least likely. For this to be true, the framework succeeds in the other environments (writing, programming), but doesn't adequately explain this one. However, although the structure of variation seems not to be explained fully, the dimensions of variation that have so far emerged from the data are largely in line with those given in the conceptual

framework. Also, the ways in which the two diverge, while they may relate to the medium, could apply to any medium.

The contribution of this research to and implications of this research for a variety of audiences

This research has drawn on three very different fields of practice in the development of its thesis: 3D material/digital design practice, writing, and programming. It has shown that, while the fields may be different, studies in each reveal a similar range in the underlying approaches taken by individual practitioners. Further, it has made explicit a number of detailed 'dimensions of difference' which can be observed within these fields. (Although Turkle & Papert and Chandler discuss a number of 'dimensions of difference' within individual approach, these are not detailed explicitly in the papers reviewed for this research; the list of 'indicators' in Table 6 was derived from an examination of a number of publications by a variety of commentators.) However the broad comparative basis of this thesis has also revealed that the differences in approach identified in these different studies may not entirely explain the differences that can be observed between individual practitioners and their relationship with media. It has tentatively suggested an alternative explanation, and proposed that further research is necessary to address this variance.

Although this research has demonstrated the added insights that arise from the comparisons between these similar but different fields, this cross-disciplinary approach appears, certainly from the research reviewed for this thesis, to be the exception rather than the rule. Chandler does not discuss practice other than writing, although he, like Turkle & Papert, draws on Levi-Strauss's concept of *bricolage*. Turkle & Papert's concern is different approaches to knowledge and intellectual styles, focusing on programming as a particularly fruitful area of exploration given its cultural associations with 'hard mastery':

> *"...When we look at particular cases of individuals programming computers, we see a concrete and personal approach to materials that runs into conflict with established ways of doing things within the computer culture. The* practice *of computing provides support for a pluralism that is denied by its social construction."* [Turkle & Papert 1991]

Although Turkle & Papert make reference to musicians, writers and artists in examples, these are not discussed in any depth. Given their focus on an area where 'hard' mastery is the accepted canon, and their comment that "soft mastery has always had its place in

the discourse of the arts" [Turkle & Papert 1991], this is not unexpected. However, it should not be implied from this that approaches more similar to 'hard' mastery do not also occur in the arts.

One commentator who very deliberately draws links between writing and design is Sharples. In the second of his papers reviewed in Chapter 6, Writing as Creative Design [Sharples 1995], and in his subsequent book, How We Write, Writing as Creative Design [Sharples 1999], he discusses "the writer as a creative thinker and a designer of text". Examining "how creativity occurs" and "the relationship between writers and their environment", his focus is still mainly on cognitive aspects: the deliberate exploration and transformation of a writer's conceptual space, and on processes of reflection ("the deliberate and cognitively demanding process of re-representing embedded processes and exploring cognitive structures") and engagement ("the direct recording of conceptual associations"). Woodcock is also examining cross-disciplinary links in The Software Author as Designer [Woodcock 2005], looking at "programming as reflective practice" [School of Art and Design, Coventry University].

This research, with its focus across a range of elements of practice, therefore plays an important role in linking research in writing, programming and 3D design practice, and its findings have implications within a number of different areas. This research also offers a bridge between the 'traditional' design research community and the community of research into practice: those who both design and make. The examination of 3D practitioners reveals implications for the former, with its emphasis on design-by-drawing (see following section); and the research provides a more empirical view of the latter, a field which is largely characterised by practice-led enquiry.

Regarding theories of design, design research community

The findings from this research suggest that individual differences in approach do exist which are more fundamental than variation resulting from the personal and situational context of the designer, as described in Schön's model of design as reflective practice; that the differences cannot adequately be explained by Louridas' conclusion that they represent the same process but at different levels (metaphorical or literal), or by Sharples' distinction of emphasis between different aspects of the same process (reflection or engagement). They support the view that wholly different approaches to design do exist, with several 'dimensions of difference' across different levels of practice, as proposed by Turkle & Papert; and further, as concluded by Chandler, that these are "not simply

different ways of describing the same experience: they represent quite different experiences reflecting basic orientations" [Chandler 1995].

This study has implications for researchers both in design and other fields, to be aware that individuals do vary in significant ways, and that there is not a single approach to design. Assuming there is one ideal approach to be discovered is to ignore important differences in the ways in which individuals approach work, and relate to the objects they work with. It should also be recognised that there is value in exploring not just 'design', but 'design-make' processes, as this is a good situation in which to observe individual differences in approach. Although an increasing number of practitioners are undertaking research, and aspects of this are being addressed in the context of practice, 'traditional' research into design processes has, to date, focused largely on the 'design' element.

Regarding creative practice

This research has a number of implications regarding creative practice: both for practitioners, but also for those looking at practice from the 'outside'.

A common view of creative practice is that it is first and foremost about doing, rather than about analysing what is done. Involving as it does tacit ways of knowing, it can be imbued with an air of mystique. In comparison with computer programming, for example, it could be argued that in applied arts the primary product is the artefact: the 'analysis' may happen, but that is not what is delivered. In programming, in effect it is the analysis/underlying structure that is being delivered: the code is the vehicle by which this is achieved. However, this comparison is not as straightforward as it appears: a functional artefact embodies the decisions the practitioner has made about how best to deliver that functionality; a less functional artefact nevertheless embodies the considerations that have gone into its creation. (Indeed, the extent to which an artefact can embody and communicate knowledge is the subject of much debate around practice-based doctorates in Art & Design, and in conferences such as Research into Practice 2004, "What is the role of the artefact in art and design research?".) Perhaps one difference between applied arts and programming is the extent to which the analysis or knowledge is made *explicit* in the final product. It may be true to say that practitioners are primarily concerned with doing, rather than with examining theories of how they do what they do. However it would be wrong to assume that practitioners do not consider their processes; this thesis contains examples of practitioners who have thought deeply about their practice.

This research has shown that differences exist between design practitioners that are more fundamental than simply personal style, and represent very different approaches to practice (the reader is referred to a discussion of the use of the term 'style' in Chapter 1, p. 9). Further, it has demonstrated not just that there are differences, but provides an explanation of what these differences might be.

It has pointed out the pitfalls of assuming that these differences can be explained by comparisons between 'design' and 'craft'. In particular it challenges any assumption that the fundamental differences between these ways of working and knowing are embedded in the material context of the real world: practitioners in quite different fields can also experience a close relationship with their medium, whether that medium be software or language; differences in approach exist that do not simply relate to working at the level of the representation or the medium; and even between practitioners who appear to share a close relationship with the medium, this relationship may not be the same, as the role of the medium in their practice may be different. It warns against confusing approach and context, and classifying a practitioner as a 'designer' or 'maker' solely by the context in which they're working. It illustrates the spectrum of approaches used by those who design and make, and demonstrates that the conjecture I had made at the beginning of this enquiry - that the differences concerned whether work was 'design-led' or driven by an 'exploration of techniques' - is not sufficient to explain all the differences that could be observed. It stresses the importance of recognising the distinction between 'making' – working directly with materials at the bench to create a piece – and using materials as a medium for design. This last aspect illustrates a point which may be less evident to readers outwith the field of design, and which is amply demonstrated through this research, that a medium may be used as an abstraction/representation of another one, or for its own sake. This is true not just in the physical environment, but also in the digital, and is particularly evident in the Practitioner Interviews.

While this research has mainly concerned differences in the way individual practitioners relate to the medium with which they work, it also reveals other important aspects of the relationship between design practitioner and medium. It proposes that an individual practitioner may use the same medium differently for different activities. More importantly it concludes that the characteristics of a medium are not absolute, resulting from notional inherent properties, rather they are defined through a practitioner's relationship with the medium. It demonstrates that an individual practitioner will relate to/approach different media in similar ways.

These findings support the position that creative practitioners have markedly different approaches to practice, and that when looking at ways of fostering creativity (or particularly when debating what 'creativity' is or how it can be understood) these differences should be recognised. It also has implications for educators in creative practice to acknowledge differences in approach, and the breadth of practice that needs supported (this may be particularly challenging in the digital environment). On a more personal level, if you're a student who finds that the way design practice is taught doesn't seem to 'fit', it doesn't automatically mean that there is something wrong with *you*; it may be that an alternative approach would be more effective.

Regarding the application of digital technologies in design and creative practice

While some of the observations in the previous section may be familiar to those who practice, they may be less familiar, and therefore of more significance, to others exploring the ways in which digital technologies can be used within or as a medium for creative practice.

Many recent developments in digital technologies to support creative practice have focused on replicating and extending the ways in which creative practitioners currently work with materials, or in harnessing the potential benefits that can arise from combining the capabilities of computer systems with the traditional skills and working methods of artists and designers [Chapter 2]. Systems like these often reflect the belief that 'hands-on' access to materials is very important to makers/creative practitioners, and should be replicated when developing new digital environments for design.

One of the most striking aspects of the interviews with creative practitioners now working in digital media was that not being able to be physically 'hands on' with the medium, and not working with physical materials, appeared not to be a big drawback; moreover, as PractB commented, aiming to emulate that aspect of work when interacting with digital media is not without problems, both technical and philosophical. Other aspects, such as achieving a sense of 'immersion' characteristic of a maker's relationship with their materials, were more important.

Also, many makers' 'hands-on' interaction with physical media is mediated through tools: PractC, as a sculptor, is familiar with mechanical processes; for him, working with the software is, in a sense, a mechanical process. This is not to say that being able to work with their hands is not important to some practitioners, but to recognise that a number of factors may contribute to this perception including the ability to manipulate

things directly, the immediacy and responsiveness of the medium, the 'physicality' of objects, as well as the physical 'hands-on' interaction.

This research has also demonstrated the importance of taking into account the less 'tangible' aspects of the relationship: for example how a practitioner approaches the medium, and its role in their practice, particularly as the characteristics of a medium are defined in relation to each practitioner. The ways in which the three practitioners interviewed approach their digital medium is in line with, and largely derives from, the approach they used with physical media. However, this does not imply that the way to design new digital systems for the use of creative practitioners is to replicate existing techniques and ways of working with materials. These practitioners' approach to the medium was to question it, engage with it, use the qualities it possesses as a medium, 'find its edges', exploit its limits, and take advantage of unpredictability and unexpected effects. A valuable lesson here is that practitioners, particularly those using the digital as a medium rather than as a tool for simulation, will use the medium in whatever way they see fit; this may result in the medium being used in ways other than for which it was intended, or beyond that for which it was 'designed'.

This does not mean that the ways in which we interact with computer systems could not be improved; a number of practitioners and students interviewed during this research commented on aspects of the software interface which they found frustrating. But while the goal of designing interfaces to make them more intuitive for creative practitioners (and indeed all users) may be commendable, it is not merely a matter of replicating the ways in which creative practitioners currently work with materials: the role of the medium in one individual's practice may be quite different than in another's; individual practitioners will approach and use a digital medium in different ways; and what one practitioner may find frustrating about working with a medium may be someone else's creative springboard.

This research illustrates that digital media afford a broad variety of ways of working. These may not be the *same* ways of working, but it is this aspect that is of particular interest: how ways of working and knowing can be dissociated from the material context of the real world, and brought into new spheres of practice. It also emphasises that the digital is not just a tool with which to simulate reality, it is a medium in its own right with unique properties to be explored.

At a philosophical level, approached with the desire to simulate reality through representation, or through devising systems whereby it is possible to work with digital media in the same ways as we can with physical media, a digital medium embodies our assumptions about the how we see, experience and relate to the world. When its inherent qualities and limitations are explored and exploited, it has the potential to reveal our assumptions about the world, and to allow us to rethink our experience of and relationship with the world.

Regarding programming

There may be readers with a background in computing science who would equate the different approaches discussed in this thesis to the 'top-down'/'bottom-up' distinction in approaches to programming. However I believe that this does not adequately describe the range of approaches used by the practitioners studied within this research. If the differences did equate to the top-down/bottom-up distinction, a bottom-up approach would equate to an emergent approach. However, the results from the studies suggest that there are two quite different types of emergent approach, relating to whether the emergence relates to the conceptual idea or design, or an exploration of the properties of the medium. This suggests either that the top-down/bottom-up dichotomy is not applicable in this case, or that it does not in itself adequately describe the range of programming approaches.

The main distinction that Turkle & Papert appear to make is between 'structured' programming and bricolage. The terms they use when describing the former include planning, black-boxing, rule- and plan-oriented, abstraction, logic, hierarchy, analytic, divide-and-conquer, modular solutions, dissect problem, assembled from sections/parts, specification in advance, clear plan defined in abstract terms. These are in contrast to bricolage, "a style of organising work that invites descriptions such as negotiational rather than planned in advance, what Warren McCulloch describes as 'heterarchical' rather than hierarchical" [Turkle & Papert 1990]. However, although Turkle & Papert use the phrase 'top-down' in some of their examples of the formal or hard approach, it cannot be assumed that the differences which they discuss between planners and bricoleurs equate to the 'top-down/bottom-up' dichotomy. I don't believe that the 'soft' approach which Turkle & Papert describe directly equates to a 'bottom-up' approach.

There are commentators from within programming who propose a wider spectrum of approaches than the 'top-down'/'bottom-up' dichotomy. Rebecca Mancy describes three

'modes of programming': top-down, bottom up and 'interactive' [Mancy 2004]. She distinguishes between a 'bottom-up' approach, where elements of a program are built before considering the final structure, and an 'interactive' approach, where you "build a simplified version of the problem, and then work on extending it". In a deeper analysis of these approaches, she proposes that there are three "modes of creation": top down, bottom up ('from parts'), and "from simpler", and has examined them in reference to another dimension, "precise desired outcome" v "loose or no desired outcome".

When examining the intersection of these dimensions, the approach above, "from simpler" can in turn be defined as "*interactive*" in the case of a 'precise desired outcome': "Take a simplified version of the problem, create a fully-working version of this simplified problem and then build on it", and as "*growing*" in the case of a 'loose or no desired outcome': "Start with something, and build on it, see where it goes".

In Mancy's discussion, she comments that the 'interactive' approach she discussed correlates well with Turkle & Papert's description of Anne, who 'sculpts' her program:

> *"Anne does not write her program in "sections" that are assembled into a product. She makes a simple working program and shapes it gradually by successive modifications... Each step is a small modification to a working program that she has in hand. If a change does not work, she undoes it with another small change. She "sculpts." At each stage of the process she has a fully working program, not a part but a version of the final product"* [Turkle & Papert 1990]

Mancy has therefore identified another dimension - 'mode of creation' – distinct from her dimension of 'precise desired outcome' v. 'loose or no desired outcome' (similar to what I would term 'planned' or 'emergent').

Mancy's analysis of different approaches within programming appears partly to correlate to the differences I had observed in an emergent approach: in one there is the sense of predefining elements, then building something from them; in the other there is a strong sense of 'growing' the piece of work. However, my interpretation effectively amalgamates Mancy's 'modes of creation' within the 'planned v. emergent' dimension. I had also proposed that this dimension works alongside a separate dimension (see Figures 71 & 72): 'relates to self', where an emergent approach can be viewed as a dialogue *through* medium; and 'relates to medium', where the emergent approach can be viewed as a dialogue *with* medium.

Sutherland & Hoyles describe a number of 'dimensions' of difference which they observed in the ways in which children approached programming projects [Sutherland & Hoyles 1988]. One of the main differences they observed was between whether the

children worked with well-defined goals (a "well worked-out and preplanned overall structure and global product") or loosely defined goals ("build up their goal whilst interacting with the computer"). Within those who had well-defined goals, they identified further differences: top-down and bottom-up approaches to *planning*. This implies that a bottom-up approach does not necessarily equate to implementing or making the final product, but is rather a different approach to planning it. The following description given by Sutherland & Hoyles may serve as illustration:

> *"George and Asim are two of our case study pupils. Throughout their first year of learning Logo they always chose for themselves well defined picture goals. They preplanned their work very carefully, usually away from the computer. Their planning took the form of drawing out their design on graph paper, writing a linear series of commands and splitting these into sub-procedures only when this was imposed by the storage restrictions of the machine... They never worked in an experimental way with sub-procedures and did not come to appreciate the intrinsic nature of turtle geometry; that is that the same 'shape' in a different position of orientation can be defined by the same procedure. This absence of 'hands on' exploratory activity was detrimental to their understanding of the ideas of structured programming."*

This approach, while sharing some aspects of Turkle & Papert's 'hard' mastery, is quite different in others. While the pupils certainly preplanned their work before executing it on the computer, there appears to be little in the way of abstraction, in the way of dissecting the problem, or working with modular solutions.

Across these dimensions of well-defined and loosely-defined goals, and top-down or bottom-up planning, Sutherland & Hoyles also observed differences between the ways in which children chose to interact with the computer: their "mode of computer interaction". This was either 'hands-on', dealing with the programming interface directly, or more distanced:

> *"Throughout the Logo Maths Project we occasionally gave the case study pupils, either individually or in pairs, the same well-defined task and we observed differences in programming style between the girls and the boys. These differences cannot be adequately described by reference to the dimension of top-down planner and bottom-up planner but are more to do with mode of computer interaction. In fact one boy and one girl, Asim and Sally, both tended to be top-down planners whereas George and Janet both tended to be bottom-up planners. In contrast to Asim, though, Sally always wanted to work initially in direct mode. Her behaviour masked the fact that she nearly always started a project with a clear top-down plan... Sally and Asim both made top-down plans but, whereas Sally tested all the modules of her top-down plan and then used these to build up the row of decreasing squares before defining the final superprocedure, Asim defined a superprocedure straight away in the editor. He then had considerable debugging problems because he had not attended to state and interface details in his square module. Similarly, when Sally and Janet were working together on a well-defined task, they consistently worked in a way which involved testing individual modules and building these into the final product* before *defining the*

superprocedure. The fact that they did not start the project by defining the superprocedure did not mean that they did not have a top-down plan of the problem solution. When given the same task Sally and Janet, unlike George and Asim, used 'hands on' activity as a way of getting into the problem. Once involved in the problem, they took time off to discuss their global plan, whereas George and Asim discussed their global plan before typing any commands into the computer. There is the danger that superficial observation could lead to the conclusion that Sally and Janet were not planning. Our evidence suggests that they did plan when working to well-defined goals but the nature of their interaction with the computer was different from the boys. They used interaction with the computer to get started and to engage on the problem..."

There are two possible interpretations of Sutherland & Hoyle's descriptions of these differences in approach. First, that they represent two different 'dimensions' of variation: one relating to goals (a spectrum from well-defined goals, incorporating top-down planning and bottom-up planning, to loosely defined goals); the other to the mode of interacting with the computer (direct/hands-on v. distanced). The first dimension has some similarities to my 'planned v. emergent' dimension, although their definition of 'bottom-up planner' is not the same as my 'predefined elements', which is more like Mancy's 'bottom up' categorisation. (Sutherland & Hoyles' description of George and Asim's 'bottom up planning' is different from Mancy's intersection of bottom-up and 'well-defined goals': 'defining the elements then worrying about how they are put together', which has partial similarities to some elements of Sally's approach (above), whom they describe as a top-down planner, working in direct mode.) The second, 'mode of interaction', although similar, does not appear to be the same as my 'relates to self/relates to medium' dimension, although it is significant that they define it as a separate dimension working alongside others, rather than an element of another dimension.

Alternatively, although Sutherland & Hoyle don't mention a 'bottom-up' approach to loosely defined goals, it may be that 'top-down/bottom-up' is a separate dimension, distinct from well-defined/loosely defined goals (see Figure 73).

well-defined goals	top-down	'hands-on'/direct
loosely defined goals	bottom-up	distanced

Figure 73: Three dimensions

In the context of my own research, I had thought that the top-down/bottom-up distinction, as I had originally interpreted it, could relate entirely to the organisation of work (the planned/emergent dimension) and say very little about the practitioner's relationship to the objects of work, or the role of the medium (be it written language, programming

language, or physical medium) in their practice (the 'express/engage' and 'internal/external' dimensions). While this may be true, Mancy's and Sutherland & Hoyles' observations would suggest that, while the top-down/bottom-up dimension might relate to the organisation of work, it does not necessarily equate directly to my 'planned/emergent' dimension.

Regarding writing

Further comparisons with the field of writing allow useful parallels to be drawn and insights to be obtained in the search for relationships between the different dimensions.

Function of writing and role of language

Britton et al [Britton, Burgess et al. 1975] developed a framework for classifying writing, based on studies of the writing of students in secondary school, across disciplines, and spanning first to final year. Finding the existing classifications of writing too limiting, they were concerned with developing a

> *"...means of classifying writings according to the nature of the task and the nature of the demands made upon the writer; and, as far as possible, a way of classifying that is both systematic and illuminating in the light it sheds upon the writing process itself"*

They also wanted a framework which could accommodate both the writing of mature writers, and the development of writing abilities.

Their major concerns were the aspects of *process* and *function* in writing. Their 'function categories' are of particular interest here: "These are an attempt to provide a framework within which to ask or answer the question 'Why are you writing?' in a specifically limited way". 'Function' here is defined in terms of the relationship between the writer and the reader, and largely relates to the role of language.

Mature writing can be classified into three function categories: Transactional, Expressive and Poetic. These categories are seen as a spectrum, with Expressive in the centre, and Transactional and Poetic at the extremes. (Within this framework, learner writers begin as Expressive: "...in developmental terms, the Expressive is a kind of matrix from which differentiated forms of mature writing are developed.")

Transactional language is "language to get things done", writing as a means to an end; the language is transparent. *Expressive* language is language "close to self", "revealing the speaker, verbalizing his consciousness". *Poetic* language is writing as an end in itself, which "uses language as an art medium"; "a piece of poetic writing is a verbal construct,

an 'object' made out of language"; the language is used concretely, "the phonic, syntactic, lexical and semantic aspects of the utterance itself are the objects of attention, by the writer and the reader".

Although Britton et al. are discussing functions of writing rather than types of writers, their distinctions between 'function categories' resonate in many respects with the axes and dimensions of difference discussed in this thesis. Table 10, adapted from [Britton, Burgess et al. 1975], contrasts characteristics of the two polar extremes of the spectrum.

Transactional	**Poetic**
The writing is an immediate means to an end outside itself.	The writing is an immediate end in itself, and not a means: it is a verbal artifact, a construct.
The form it takes, the way it is organized, is dictated primarily by the desire to achieve that end efficiently.	The arrangement *is* the construct: the way items are formally disposed is an inseparable part of the meaning of the piece.
Attention to the forms of the language is incidental to understanding, and will often be minimal.	Attention to the forms of the language is an essential part of the reader's response

Table 10: Contrasting the extremes: Transactional and Poetic
(adapted from [Britton, Burgess et al. 1975])

These have strong similarities to a number dimensions of difference in the framework described in Chapter 7, ***Comparative study***, such as:

- medium as a means to an end/means separate from end v. medium is end in itself
- form and content separate v. form and content developed together
- medium is used transparently v. medium is used concretely

In Table 11 I have placed characteristics of the functions in another relationship, illustrating aspects of the shift from the focus on self and fewer 'external' demands of the *Expressive* function to, on one hand the focus on writing as a means to an end and the demands of the task of the *Transactional* function, and on the other the focus on writing as an end in itself, language as a medium, and the demands of the construct of the *Poetic* function.

Transactional	Expressive	Poetic
focus on topic, content	focus on self	focus on medium
demands of task	freer from outside demands (*but demands from self?)*	demands of construct
language as a means to an end	language as exploration, as "thinking aloud on paper"	language as an end itself; for its own sake

Table 11: Some characteristics of the Function Categories

Looked at this way, the differences between these functions have strong similarities to the differences that could be discerned between Practitioners A, B and C in Chapter 8. In particular, these different 'function categories' would appear to accommodate the difference between PractA's identification with the medium as part of self, and process as 'a journey driven by a feeling' (*Expressive*), PractB's with the medium as 'other' and a means of 'rethinking the world' (*Transactional*) and PractC's with it as 'other', deriving meaning from the objects he finds and brings into being (*Poetic*). (Whether the focus on topic, self or medium is a dimension in itself, or results from the interaction between other dimensions, is yet to be determined.) These function categories may also provide another way of classifying the types of response to objects of students in the Artefact Study (my original types were Descriptive, Responsive or Generative).

Writing strategies

In The Act of Writing Chandler, as well as proposing two main orientations to writing – 'planner' and 'discoverer' - describes four different writing 'strategies' which writers would recognise as their methods of composition: Architectural strategy; Bricklaying strategy; Oil Painting strategy; and Water-colour strategy [Chandler 1995]. These were based both on a review of accounts of writers' processes in literature, and a survey of academic writers.

In How We Write: Writing as Creative Design Sharples also discusses writing strategies, based on studies by van Waes and Wyllie [Sharples 1999]. van Waes developed a classification based on the cluster analysis of data collected from a number of writing episodes, resulting in five strategies: Initial Planners; Average Writers; Fragmentary First-phase Writers; Second-phase Writers; and Non-stop Writers. Wyllie's study was

based on writers' accounts of their practice; she used a taxonomy based on Chandler's (Watercolourist; Architect; Bricklayer; Oil Painter) but with the addition of one more category, Sketcher. Sharples draws parallels between these and the five categories developed by van Waes (see table 8.1 in [Sharples 1999]).

These writing strategies largely concern the relationships between what Sharples describes as the main activities of writing: planning ("generate notes and plans"); revising ("annotate and edit text, notes or plans"); and composing ("generate text").

The strategies are not strict subdivisions of the 'Planner' and 'Discoverer' dimensions, although, for example, those who used the Architectural strategy (which Chandler describes as "plan-write-edit") tended to be Planners, in that the form of the work was preplanned, and they tended not to think of writing as a form of thinking. The Oil Painting strategy is closest to the Discoverer, with what Chandler describes as "minimal planning, maximum revision", and "a strong tendency to write to understand better what they wrote". Chandler appears to include two types of writer in this category; those who could be described as working from the 'bottom up', and those who start off with a whole and work into it:

> *"...'I evolve a paper out of the mist. It comes in pieces, each piece being smoothed a bit as it comes along. And so it isn't a linear thing starting at the beginning and going to the end, but rather clusters'. Another reported 'writing it several times until I see how I'm going to convey crystallize, and then sort of letting the paper flow... I write the paper and let it come as it comes... My first draft is an enormous, lengthy, amorphous mass... I found myself crossing out... I do a tremendous amount of pruning'..."*

Writers using the Water-colour strategy (those who van Waes called 'Non-stop Writers) aim "to produce a complete version at the first attempt, with minimal revision". Wyllie has classed Watercolourists as 'mental planners', but Chandler seems to include two types of writer in this category: those who "refer to complete texts being formed in the mind after a long period of mental 'incubation' or 'germination'", and those who describe their writing as "'unpremeditated'... 'dictated' by an inner voice". (In terms of orientation (Planner/Discoverer) these two types, while appearing to have similar strategies, would be polar opposites.)

Those who use the Bricklayer strategy refine the text as they go. Chandler quotes one writer:

> *"I have to get every paragraph as nearly right as possible before I go onto the next paragraph. I'm somewhat like a bricklayer; I build very slowly, not adding a new row until I feel that the foundation is solid enough to hold up the house."*

Wyllie classes Bricklayers as Planner/Discoverer (as opposed to Discoverer/Planner), although Chandler reports that "they tended not to be Discoverers" – "They usually had a clear idea of what they wanted to say and strongly disagreed that thinking would be difficult without writing".

Wyllie's addition of the Sketcher category to Chandler's four (in her terms Discoverer/Planner and what van Waes classified as Average Writer, in the sense that "this strategy combines aspects of all the other profiles, with close to average values for each of the variables"), includes those writers who start with a rough plan, who sometimes work sequentially but sometimes not, and who revise a lot. Her description suggests that the plan is not detailed, and can also be revised in the light of the form of the work that is emerging.

In How We Write: Writing as Creative Design, Sharples observes that there are different levels of planning in writing as compared to, for example, architectural design in which a complete specification of the item in question has to be produced. In terms of the research reported in this thesis, where the model is 'design and make', there can also be more flexibility in terms of planning the work, as we have seen.

Differences between the various writing strategies described above include:

- the extent, level of detail, and flexibility of preplanning
- whether the text is produced sequentially, or whether it is produced in sections which are then put together
- the extent, level and timing of revision
- whether activities are performed internally or externally
- whether the writer views the work primarily at the level of the text, or at the level of the structure
- whether the writing is focused to the writer (writing to think) or towards the reader
- the extent of recursion in the process.

Some writers may use a variety of strategies, while others may have a strong preference for one; Chandler discusses the relationship between choices of strategy in [Chandler 1995]. Further examination of the differences between writing strategies can therefore add insight into the interaction between the various dimensions of difference between individual approaches to writing. It suggests a more complex structure of variation, along similar dimensions to those discussed previously.

The examination of the writing strategies above suggests that they concern the pattern of relationships between the main activities of writing and their manifestation, resulting from the interaction between the orientation of the writer, their preferred style of organising work, their relationship with the medium and its role in their practice, and the task at hand.

Relationship between 'dimensions of difference'

Without further analysis of the data, and given the many dimensions of difference identified in the conceptual framework derived from the literature [Chapter 7], it is not profitable to speculate further at this point as to the exact relationships between the various 'dimensions of difference' within the data. However, what is suggested by the above discussion (and from the observations made by Turkle & Papert discussed earlier in this chapter) is that individual approaches may result from different combinations of orientation towards practice (goals/discovery), preferred style of organising work (preplanned/emergent), way of relating to the medium (close/distant), role of the medium (a means to an end/an end in itself), and mode of thinking (formal & abstract/intuitive & concrete). Each of these broader dimensions of variation are included in the original framework, but this suggests that the interplay between them may result in a more complex structure of variation than the two-dimensional structure of the original framework with its 'formal/concrete' axis.

As becomes clear from this discussion, the examination of differences in approach to creating artefacts, whether they be three-dimensional objects (physical or digital), computer programs or writing, is a non-trivial exercise, dealing with many interdependent dimensions of variation. However, it also illustrates the insights that can arise from comparisons between and within disciplines.

Recommendations for future systems to support creative practice

Above, I outlined limitations of replicating existing techniques and ways of working with materials when designing new digital systems for the use of creative practitioners. However, if this is not the right approach, what could be the alternatives? That is a question which must properly be left for the next stage of this research, although certain observations can be made, and possible areas of enquiry sketched out.

An examination of diversity in design practice has revealed fundamental differences in the relationships between individual design practitioners and the artefacts they create and

work with in their design processes. While it has not yet been able to provide a fully coherent explanation of these differences, it has identified a number of dimensions in which the approaches differ, broadly relating to the 'hard' and 'soft' approaches identified in the original conceptual framework. It has also identified a number of different elements of working with physical materials which, though important, do not all rely on working in a 'physical' environment: the ability to manipulate things directly, the immediacy and responsiveness of the medium, the 'physicality' of objects, as well as the physical 'hands-on' interaction. This research has therefore demonstrated that the relationship between design practitioners and the artefacts they work with encompasses important ways of working and knowing that are not embodied in the material context of the real world, which should be acknowledged and could be harnessed in the development of new ways of working in future digital environments.

It is inaccurate to claim that most existing computer systems for 3D design and modelling only suit those with a 'hard' approach: this research has shown a variety of examples where practitioners and students who display elements of a 'soft' approach have successfully used complex 3D modelling software. Although some found that the hierarchical system of menus and abstract style of interface engendered a distance from the medium, for others this did not seem to be a problem. While some carefully planned their work before starting in the software, others found it possible to interact with it directly and create their work through a dialogue with the medium. This underlines the argument that the characteristics of a medium are not absolute, rather they are defined in relation to the practitioner. Yet a number of participants did say that they felt the style of interacting with the software was at odds to those whose experience of working with materials was very different. This being the case, is it therefore possible to design systems which take advantage of the particular differences in approach that have been observed?

I believe that the key to making real differences in the way in which computer systems can support creative practice is to consciously focus on those "ways of working and knowing that are not embodied in the material context of the real world", in a sense abstracting or subverting them from their embodiment in the contexts in which they have been examined here: it is all too easy, even when thinking along these lines, to fall back into the 'material' trap, or to approach the problem in terms of making modifications within the way existing 3D computer graphics software, for example, is designed.

Indeed, it soon becomes evident that achieving such change is non-trivial, particularly as the characteristics of a medium are defined in relation to the practitioner. Perhaps there are actually two questions here: how can we improve digital systems for those who want to use them as tools in different areas of practice; and can we create digital environments which enable new ways of exploring 'the digital' as a medium?

One way to proceed is again to examine the work of researchers in different fields who have taken similar approaches. Ackermann and Strohecker used the distinction between planners and bricoleurs in the design of their PatternMagix Construction Kit software, "a game-like software construction kit" with a "*constructive-dialogic* style of interaction [which] supports learning through playful exploration" [Ackermann & Strohecker 2001]

> *"Users play in a world of colourful tiles and geometric operations, from which they forge mosaic-like patterns. Interactions are modelled as a conversation between the player and the system. The dialogic turn-taking manifests as spatial changes in the display of constructions and system states."*

(Selected quotations and the figures in this section are taken from the PatternMagix presentation included on [Arnowitz, Dykstra-Erickson et al. 2001].) The PatternMagix program allows the player to "select elements to build colourful tiles, and experiment with geometric transformations by rotating an element or reflecting it around the x- or y-axis" (Figure 74). Once a tile has been created, it can be added to the 'library' of tiles for use as an element in further operations.

Figure 74

Figure 75

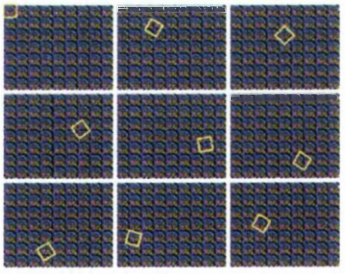

Figure 76

When the tile is completed, the system generates a pattern by replicating the tile (Figure 75). A floating frame then appears, which moves slowly and randomly across the pattern (Figure 76). The user can select this frame and move, scale and rotate it to outline a particular piece of the pattern; alternatively, they can leave it to float at random, outlining possibilities for new tiles, and selecting the frame when a fragment appeals. In either case, once the desired pattern is in the frame, a 'snip' facility copies it into the library for future use (Figure 77).

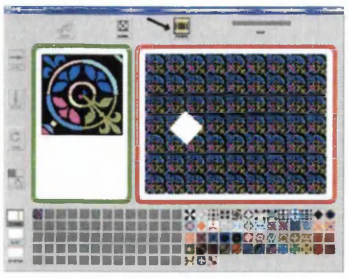

Figure 77

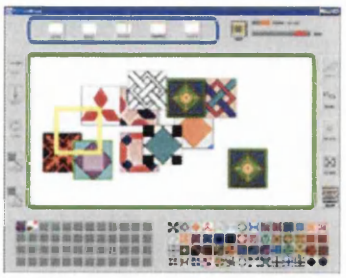

Figure 78

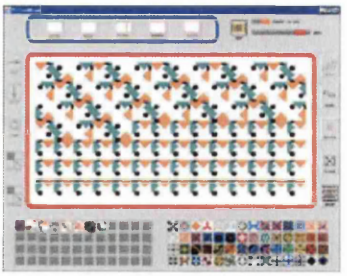

Figure 79

The program is designed to support two different types of interaction: direct manipulation, which is more akin to a monologue by the user, and automatic, in which the system plays a more active role. The first of these has two modes: 'Draw'[70], in which the player can create freehand "decorations" for the tiles; and 'Quilt', in which the tiles in the library can be dragged onto the working area, and a selection made from the resulting pattern to form a new pattern (Figure 78).

The automatic style of interaction also has different modes: 'Shuffle' (see Figure 79) and 'Kaleid'[71]:

> *"In the two automatic modes... the activation area expands to its maximum width, and the system automatically generates variations of user-crafted patterns. The player relinquishes control temporarily but can contemplate the evolving transformations and use them as inspiration for further constructions."*

The different modes within the PatternMagix system

> *"...enable varying degrees of control in the dialog with the system. Manual modes maximize the player's constructive capability, automatic modes maximize the system's contribution, and the basic Tiling mode offers a balance between the two."*

Thus the software supports two quite different 'conversational' models: 'monologue' and 'dialogue' within the one system.

Where next?

The following discussion represents very preliminary speculation on possible avenues of exploration.

Choice of materials

One dimension on which individuals differed concerned whether the materials are chosen to suit the design, or whether the design is determined by what materials are available.

---

[70] At the time of publication at CHI2001, the 'Draw' mode had not been implemented.

[71] At the time of publication at CHI2001, the 'Kaleid' mode had not been implemented.

On closer examination, further variation could be discerned within this spectrum, relating to at what level of process and how 'material' constraints arise: either *defined* (repertoire of techniques and processes; physical elements) or *selected* (palette of materials; components or materials) in the case of the students in the Comparative Study.

3D modelling software packages offer primitives: a basic set of predefined forms such as cube, sphere, etc, which prevent you having to build every model from scratch. However this does not have the same connotations as the notion of a 'palette' of materials which have been collected. As it is more difficult (certainly in 3D software) to collect the equivalent of found material objects (although it is possible, for example, to import pictures, textures, 3D models from libraries) perhaps future systems could provide the ability to generate primitives in new ways, or to provide other ways of instantiating objects.

However there are already alternative approaches to using primitives in Maya (other than starting models from scratch): one of the students in the Comparative Study used drawings via a graphics tablet to give her a starting point in the digital environment:

> *"...I don't tend to use primitives as much as I tend to use drawings, to start off any kind of- ...'Cause I feel like I have more control over it, I suppose. I feel like it's more mine by having the drawing first. Definitely control, I think, and that's just familiarity, I guess."*[72]

But perhaps this still sits within the constraints of existing paradigms: do we need to take the idea further? Should we provide a digital 'rummaging room' where you could collect things that you liked for use later? Could it store all different kinds of digital 'things' that could be used in unexpected ways?

Ways of seeing

One of the truly different characteristics of 'the digital' is that it can take many forms, and digital objects could be manipulated in all kinds of ways. One of the characteristics of the *bricoleur* approach is to use things other than for which they have been designed; to see things in terms of 'what they can do' as opposed to 'what they are for'. From this viewpoint, you could exploit the notion that something can be seen as a tool or a medium, or that one medium can be used as an abstraction for another. How could an abstraction be used as a medium? Could you use sound as the basis of generating 3D objects?

---

[72] Digital student 5, interview 1

Different ways of introducing change into the situation

Within the data two different types of 'emergent' approaches could be observed: one related to working directly with the medium, and an exploration of its properties; the other related to the conceptual idea or design.

One of the differences between these two approaches concerns ways of introducing change into the situation. In the first case, the *medium* effects the change by reacting to what you do to it, possibly in unexpected ways; I have equated this to a dialogue *with* the medium, where the set of possibilities is undefined (as far as you're concerned). In the second case, *you* effect the change through arranging and rearranging elements (it is a conscious change that is being made, even though you can't foresee the exact outcome). I have equated this to a dialogue *through* the medium, where in a sense you define the set of possibilities, or at least control the change of possibilities.

In the second case, one approach might be to make it easier to rearrange elements within a digital environment (in most cases digital models have, or at least tend, to be very tightly specified). In the first case, one approach might be to increase the possibility of happy accidents or unexpected effects (although that could be seen as a contradiction in terms!). Another might be to create a positively active medium, rather than a passive or reactive medium; or provide the ability to change the activeness/reactiveness of the medium.

Exploring possibilities

What might a truly digital 'workshop' be? What kinds of tools would you want? Many different ways of instantiating things? Many different ways of introducing change? Ways of creating your own tools or your own media?

In terms of the variety of disciplines discussed in this thesis, one possibility might be to create a true 3D environment for writing poetry: instantiating words through speech (or writing) as objects with sound or other 'physical' attributes; move them around as physical objects in 3D space; combine and manipulate them; set them in motion through the environment to take paths of their own...

Areas for future research

There are two main directions in which the research undertaken for this thesis could usefully be extended: firstly, towards a greater understanding of individual difference

between design practitioners; and secondly, towards the development of new digital environments for creative practice.

One of the limitations of the empirical studies within this research is that while they identified differences in approach that could be observed along certain dimensions, within the various groups, they lacked the formal connection between these dimensions within an individual's practice to allow a rigorous comparison between individuals across all the 'dimensions' of their approach. This is especially significant in the Artefact and Comparative studies, where although interesting differences can be observed, it is not yet possible to accurately distinguish the number of broadly different types of approach (i.e. whether there are two (as in the original framework), four, etc.).

This could be improved in two main aspects: extending the analysis of the collective variation within the groups (i.e. undertaking a more detailed analysis of the various dimensions of difference, as the existing analysis was relatively broad); and examining the connections and correlations between these to understand the relationships between the dimensions within individuals' processes (the structure of variation). This would allow a more rigorous comparison between the emerging structure of variation and the original framework, and therefore a proper assessment of how well the conceptual framework derived from the theoretical review fits the data.

Another area of enquiry that could usefully be pursued is a deeper investigation into parallels and differences between the three fields discussed in this thesis: 3D design, programming, and writing. Comparisons of the similarities and differences between these fields provided useful insights into individuals' approaches. The examination of other fields, such as music, would also be beneficial.

The second principal area for further research is the development of new digital environments for creative practice based on the premise, proposed and discussed briefly above, of focusing on those 'ways of working and knowing that are not embodied in the material context of the real world'. Building such systems would not only allow the exploration and testing of various 'fledgling' ideas, it would also provide additional means of examining and testing what the essential characteristics are of various 'dimensions of difference'.

Both of these areas – developing a greater understanding of individual difference between design practitioners, and developing of new digital environments for creative practice – would benefit from the introduction of additional methods of investigation, such as

different instruments for comparing individuals across a range of dimensions of variation, and more focused experimental studies based around techniques such as design games discussed by Schön [Schön 1992] and Habraken & Gross [Habraken & Gross 1987a; Habraken & Gross 1987b]. These have the advantage of dealing with similar underlying approaches as are encountered in design practice, without being mini 'normal' design projects artificially constrained for the purposes of experimentation. While these may not have been appropriate for this first stage of the research, they would be certainly be suitable for the more focused enquiry required for these second stages.

Conclusions

This examination of differences in approach has demonstrated an underlying commonality between disciplines including 3D design practice, writing and computer programming as regards how practitioners work, and their relationships with the medium they work in, on or through. It reveals important aspects of working and knowing that are not embedded in the material context of practice, which should be acknowledged by theory, and could be harnessed practically in the development of future digital environments for creative practice.

Finally, it is important to stress that while this research identifies a number of important differences which could be observed between individuals, it represents only an initial examination of the collective variation within the overall data, which has uncovered a complexity which this thesis has just begun to address.

10. Critique

The previous chapters have described the motivation behind this investigation, and introduced the different elements of the research, and their purpose and role in exploring and defining the territory of the enquiry, resulting in its thesis:

> *that individual practitioners experience different relationships with the artefacts they create and work with in their processes, and that elements of these differences can be attributed to the nature and extent of a dialogue between designer and media*

They have proposed a conceptual framework by which to describe and within which to examine this diversity in design practice: in essence a model of 'the nature and extent of a dialogue' which embodied the thesis. They have described two studies of practitioners designed to both test and illuminate this conceptual framework. They concluded that, while the findings of these studies broadly support this conceptual framework, it could not completely explain the diversity that can be observed between individual design practitioners in terms of their relationship with the artefacts and media they use in their design processes, and suggested possible reasons for these discrepancies.

The previous chapter, ***Discussion***, placed this research and its findings within their wider critical and practical context. It examined the collective results from all the studies and drew a number of conclusions, describing how they are supported or challenged by the different elements of this research. It assessed whether the findings of the research support the thesis, in particular how well the conceptual model of dialogue which I had derived to explain this diversity in design practice matches the differences observed in this research. It briefly assessed the effectiveness of the method(s) chosen, in terms of the different elements of the chosen approach, and how they worked together. Finally, it assessed the contribution of this research to and implications of this research for a variety of audiences, and proposed a number of areas for further research.

While these previous chapters have dealt largely with the subject of the enquiry, this chapter presents a short critique of the research, relating to the theoretical stance of the work and the method chosen. (The emphasis in this chapter is on whether the supposed benefits of the method were realised in practice, and their impact on the research; the theoretical basis of this research, and the reasons for choosing the method have already

been discussed in previous chapters, therefore I do not propose to deal with them in detail here.) This chapter aims to assess the 'structural rigour' of the research, examining the strengths and weaknesses of the method and its implementation, to enable the reader to assess not only the strength of the argument, but its weight.

Weaknesses

There are three main limitations of the research undertaken for this thesis: the extent of analysis of the data undertaken to date; the limited range of instruments used in the empirical work; and a lack of external validation of the analysis.

Extent of analysis undertaken

While the existing analysis of the data has identified a number of dimensions within the collective variation of the data, it has not yet been able to define the structure of variation i.e. how these differences relate to one another within an individual's practice. It has questioned the 'two-dimensional' structure of variation embodied in the original conceptual framework, but it has not yet been able to propose any firm alternatives.

The main reason for this is that while the empirical studies within this research identified differences in approach that could be observed along certain dimensions, they lacked the formal connection between these dimensions within an individual's practice to allow a rigorous comparison between individuals across all the 'dimensions' of their approach. The original analytical framework designed for the Comparative Study (which eventually formed stage 1 of the analysis of that set of data) incorporated this link between dimensions and structure of variation; however, due to limitations in its implementation[73], these could not be fully taken advantage of. (In any case, the subsequent stages of that study suggested that the original 'two-dimensional' structure of variation could not explain all the differences that could be observed.)

Another limitation of the analysis arose largely from the additional time required to undertake the 'emergent' phase of the Comparative Study, in comparison to coding the data against the analytical framework as in the original design. Although three sets of interviews were carried out in the Comparative Study, the main analysis of the data was

[73] These are discussed in Chapter 7, ***Comparative study***

based largely on the original set, with updates from later interviews as appropriate. However, there was little investigation undertaken of changes over time (apart from in cases where distinct changes occurred, or were remarked on) and their impact on the results has yet to be fully explored. Again, an analytical framework would have provided an initial means of examining this aspect, but for the reasons given above, this was neither possible nor ultimately appropriate.

It could be argued that this study was over-ambitious in its expectation of the extent of analysis possible within the period available. However, it should be remembered that the study was designed to use the analysis schedule, and the emergent form of the analysis was an adaptation made to address problems arising from its implementation.

Despite these drawbacks, I am satisfied that the chosen instruments have gathered data relevant to the overall thesis, and to the various 'questions' asked in each individual study. The data is in a suitable format for future examination. Further analysis of this data, using existing methods to undertake a more detailed analysis of the collective variation within the groups, and new instruments to examine the connections and correlations between the different dimensions, will enable a clearer understanding of the relationships between the dimensions within individuals' processes (the structure of variation) to emerge.

Range of instruments used in empirical work

Another criticism which could be levelled at the research is that the empirical work is based largely on one technique: interviews with participants.

I have explained earlier in the thesis why I believe that interviews (as opposed to examining working processes 'in action', or examining the artefacts produced) were the most appropriate technique for this stage of research: partly because of the nature of the data I wanted to collect[74]; and partly because of the limitations introduced by an experimental approach[75].

The aspects of practice with which I am concerned in this research involve people's experiences, perceptions, opinions, and emotions, as well as accounts of their own process. The artefacts they create and work with are integral to this process, but cannot

[74] See Chapter 7, ***Comparative study*** and Chapter 8, ***Practitioner interviews***

represent the whole process, and therefore an approach which only uses an analysis of artefacts to gain insight into each individual's approach was unsuited to this enquiry. In the Practitioner Interviews, for example, I was interested in how each practitioner viewed the digital medium, how they engaged with it, and how their material practice related to their digital practice. I was also keen to identify insights they had obtained into their own practice in moving from material to digital, and the differences they highlighted between the two working environments. A lot of important information was gleaned from the different ways in which participants described their processes, and their relationship with the medium. In the Practitioner Interviews, for example, the subtleties of the differences in the role of the medium within their practice emerged from the language each practitioner used when describing their work.

However, while the interview was the major instrument used in this research, different methods were used to analyse the interview data, and it was not the sole technique used in the research.

While the Practitioner Interviews and Comparative Study did not examine any artefacts (other than incidentally during interviews), the analysis of the Artefact Study was largely based around an examination of artefacts produced by the participants in a situation which, while it was not a formal experiment or an artificially constrained design project, did involve the production of work. This study revealed some of the difficulties in using artefacts themselves as a basis for analysis; however examining the differences between artefacts opened up a new thread of enquiry, as it revealed differences *within* as opposed to *between* artefact types[76]. At the time of the study I had not anticipated that an examination of the artefacts would represent a comparatively large part of the analysis; on reflection, the techniques used for this element of the research were rather informal. It was, however, very much an exploratory study; a more formal approach of this type would certainly be considered in future research, using more rigorous methods of examining physical artefacts.

Now that the parameters for this research have been more clearly defined, it would benefit from the introduction of additional methods of investigation, such as different instruments for comparing individuals across a range of dimensions of variation, and

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[75] See Chapter 4, ***Difference as a means of enquiry***, and Chapter 9, ***Discussion***

[76] See Chapter 5, ***Artefact study***

more focused studies based around techniques such as design games[77]. While these may not have been appropriate for this first stage of the research, they would be certainly be suitable for the more focused enquiry required for these further stages.

Lack of external validation of the analysis of the data

Further criticism which could be levelled at this research is that for each study, the analysis of the data has been subjective on the part of the researcher, whether against a 'framework' derived from other commentators, or emergent from the interview data or artefacts.

In the Comparative Study it had been the original intention to have additional external coding of the interviews using the analytical framework. However, difficulties were experienced in the application of this framework (relating to the definition of the categories)[78] which would have made its use by other researchers less valuable. This is exacerbated by the fact that the original two-dimensional structure of the framework now appears to be in doubt. At this exploratory stage of the research the value of this type of validation might therefore have been limited. It is probable that a revised framework, in which the categories were more closely defined using the results from this first stage of the research, would form the basis of future analysis of the data, particularly in relation to examining the structure of variation; it is expected that this would be subject to external validation.

In this research, these drawbacks have been mitigated to an extent by the range of studies which comprise the research. In the Comparative Study, for example, the conceptual framework was derived from a rigorous examination of commentators from other disciplines, and provides an external reference against which to compare the findings from the groups under investigation.

In conclusion, I am satisfied that the method chosen was appropriate for this stage of the research, and that the main drawback has been the extent to which the method has as yet been implemented. This could be improved through further analysis of the data, in conjunction with a suite of complementary studies using different instruments as suggested above.

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[77] See Chapter 9, ***Discussion***

[78] See Chapter 7, ***Comparative study***

Strengths

The main strength of this research is the breadth of elements which contribute to its findings. This includes the broad foundation of the theoretical basis of the research; the variety within the overall design of the research; and the benefits that arise from using difference as a means of enquiry.

Broad foundation of theoretical position (different disciplines)

The benefits of a broad foundation to the theoretical basis of the work have been discussed in Chapter 4, ***Difference as a means of enquiry***, and Chapter 9, ***Discussion***. These benefits relate to the additional weight of argument that arises from there being similar differences in approach within different disciplines, and the clarification and additional insights that can be gained from comparing these 'similarly different' approaches from quite different fields.

In this research, writing in particular has provided a useful comparative discipline. There are studies in writing and design which propose not only similar models of the creative process and the relationship between practitioners and artefacts (or similar explanations of differences between individuals), but each has a range of similarly different models of the creative process (with the exception that there had not appeared to be an equivalent in design of that proposed in writing by Chandler, which provided a route in to this enquiry).

The first benefit, therefore, of this broad theoretical stance was in providing an initial focus for the research: the differences that Chandler and Turkle & Papert identified resonated very strongly with things I'd observed in my previous research, and had been exploring further in the early stages of the research for this thesis, but there did not appear to be any existing models in the design literature that accommodated the types of individual difference with which I was concerned.

It has also provided, through the conceptual framework derived from these commentaries, a strong external element of comparison within the research, which has countered somewhat the current lack of external validation within the research, as discussed above.

Comparison within these other disciplines has also added clarity in areas where, although people may appear at first to be referring to similar differences, they are in fact not. Chapter 9, ***Discussion***, describes why I concluded that the top-down/bottom-up distinction does not equate to the planner/bricoleur distinction, and illustrates how an examination of why these are not in fact the same provides insight into other possible 'dimensions of difference'.

Variety within overall design of research

Although it could be argued that the variety of instruments used on this research was small (as discussed above), nevertheless the range of areas within which these instruments were used was broad.

The research contains both theoretical and empirical elements. It has involved a range of participants with different 'profiles': students and practitioners; students working in physical or digital environments; practitioners with experience in both physical and digital media, who use different digital (and physical) media. Although interviews were the main instrument of data collection, the research has also involved more empirical techniques (Artefact Study). It has examined a number of different phenomena: models of the creative process from different disciplines or theoretical viewpoints; physical artefacts; and people's creative processes and their relationship with the media they work with (through interview data). Interviews have ranged from following a fairly detailed schedule in the Comparative Study, to being more open-ended in the Practitioner Interviews. The research overall has combined 'predefined' and 'emergent' elements, as discussed in the previous chapter, and it is worth emphasising that the gaps between these two elements form a fruitful area for further research.

This variety within the design of the research has contributed to its strength as support for the thesis has come from these different quarters, thus broadening the basis on which the thesis is grounded.

Using difference as a means of enquiry

This research has confirmed the benefits of using difference as a means of enquiry, in its three guises: the comparative framework; the comparison of the individual against the collective (*difference*); and the added insight from comparing phenomena which are

similar-but-different (*distance*). Although these have been identified separately, as they address different phenomena, in practice they operate closely together.

Individual against collective variation **(difference)**

The primary method used in this research has been the examination of an individual against the collective variation that can be observed within a group. This involved exploring, through comparison between all the individuals in a group, the 'dimensions of difference' within that group to determine the collective variation against which an individual could be viewed. This research has included a range of individual/collective comparisons: between artefacts; between theoretical positions; and between practitioners, through interview accounts of their own practice.

In theory, this approach has a number of benefits: as the 'dimensions of difference' emerge from the data, it provides a route in to exploring a situation where there may be little previous knowledge; it can identify dimensions along which individuals may differ, particularly in regard to aspects which may not have been expected; and most importantly it can identify aspects of interest which may not be apparent from looking at one individual's practice. Previous chapters have largely described how these benefits have been realised within the individual studies, and I therefore do not propose to discuss them in detail here. The following examples illustrate particular benefits which have resulted from this approach.

In the Artefact Study the collective examination of the artefacts revealed what appeared to be significant differences along a completely different 'dimension' to what I'd been originally been exploring but which actually aligned with the eventual direction of enquiry of the thesis.

In the Comparative Study, despite problems implementing the analytical framework, the analysis of the data using this emergent technique identified a large number of dimensions of variation, the most relevant of which have been discussed in this stage of the research (by 'relevant', I mean those dimensions pertaining most closely to the subject of this initial stage of the research). It also highlighted the importance of differentiating the variety of ways in which students use the media with which they work. This was particularly noticeable within the group of students working with physical media, and revealed the important distinction between those students who originally appeared to be what I would have termed 'making' – working directly with materials at

the bench to create a piece – but who, as revealed through further discussion, were actually using materials more as a medium for design.

In the Practitioner Interviews comparisons between practitioners who had what at first appeared to be quite similar approaches, in terms of the original analytical framework, revealed distinct and significant differences relating to the role of the medium in each practitioner's practice.

Comparisons of this nature led to one of the most important conclusions that can be drawn from this research: that the characteristics of a medium are not absolute, resulting from notional inherent properties, rather they are defined through a practitioner's relationship with the medium.

Comparison between similar-but-different **(distance)**

The principle behind this approach is that insight can be obtained by comparing 'similar but different' phenomena. It is based on Chandler's observation in The Act of Writing, where he states:

> *"To become aware of the ways in which we engage with a medium we need to* distance *ourselves from it: to look with other eyes, to feel with other hands and so on; making the medium more visible or tangible."* [Chandler 1995]

Within this research this principle has been used to inform comparisons between individuals, between environments, and between disciplines (as described in the previous section). It underpinned the theoretical review; it was a major component of the design of the Comparative Study; and it formed the basis of the Practitioner Interviews, comparing approaches between material and digital environments within each practitioner's approach.

In the Comparative Study, the comparison between groups working in the physical and digital environments added rigour to the collective variation emerging from the data. This arose not only from there being similar dimensions of difference within each group, but from the particular insights which arose from the differences between the two environments: one example is where the digital acted as a 'prism', separating the different aspects of 'working with physical materials' into constituent parts (being able to manipulate things directly, immediacy and responsiveness of medium, the physicality of objects, and physical 'hands-on' interaction). The comparison between groups also

revealed that an external approach does not equate to an emergent approach, nor does it necessarily equate to an inability to visualise objects in one's 'mind's eye'.

In the Practitioner Interviews it showed that, in all cases, the practitioner's approach to the medium in their digital practice was in line with, and largely derives from, the approach they used in the physical environment. It also revealed the degree to which elements of their practice have, or have not been transferred between media (as distinct from their actual approach, which was broadly consistent across media). Perhaps the most striking aspect of this is that not being able to be physically 'hands on' with the medium, nor working with physical materials, doesn't appear to be a big drawback.

Finally, this principle applied throughout the research challenges any assumption that the fundamental differences between the different ways of working and knowing explored in this thesis are embedded in the material context of the real world: practitioners in quite different fields can also experience a close relationship with their medium, whether that medium be software, language, or 3D computer graphics.

Comparative framework

Chapter 4, ***Difference as a means of enquiry*** proposes the benefits of using comparative frameworks in this type of research: they add rigour to comparisons made between individual items (whether personal approaches or physical objects) by providing a context within which to make the comparison, and providing a means of placing different factors in relationship to one another.

The benefits that have arisen from using this approach to address the theoretical aspects of this research have been discussed above. It produced a robust comparative framework: a rigorous framework to provide strong basis for comparison between disciplines, and to understand how models from other fields might apply in design; and a complete framework which can also accommodate the broader range of studies included in the literature review.

In the Comparative Study, the implementation of the original analytical framework was problematic, and the 'emergent' analysis of the data does not yet permit the formal connection between dimensions within each individual's practice to allow a rigorous comparison between individuals across all the 'dimensions' of their approach. Although these problems have meant that the role of the comparative framework has been less than

envisaged, nevertheless the principle of examining the ways in which dimensions interact within certain individuals' approach still applies, and has revealed a number of important ways in which the data diverged from the original conceptual framework.

The principal example of this was in the Comparative Study, where it became clear that an emergent approach did not equate to a 'dialogue *with* the medium', but might also be observed as a dialogue with oneself *through* the medium. In this case the differences relate to whether the emergence relates to the conceptual idea or design, or an exploration of the properties of the medium.

Summary

It could be argued that this comparative approach might spiral endlessly, that the framework might be split into tiny fragments, with no visible underlying structure. I don't believe this to be the case: although the research has identified cases of differences between what originally might have been similar approaches, dimensions relating to these 'additional' differences often already exist within the framework; it is the ways in which these dimensions combine within an individual's approach which result in the differences that are observed. This is one of the areas for further research proposed in Chapter 9, ***Discussion***.

In conclusion

Although the research described in this thesis has certain limitations, it has provided a substantial foundation from which to proceed. As a first stage of research in this area it has mapped out a territory, both theoretical and practical, within which subsequent investigations can be focused. It has examined the phenomenon in both students and experienced practitioners; and in both material and digital environments. It has extended research into three-dimensional practice. This thesis has identified ways in which the findings may impact on a variety of audiences, and it has proposed directions in which further research could usefully be pursued.

11. Conclusions

With due reference to the points made in the previous chapter, this research has demonstrated that important underlying differences exist between individual design practitioners which are more significant than variation arising from each designer's personal style, unique experience, or working context; rather they represent wholly different approaches to design. Further, it has demonstrated that these differences in approach are consistent across media, and concern each practitioner's relationship with the medium with which he/she works, and its role in his/her practice.

A review of literature from other disciplines, including writing and computer programming, revealed differences in approach which could be characterised by two 'ideal types': clusters of attributes observable across different levels of practice, divided broadly along a 'formal'/'concrete' axis. At one end of the spectrum the 'hard' or formal approach is characterised by explicit goals achieved through planning and working with representations. The medium is viewed as a tool to achieve a predetermined end. Risk is minimised, and mistakes viewed as problems. The relationship with objects is objective, formal and distanced, with an approach to thinking characterised by analysis, abstraction and reasoning in terms of rules. At the other extreme, the 'soft' situated, relational approach is characterised by tacit aims which allow the form of the work to emerge through engagement with the medium. The medium is viewed as interlocutor, with unexpected events viewed as part of the process of negotiation. The relationship with objects is subjective, concrete and situated, with a contextual approach to thinking characterised by transparency and a mastery of details, and concrete, bodily and intuitive forms of reasoning.

A detailed investigation of the creative practices of students and professional practitioners working with three-dimensional media, both material and digital, revealed that differences in approach along these lines could be observed in design practice, demonstrating an underlying commonality between the disciplines of 3D design practice, writing and computer programming. However, discrepancies between the data and my categorisation in terms of these two different approaches derived from the literature suggest that differences in approach exist over and above those that can be mapped directly to the formal/concrete axis. For example, there appear to be two different types

of emergent approach: one related to a conceptual idea or design, the other an exploration of the properties of the medium. There is also the suggestion of an underlying difference running parallel to a number of other dimensions, concerning whether the work is developed through reference to 'self', or to the medium.

Although the underlying dimensions along which these approaches differ have yet to be fully determined, this examination of differences in approach reveals important aspects of working and knowing that are not embedded in the material context of practice. It also emphasises that the characteristics of a medium are not absolute, resulting from notional inherent properties, rather they are defined through a practitioner's relationship with the medium. These findings suggest an alternative approach to developing future digital environments for creative practice: to consciously focus on those different 'ways of working and knowing' described above (separate from their embodiment in the contexts in which they have been examined here), rather than on replicating or enhancing aspects of material practice.

Appendix A: List of publications arising from this dissertation

Below is a list of publications arising from the research undertaken for this thesis (for completeness, the following list includes published journal and conference papers, and also papers presented at conferences and seminars where the proceedings were made available to attendees or on the web, but not published in official proceedings).

McLundie, M. (2001) Towards digital design environments. Position paper to CHI '01 Workshop on Tools, Conceptual Frameworks, and Empirical Studies for Early Stages of Design, 1 April 2001, Seattle, Washington, USA (http://depts.washington.edu/dmgwksp/design_wksp.html)

McLundie, M. (2001) "Towards Digital Design Environments: Crossing the Borders." Proceedings of CADE 2001, Digital Creativity: Crossing the Border, 10-12 April, 2001, Glasgow, Scotland, The Glasgow School of Art Press.

McLundie, M. (2001) Design in a Digital Environment? Paper to research seminar on The Role of Haptics in Art and Design Research, 19 May 2001, University of Central England, (unpublished).

McLundie, M. (2001) "Building on diversity: crafting a paradigm for digital design environments." Digital Creativity 2001, **12**(2): 109-111. Swets & Zeitlinger.

McLundie, M. (2002) "A Guide to Haptics Applications in the Digital Realm", Research Issues in Art, Design and Media, Issue 2, Spring 2002, Research Training Initiative, Birmingham Institute of Art and Design, University of Central England. (This online journal ISSN 1474-2365 can be viewed at htttp://www.biad.uce.ac.uk/research/riadm)

McLundie, M. (2004) "Talking Digital: exploring diversity in practitioners' relationships with digital artefacts." Proceedings of PixelRaiders 2, 6-8 April 2004, Sheffield Hallam University

Appendix B: Visualisation and interaction in 3D

This appendix provides a brief introduction to some of the technologies and principles involved in creating, visualising and interacting with digital models in three dimensions. This is an area where technologies are continually and rapidly advancing: this appendix does not aim to provide a comprehensive review or a comparative evaluation of the different technologies and current technical solutions; rather it aims to introduce this area to the reader who is not familiar with the technologies, techniques and principles involved.

3D visualisation

A variety of techniques exist which allow a user to 'see' a virtual model in three dimensions, and methods of displaying virtual 3D models in true physical space are increasingly viable. A selection of these techniques is discussed below. These range from fully immersive stereoscopic systems, where images for each eye are displayed on goggles worn by the user, 'immersing' them in the virtual environment, to volumetric and holographic systems, where the model is displayed in true 3D space, allowing the user to work with the digital model in the physical environment.

Stereoscopic

Stereoscopic displays take advantage of the principles of binocular vision by projecting a pair of images, one for each eye, that when combined by the brain produce the illusion of seeing a three-dimensional image.

In fully immersive systems the user is provided with a separate display for each eye (via goggles, for example), 'immersing' the user in the virtual environment: they can see only what is displayed to each eye. While head tracking allows the user to move easily around the model, the user's whole environment must be generated virtually, including representations of the user's hand in the case of interactive systems.

In semi-immersive systems, a stereo pair of images is projected onto a display. This display is viewed through glasses which restrict each eye to receiving a single image, producing the three-dimensional effect (there are a number of different techniques which can be used to achieve this, but the underlying principle is the same). Unlike fully immersive systems, objects in the physical environment can still be seen, e.g. the user's

own hand interacting with the virtual model. Different types of display devices exist, varying both in configuration and size.

Multiple-screen stereoscopic displays range from CAVE systems, such as the Immersive Room (Figure 80) [Fakespace Systems], which are the size of small rooms, and where walls, floor and ceiling can all be used as display surfaces, to small, desktop displays such as the 'Cubby' developed at the ID-StudioLab (Figure 83) [Djajadiningrat, Overbeeke et al. 2001]. Single screen devices range from large wall displays such as the PowerWall™ PRO (Figure 82) [Fakespace Systems] to displays integrated into laptop computers. Bespoke displays can be configured to even larger sizes, within the technical limitations of the current technology. Flat, table-sized displays which can be tilted to different angles are among the most popular: the M1 Desk (Figure 81) [Fakespace Systems] is an example of this type. The most common systems for 'true' 3D visualisation in current use are based on semi-immersive stereoscopic displays.

Figure 80: Immersive Room
Image courtesy of Fakespace Systems Inc.

Figure 81: M1 Desk
Image courtesy of Fakespace Systems Inc.

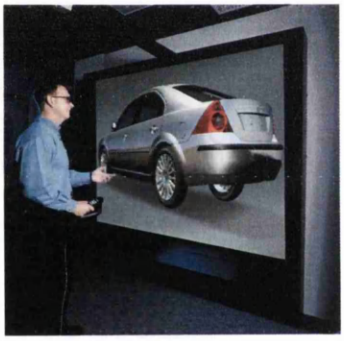

Figure 82: PowerWall™ PRO
Image courtesy of Fakespace Systems Inc.

Figure 83: The Cubby desktop 3D display. Tom Djajadiningrat; reproduced by kind permission of ID-StudioLab, Delft University of Technology

Autostereoscopic

Autostereoscopic displays work on a similar principle to stereoscopic displays, but require no special goggles or glasses to view. Unlike a stereoscopic display where the viewer has a single image mechanically displayed to each eye, in an autostereoscopic display a series of images is projected into adjoining 'windows' in space, and the viewer is putting their eyes into the field of display: effectively the series of images 'fan out' like rays from the screen in which the viewer is free to move, and where each eye receives a different view. In lower specification displays (i.e. fewer 'rays' in the fan) the point where the eye moves between images can be quite noticeable, the viewing range is limited, and it can be awkward for more than one or two people to view the image simultaneously. In higher specification displays with many more 'rays' in the fan, such as the HoloVizio range [Holografika], the eyes move more smoothly between images, enhancing the perception of three-dimensionality.

Small and medium-sized autostereoscopic displays are now available commercially, both stand-alone like the HoloVizio range (Figure 84) [Holografika], and integrated into notebook computers such as the Actius RD3D (Figure 85) [Sharp Systems of America]. Larger displays are now beginning to emerge from research labs: Opticality Corporation recently developed a prototype180 inch autostereoscopic wall display for the National Museum of Emerging Science and Innovation in Japan which is on display at the 2005 World Exposition in Aichi, Japan [Opticality Corporation].

Figure 84: HoloVizio 128W
Reproduced by kind permission of Holografika

Figure 85: Actius RD3D
Reproduced by kind permission of Sharp Systems of America (pending)

Volumetric

All displays based on stereoscopic principles are fixed focus, and therefore cannot provide proper depth cues: the eyes cannot converge or change focus within the virtual

scene, as happens when viewing real objects. Volumetric display systems construct an image in three-dimensional space, within a physical volume. A number of volumetric imaging techniques exist, although many are still under development.

The FELIX 3D-Display (Figure 86) [Langhans, Bezecny et al. 2002] uses a swept volume method, with lasers illuminating points on a rapidly rotating display surface. This surface moves at a speed that renders it invisible to the viewer, leaving only the three-dimensional image visible. This image can be viewed simultaneously by many viewers and from almost any angle. Normal variable focus and depth perception apply, but as the image is displayed within a volume, it cannot support co-incident interaction with the user's hand, or haptic devices; researchers are exploring the unique requirements for interacting with this type of display [Balakrishnan, Fitzmaurice et al. 2001].

Displays of this type are now commercially available: the Perspecta Spatial 3D System is a desktop volumetric 10" diameter display with full colour (Figure 87) [Actuality Systems].

Figure 86: FELIX 3D Display
Reproduced with kind permission of Knut Langhans

Figure 87: Perspecta Spatial 3D System
Image courtesy of Actuality Systems, Inc. Bedford, MA USA (copyright 2004, David Shopper)

Holographic

Holograms can display true 3D high quality images which provide all the depth cues used by the human visual system, including depth of field which allows variable focus. While the viewing volume has limits, multiple users can view the image simultaneously.

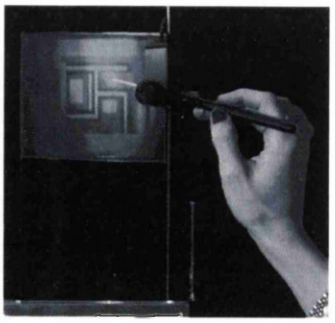

Figure 88: Edge-illuminated block haptic hologram
Reproduced by kind permission of Webb Chappell

A number of research groups including the Spatial Imaging Group at MIT (Figure 88) are developing techniques for producing computer generated holograms, where the holographic image is generated from a digital model, rather than being a copy of a physical object, as is the case with normal holograms [Plesniak & Pappu 1998; Plesniak & Pappu 1998; Plesniak, Pappu et al. 2003].

'Immersive'

Other systems have been developed which, although not true 3D displays, give a sense of 3D perception without the need for special glasses or goggles. Examples include the VisionStation® and VisionDome® series of hemi-spherical displays (Figures 89 & 90) [Elumens]. Images, predistorted so that they display correctly, are projected onto the concave or hemispherical screen. In this viewing volume the image is displayed in its spatially correct position with reference to the viewer, producing enhanced depth perception. However, as the image is not truly perceived in space, co-incident interaction using haptic devices is not possible.

Figure 89: VisionStation
Reproduced by kind permission of Elumens Corporation (pending)

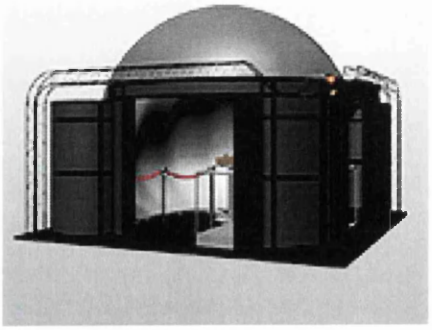

Figure 90: VisionDome V5
Reproduced by kind permission of Elumens Corporation (pending)

Gesture interaction

A variety of techniques provide the ability to interact with digital systems via hand gesture.

Gloves

The simplest devices which use 'gesture' are, in effect, selection devices with a greater repertoire. In the Pinch® Glove (Fig. 91) a range of 'pinch' gestures between different fingers and the thumb can be recognised and used to correspond to a series of instructions, for example [Fakespace Systems].

The CyberGlove® is a tethered, multi-sensored glove that can sense the position and movement of the fingers and wrist (Figure 92) [Immersion]. It can be used with software to provide gesture control of systems (via up to 254 individual gestures), and when combined with a tracking device to determine the hand's position in space, it can be used to manipulate virtual objects.

Figure 91: Pinch® Glove
Image courtesy of Fakespace Systems Inc.

Figure 92: CyberGlove®

3D gesture in space

In the above devices, the term 'gesture' relates to postures or shapes of the hand i.e. the relative positions of the fingers, for example. Other devices, such as 3motion™ being developed by researchers at the Digital Design Studio, Glasgow School of Art, contain sensors which track the trajectory of the device in space (Figures 93 & 94) [Payne, Keir et al. 2005]. This allows the user to make physical gestures in 3D space, which can be used either as commands to control software, through recognition of particular gestures, or as natural movements such as a 'golf swing' in a computer game.

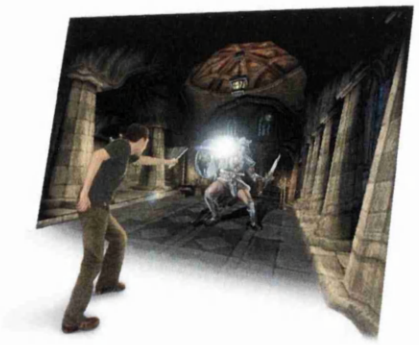

Figure 93: 3motion™
Reproduced by kind permission of Digital Design Studio, Glasgow School of Art

Figure 94: 3motion™
Reproduced by kind permission of Digital Design Studio, Glasgow School of Art

Haptic interaction

Haptic devices allow the user to experience a sensation of touch and physical properties when interacting with virtual materials. The term 'haptic interaction' is used to describe two different things: the tactile sensation of the skin touching a surface; and the resistance or force feedback experienced when you push against a material. It is most frequently used to allude to the latter, as the capability of most devices currently available is limited in conveying a true tactile sensation of a surface. Force feedback haptic devices exert force in response to a user's action, at the point of action. They enable active 'two-way' interaction with virtual objects, where action and perception are brought together. There are a range of haptic devices available, including mice and joysticks such as those used with computer games, and specialist devices such as those designed for simulating laparascopic surgery. Those reviewed below have been selected because they can be used not only to interact intuitively with virtual models, but to interact directly with such models in 3D space, providing co-incident interaction between hand and eye. (A wide range of haptic devices, both research and commercial, can be viewed on The Haptic Community Web Site [The Haptic Community Web Site].)

Single point force feedback

The PHANTOM® range of desktop haptic devices provide single point, 3D force-feedback to the user via a stylus (or thimble) attached to a moveable arm (Figure 95)

[SensAble Technologies Inc.]. The position of the stylus point/fingertip is tracked, and resistive force is applied to it when the device comes into 'contact' with the virtual model, providing accurate, ground-referenced force feedback. The extent of the arm determines the working volume.

A number of models are available to suit different user requirements; SensAble recently introduced the PHANTOM® Omni™, a slightly lower specification but less expensive model aimed at commercial users such as the 3D modelling market (Figure 96).

Figure 95: PHANTOM® Desktop™
Reproduced by kind permission of
SensAble Technologies Inc.®

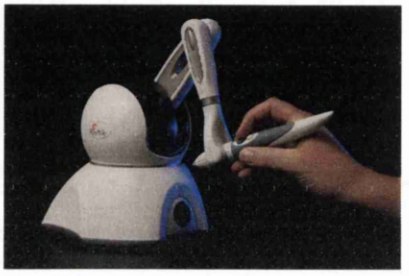

Figure 96: PHANTOM® Omni™
Reproduced by kind permission of
SensAble Technologies Inc.®

Multiple point force feedback

Immersion produce a family of products based around their CyberGlove® (see above). The CyberTouch™ option provides a sense of tactile feedback through the addition of vibrotactile stimulators to the palm and fingers of the CyberGlove (Figure 97). While not true tactile feedback, it can give the perception of touching an object. The CyberGrasp™ is a full hand force-feedback exoskeletal device, which is worn over the CyberGlove (Figure 98). Resistive force can be exerted on the fingertips through a series of 'tendons' controlled by actuators, allowing the user to experience resistance when interacting with virtual objects. This force is hand-referenced: it can prevent the user from crushing a virtual object in their hand, but it cannot prevent them pushing through a wall, or allow them to feel weight, for example. This can be achieved through the CyberForce®, a fixed-base force-feedback armature designed to be used with the CyberGrasp to provide ground-referenced forces to the hand and arm (Figure 99).

Another variety of haptic device can provide multiple point force feedback via a system of lightweight tensioned cords. Originally developed by researchers at the Tokyo Institute of Technology the SPIDAR-8 (SPace Interface Device for Artificial Reality)

provides force feedback to the fingertips of four fingers on each hand (Figure 100) [Sato, Walairacht et al. 2000]. Other researchers have built on this concept: the prototype Scaleable-SPIDAR provides one 'fingering' for each hand to interact in a large-scale environment (Figure 101) [Buogulia, Ishii et al. 2000], while the Stringed Haptic Workbench adapts the idea for interacting directly with stereoscopic 3D images on a workbench-scale display (Figure 108) [Tarrin, Coquillart et al. 2003].

Figure 97: CyberTouch™

Figure 98: CyberGrasp™

Figure 99: CyberForce®

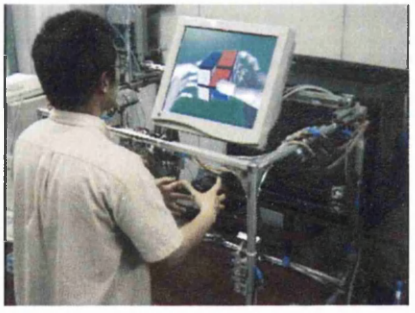

Figure 100: SPIDAR-8
Reproduced by kind permission of P&I Laboratory, Tokyo Institute of Technology (pending)

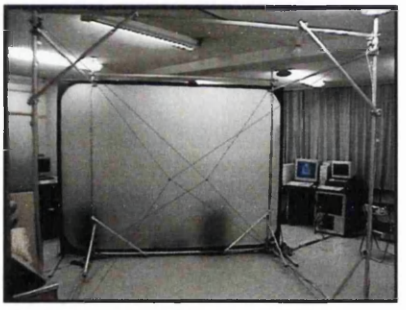

Figure 101: Scaleable-SPIDAR
Reproduced by kind permission of P&I Laboratory, Tokyo Institute of Technology (pending)

Direct manipulation: coupling physical and virtual objects

Another method of achieving direct manipulation of virtual objects is to couple them with physical devices or objects. Although such devices, or 'props', do not give haptic feedback to the user, they enable tangible interaction, often with both hands, taking advantage of our existing skills and experience in manipulating objects. A well-designed prop has a physical form which gives cues to the way it works, making it more intuitive and easier to learn than traditional techniques for manipulating virtual objects.

The CubicMouse™, a "physical co-ordinate system prop" initially developed at GMD[79] and until recently supplied by Fakespace Systems, is a hand-held cube with three rods running through its centre, one along each of the x, y, and z axes (Figure 102) [Kruijff 2000]. The cube is mapped to the position and orientation of the virtual environment, and the rods to the co-ordinate system of an object within that environment. Rotating a rod rotates the object around its corresponding axis, while pulling or pushing a rod through the cube will move the object along that plane within the environment.

Hinckley et al at Microsoft Research, Carnegie Mellon University and the University of Virginia developed an environment for neurosurgical planning in which the user manipulates "passive real-world props" with both hands (Figure 103) [Hinckley, Pausch et al. 1998]. A doll's head, "rich in tactile orientation cues", is mapped to a virtual brain model, and a clear plastic plate is mapped to a cutting plane. The viewer can examine different cross-sections of the brain, by rotating and moving the doll's head to orientate the brain model, and by moving the plate in relation to the doll's head to move the cutting plane though the model.

Figure 102: CubicMouse™. Image courtesy of Fakespace Systems Inc.

Figure 103: Environment for neurosurgical planning [Hinckley, Pausch et al. 1998] Reproduced by kind permission of IEEE, © 2004 IEEE

Figure 104: Graspable Real Reality User Interface. Reproduced by kind permission of artecLab, Universitat Bremen (pending)

Figure 105: Hybrid Environment [Lok, Naik et al. 2004]. Reproduced by kind permission of IEEE, © 2004 IEEE

[79] GMD - The German National Research Centre for Information and Communications Technology – now Fraunhofer IMK

The Graspable Real Reality User Interface concept at the University of Bremen took an alternative approach to coupling physical and virtual models (Figure 104) [Bruns & Brauer]. In this system, the user's hand was sensored, rather than the physical object. A data glove measured the shape and position of the hand, allowing the system to recognise 'grasp patterns'. A virtual model was built of each type of physical object to be used in the modelling. The system was trained to recognise a grasp pattern for each type of physical object, which was then used to map the physical object to the virtual object. Virtual models could then be built by manipulating the physical objects. The advantage of this system is that any physical object could be incorporated into the modelling system, and the same interface used to work with physical and virtual models.

In a more recent project using real objects to interact with virtual environments, Lok et al. are developing a 'hybrid environment' (HE) which uses input from multiple cameras to create dynamic 'avatars' of real objects in a fully immersive virtual environment [Lok, Naik et al. 2004]. This allows the user to see, for example, their hands and objects they are holding within the virtual environment; software allows the user to interact with virtual objects using these real objects (Figure 105).

Integrating advanced technologies for visualisation and interaction (co-incident interaction)

Integrating advanced technologies for visualisation and interaction combines the benefits of more natural ways of working with moving the three-dimensional virtual model into the user's physical workspace, allowing co-incident interaction between the eye and hands or tools.

MIT's Spatial Imaging Group have combined computer-generated holographic video and a PHANTOM haptic device to explore naturalistic, real time interaction with a 'tangible hologram' (Figure 106) [Plesniak & Pappu 1998; Plesniak & Pappu 1998; Plesniak, Pappu et al. 2003]. To achieve near real-time interaction, series of pre-computed holographic images are displayed in response to the user's interaction with the three-dimensional image. The 'Lathe' experiment allowed the PHANTOM stylus to modify a cylinder in a lathe scenario: the user had the sensation of feeling the cylinder spinning beneath their touch, and when they applied sufficient force, the cylinder surface deformed in response. This principle was extended in the 'Poke' experiment, which still combined pre-computed elements of images for real-time display, but provided a more flexible

model: a "sheet of pliable material, which could be felt, poked, and deformed" using the PHANTOM.

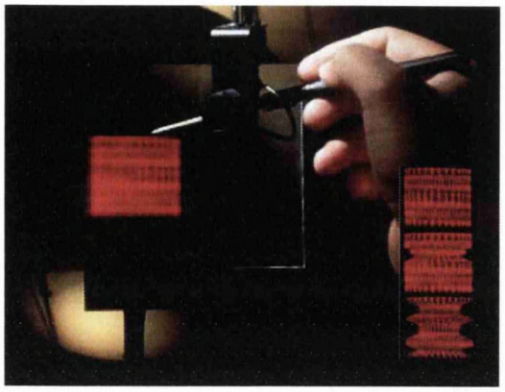

Figure 106: "Lathe"
Reproduced by kind permission of Webb Chappell

Figure 107: Two-handed direct manipulation on the Responsive Workbench. Reproduced by kind permission of Bernd Fröhlich.

A number of research groups have been investigating the potential benefits of interfaces which allow two-handed manipulation of three-dimensional virtual objects on 'workbench'-type stereoscopic 3D displays. Cutler et al at Stanford University developed a framework for two-handed interaction based around Guiard's observations of how humans distribute work between their hands [Cutler, Fröhlich et al. 1997]. Using this framework, they explored a variety of two-handed 3D tools and interface techniques to provide users with natural ways of manipulating 3D models on a Responsive Workbench (a semi-immersive stereoscopic table-type display) (Figure 107).

Researchers at INRIA and Tokyo Institute of Technology have combined a workbench with both vertical and horizontal screens (TAN Holobench) and a SPIDAR force-feedback device to produce the Stringed Haptic Workbench (Figure 108) [Tarrin, Coquillart et al. 2003]. This configuration allows the user to interact directly with the stereoscopic 3D image, and receive ground-referenced force-feedback (currently to the tip of one finger) within the large volume of the workbench display.

Commercially-available systems based on integrated visualisation and interaction are now reaching the desktop: the Reachin Display combines a stereoscopic display, a haptic device, and a positioning device, allowing eye and both hands to work co-incidentally with the three-dimensional virtual model (Figure 109) [Reachin Technologies AB]. Different configurations are available to suit a variety of applications. In their Haptic Workstation™ (Figure 110), Immersion have combined left-handed and right-handed CyberForce systems with a head-tracked fully-immersive 3D display; it can also be configured for semi-immersive displays.

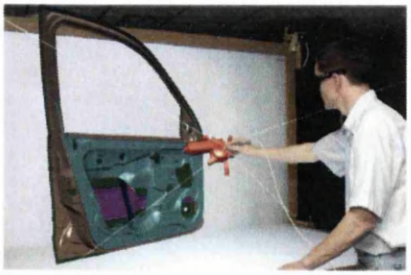

Figure 108: Stringed Haptic Workbench
Reproduced by kind permission of Nicolas Tarrin, INRIA (pending)

Figure 109: Reachin Display
© Copyright 2005 Reachin Technologies AB

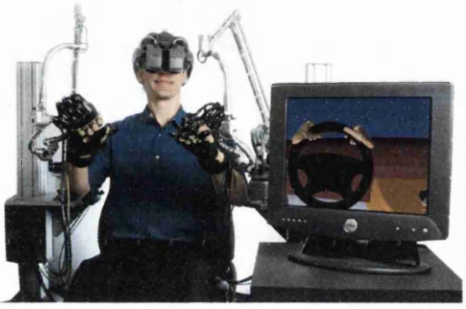

Figure 110: Haptic Workstation™
Reproduced by permission of Immersion Corporation, Copyright © 2005 Immersion Corporation. All rights reserved.

Software modelling to support interaction and visualisation

Haptic devices and 3D displays are of little value without software to model the 'physical' properties of the virtual material and its response to interaction, both haptically and visually: when you press a springy material, for example, you expect to feel it 'give', and see it deform.

A group of researchers at GMD[80], Stanford University and Carnegie Mellon University integrated the simulation of physical behaviours into a system to support complex assembly tasks, based around a Responsive Workbench (Figure 111) [Fröhlich, Tramberend et al. 2000]. In this system, multiple-user and multi-handed interaction with objects is enabled, a common requirement in assembly tasks. Although users receive no haptic feedback, the physical simulation means that objects move naturally during interaction, and good visual feedback is achieved.

James at Carnegie Mellon University is researching techniques in Linear Elastic Modelling which allow people to interact in real time with simulations of elastic or

[80] GMD - The German National Research Centre for Information and Communications Technology – now Fraunhofer IMK

'springy' materials. The virtual material responds haptically and visually to the user's touch, providing an engaging experience (Figure 112) [James & Pai 1999; James & Pai 2001].

Figure 111: Physically-based manipulation on the Responsive Workbench. [Fröhlich, Tramberend et al. 2000]. Reproduced by kind permission of IEEE, © 2004 IEEE

Figure 112: Linear Elastic Modelling Reproduced by kind permission of Doug L. James, Carnegie Mellon University

A major challenge in building applications which combine haptics and advanced visualisation is to integrate the various hardware components with haptics and graphics software so that they work together seamlessly. A growing number of toolkits are being developed for this purpose: one example is Reachin Technologies' Reachin API which manages the technology integration, allowing developers to focus on the application.

Rapid prototyping

Rapid Prototyping is a term used to describe a number of technologies and techniques for creating physical objects directly from digital data. Unlike 'subtractive' technologies used for this purpose, such as CNC (Computer Numerically Controlled) milling machines, Rapid Prototyping is an 'additive' process of building objects up in multiple thin layers; it can therefore produce geometrically more complex objects.

A variety of different techniques exist, all using the same underlying 'layered' principle: these include Stereolithography (SLA), Selective Laser Sintering (SLS), Fused Deposition Modelling (Figure 113), Three Dimensional Printing (Figure 114), Laminated Object Manufacturing, and photopolymer jetting (Figure 115). Each has advantages and drawbacks (speed, size, expense, etc), and so they are suited to different purposes; they also use different materials, and some techniques can incorporate different colours within the object. Depending on the technique used more or less 'finishing' of the model may

be required. In industry they are most often used to produce prototypes, however they can be used for finished objects where appropriate.

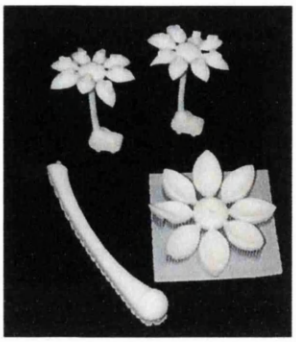

Figure 113: CALM project - final object produced by fused deposition modelling (Katie Bunnell). Reproduced by kind permission of the Learning Development Unit

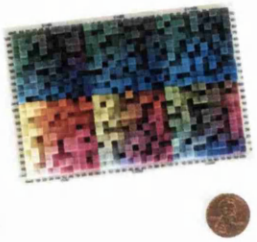

Figure 114: Colour 3D printing Reproduced by kind permission of [Z Corporation]

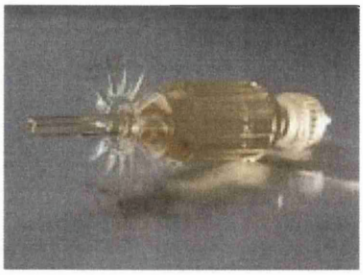

Figure 115: Photopolymer jetting Reproduced by kind permission of [Objet Geometries Ltd.]

For further information on these and other techniques the reader is referred to guides such as The Learning Factory's *Rapid Prototyping Primer* [Palm 1998] and Castle Island's *Worldwide Guide to Rapid Prototyping* [Worldwide Guide to Rapid Prototyping]. The *Rapid Prototyping Homepage* contains links to a wide range of resources on rapid prototyping [Rapid Prototyping Homepage].

Appendix C: Artefact study – research proposal

DRAFT : for discussion

Proposal for research workshop: artefact mini-roundabout

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Introduction

This paper outlines a one-day workshop for design students which explores methods of generating design ideas using a variety of different media. It takes place within a Technical Roundabout in which students are introduced to new techniques such as working with the lathe, enamelling, colouring and printing on aluminium, and working with plastics.

Research context

The research of which this study is part aims, by re-examining ways in which designers work with physical design representations, to inform the provision of virtual design representations within a digital design environment for 3D design and modelling.

Designer-makers, while producing contemporary design, exhibit a process based around traditional working methods. Although unique to each maker, its characteristic attributes of a highly integrated process, and a dynamic and vital interaction with materials, make it a useful starting point in the search for a new paradigm for digital design environments. Of particular interest is the way many designer-makers employ this dynamic interaction with materials to advance the design idea, including 'doodling', 3D 'sketches', maquettes, models, prototypes etc. This offers a qualitatively different perspective to the design-by-drawing approach. If this sensibility is to be brought to the 3D digital domain, the nature of this interaction with 3D 'artefacts', and its relationship to other elements of the designer's overall process, needs to be understood. The example of the designer-maker indicates that individual designers use different strategies, and that the ability to move back and forth between a variety of 2D and 3D representations, allowing designers to select their own preferred working method, is fundamental to the process.

The research is based on the observation that, while some designers develop their ideas using sketching, others choose to work with three-dimensional materials in the conceptual stages of design, or use a combination of both. Designer-makers interviewed in an earlier study by the researcher exhibited processes ranging from design-then-make, to design-through-make, to make-as-design. It is believed that the use of 2D and 3D techniques may indicate two quite different working strategies, and that to take full advantage of the sensibility of working with materials into digital design systems, these must be investigated more fully.

In this research, the term 'artefact' is used to denote the physical manifestations of the designer's process, including sketches, models, etc. It is used in the sense of physical evidence of that process, but it is recognised that the role of the artefact is not just as a (partial) record of the designer's intent, but as a participant in the process. Recent research into the role of sketching in conceptual design describes the sketch, not only as a form of external memory, but as "a physical setting where design thoughts are constructed on the fly" i.e. designing occurs as the result of the act of creating and working with external artefacts. The term 'artefact' will not only be used to denote those physical representations that the designer creates, but may also include other material external to the designer with which they work.

This research takes as its reference Donald Schön's description of design as "reflective conversation with the materials of a design situation", where "designing is an interaction of making and seeing, doing and discovering". He emphasises, "the designer designs not only with the mind but with the body and senses". His view of each designer creating their own 'design world' stresses the constructive nature of designing: "designers share with all human beings an ability to construct - via perception, appreciation, language and active manipulation - the worlds in which they function". This design world represents each designer's unique appreciation of the design situation: "given a stock of available materials, different designers often select different objects, and even appreciate the "same" objects in different ways, in terms of different meanings, features, elements, reflections and groupings, all of which enter into characteristically different design worlds".

The focus of this research is the relationship between an individual designer and the artefacts that they choose to use in their design process. The types of artefacts a designer uses, and the way they use them, is intimately bound up with their 'chosen' design strategy. One of the main aims of the research is to investigate the use of different strategies; to explore their relation to, for example, a designer's skills, knowledge, preferences, area of work, brief, and intellectual style; and to understand how these manifest themselves. The exploration of

DRAFT : for discussion

differences in strategy is used as a means of highlighting the characteristics of the artefacts that support each strategy, the particular interest in this research being 3D artefacts.

The current phase of the research is the development of a suite of observational and empirical studies to address different aspects of this relationship between designer, artefacts and strategy.

Research objectives

This workshop represents an exploratory study, both to observe the ways in three different 'types' of artefact - words, mark making, and materials - are used by participants in the generation of design ideas, and to evaluate the suitability of the methods used to collect the data.

The research objectives of the workshop are therefore:

- to collect information on the variety of ways in which participants use each of the three artefact types to generate ideas
- to identify the particular characteristics of the artefacts which are being used
- to look for differences in approach between participants
- to gain insight into the relative 'success' or otherwise of each method for each participant, with any indications as to why this might be
- to assess the suitability of the methods used to collect the data.

Learning objectives

This workshop takes the stance that if you understand what you are doing and why, if you can gain insight into how you work and learn what works best for you, you can begin to do it better. Each designer is unique, with their own combination of skills, knowledge, intellectual style and preferences. Part of learning to design well is the process of learning how best to communicate with yourself through the artefacts that you create and work with.

The learning objectives are therefore:

- to offer possible alternatives to the sketching/drawing approach for generating design ideas
- to encourage participants to explore a variety of methods other than they might normally use
- to help participants begin to have a better awareness of themselves and the design processes that work for them
- to increase participants' appreciation that, in a sense, design can't be taught, it must be learned.

If appropriate, a short seminar can be given at a later date, describing initial findings from the study.

Data collection

The primary method will be field observations made by the researcher, in conjunction with a photographic record of the workshop, including participants at work, and the artefacts they produce.

In addition, it is proposed to hold a short seminar at the end of the day, to review the work, and discuss the participants' experiences of each method. This will be recorded on audio tape.

A feedback form will be given to each participant at the end of the day, in which they can record their assessment of the workshop.

Consent to participate

Each participant will be asked to sign a short 'informed consent' form which will explain the purpose of the research, what their role will be, and ask for their consent for their work and comments to be recorded for the purposes of research. It will explain how this information will be used, and how their confidentiality will be ensured. It will recognise that while the workshops are included in the academic programme, and that they are expected to participate for this reason, they are free to withdraw permission for their work to be included in the research record at any time. Copies of the signed forms will be provided to the participants.

Workshop format

The aim of the workshop is to provide a series of short, intensive workouts exploring the potential of three different types of artefact - words, mark making, and materials - to act as 'catalysts' in the generation of design ideas.

At the beginning of the day, a brief introduction will be given, outlining the background to the research, the objectives for the day, and the activities which will be undertaken. A short roundup seminar will be held at the end of the day, when participants can review the work, and discuss their experiences of each activity.

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DRAFT : for discussion

The three 'workouts' will follow a common pattern. It is envisaged that each session will have time allotted for trying out techniques, followed by a time when the techniques are used to address a short brief (for guidance only).

The first session will explore methods of generating design ideas without reliance on drawing or materials, through the potential of words. It will investigate not only the descriptive and evocative qualities of words, but also their physical properties - sound, shape and rhythm - and their relationship to one another.

The second session will explore the expressive potential of a variety techniques of mark making, including printing and drawing with implements other than conventional pen/pencil etc., and how immediate, responsive, versatile and serendipitous techniques such as these can enhance a designer's creative thinking.

The third session will explore how a "dialogue with materials" might be used in the generation of design ideas. A selection of materials will be provided and participants will be encouraged to consider their role as content, as a means of exploring and investigating ideas, and as a medium.

It is envisaged that the roundup session will include discussion on ways in which these three activities might complement one another.

The proposed timetable for the day is:

9:30	Introduction
9:45	Artefact 1 - words
11:15	(coffee)
11:30	Artefact 2 - mark making
1:00	(lunch)
2:00	Artefact 3 - materials
3:30	(coffee)
4:00	Viewing of work / roundup seminar

Facilities/Materials

The workshop will require a studio space with access to water and electricity supply.

Most of the materials will be supplied, but the participants will be notified in advance of any items which they will need to bring.

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Appendix D: Artefact study - introductory handout

S&J Third Year Technical Roundabout

Artefact "mini-roundabout"

Introduction

Design has been described as "reflective conversation with the materials of a design situation", where "designing is an interaction of making and seeing, doing and discovering" and where "the designer designs not only with the mind but with the body and senses"[1]. In other words, design occurs through the doing of it: as the result of creating and working with external 'artefacts' - sketches, models, notes, experimental 'bits' etc. - which become participants in our designing.

Each designer is different, with a unique set of skills, knowledge, preferences, and working style. It follows that the act of designing is personal - it involves learning how best to communicate with yourself through the artefacts you create and work with. For example, some designers develop their ideas using sketching, while others may choose to work with materials, or use a combination of techniques.

In this workshop we will try out a variety of alternative methods for generating design ideas. The main aim is to explore each method for techniques which may be useful to you, rather than necessarily coming up with great ideas (but if it happens, don't worry!). By reflecting on what you do, you can gain insight into how you work, and learn what works best for you.

Workshop format

This one day workshop consists of short, intensive workouts exploring the potential of three different types of artefact - words, mark making, and materials - to act as 'catalysts' in the generation of design ideas.

Each workout will have time allotted for trying out techniques, followed by a time when the techniques are used to address a short brief (for focus only).

Words — During this session we will explore methods of generating design ideas without reliance on drawing or materials, through the potential of words. We will investigate not only the descriptive and evocative qualities of words, but also their physical properties - sound, shape and rhythm.

Mark Making — Here we will explore the expressive potential of a variety of techniques of mark making, including printing and drawing with implements other than conventional pen/pencil etc., and how immediate, responsive, versatile and serendipitous techniques such as these can enhance creative thinking.

Materials Finally, we will explore how a "dialogue with materials" might be used in the generation of design ideas. A selection of materials will be provided and we will consider their role as content, as a means of exploring and investigating ideas, and as a medium.

A short roundup seminar will be held at the end of the day, when we will review the work, and discuss participants' experiences of each activity.

Timetable

9:30	Introduction
9:45	Workout 1 - words
11:15	(coffee)
11:30	Workout 2 - mark making
1:00	(lunch)
2:00	Workout 3 - materials
3:30	(coffee)
4:00	Viewing of work / roundup seminar

What to bring/leave behind

All that you are asked to bring is an open mind and a willingness to explore. Source and working materials for the workshop will be provided on the day, but you are welcome to bring all or any of: your favourite writing implement; a piece of text that you like; a few things that you think might make interesting marks; an object that you find intriguing. I will bring scissors, knives, glue etc., but it's always useful to have more.

Inhibitions should be left behind, as should good clothes...

Mairghread McLundie
January 2001

[1] Schon, D.A., *Designing as Reflective Conversation with the Materials of a Design Situation.* Research In Engineering Design, 1992. **3**: p. 131-147.

Appendix E: Artefact study - workshop plan

(time) **Artefact 'Mini-roundabout' - plan**

(15) Introduction

9:30 Who I am and what I'm doing...

Schon's ideas about designing as reflective conversation with the materials, i.e. we design through creating and working with 'artefacts', the external representations e.g. sketches, models, that designers use - in a sense what's left behind after the designer's gone, but they're active participants in the process, not just a record of what we do. We see more than we intended in what we do, and so move on.

Each designer is different - different skills, interests, working style. Findings from previous designers I looked at - design-then-make, design-through-make, make-as-design. How we design is personal - so it follows that we must find out how best to 'converse' with ourselves through the artefacts we create and work with.

Worthwhile trying different approaches, to see what's good for you - also good to have different techniques available, to unjam your brain!

Explain about consent form, and ask students to sign

Prompts:
- don't feel restricted to working as you normally would - break out and try new things
- you've looked at brainstorming with Jack - this workshop is also about helping ideas flow, by exploring different ways of working
- this workshop is about communicating with yourself to generate ideas, not producing things to present ideas to other people
- I can suggest some techniques, but try other things - see what works for you!

(90) Words

9:45 Introduction
- words are powerful, and can be seductive - they can be used to illuminate, or make things obscure - they can be practical, playful, spiritual, hurtful, harmful, healing... - you can conjure with them and play with them
- a picture may be worth a thousand words, but the reverse can be true, too - think of the experience of reading a book then seeing the film
- words can be symbols, signs - they can encapsulate a whole set of associations
- words are not only descriptive and evocative, but also have physical properties - sound, shape, rhythm - think of handwriting - very personal, and can indicate mood
- words are not just groups of letters - when we write we express things by emphasizing e.g. underlining - idea of using 'emoticons', e.g. smiley faces, in e-mails

Prompts:
- build up a sensory/emotional image of the thing, and how you feel about it
- explore not only the descriptive and evocative qualities of words, but also their physical qualities - shape, sound, rhythm
- try different pens, sizes, writing styles - play with the words, their place on the page, their grouping
- your original words may suggest other words - could build up a network of associations
- work quickly to capture first impressions

Please respond using words to:

9:50 - an object that interests you
10:05 - an experience - eating a cake/cakes or fruit
10:20 - a person or animal that is significant to you
10:35 - a piece of text from the sheets provided

10:50 Using only words, generate design ideas for an object to be worn to celebrate a special personality (i.e. human, animal), place or event in your life. (You can use words both to generate ideas, and to represent the actual piece)

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(90) Mark Making

11:30 Introduction

- I spent some time in EWT before moving to S&J - they have some different approaches to drawing, and that was where I learned about mark-making
- in S&J, the emphasis in drawing can be on line and form, so sometimes it's useful to try different techniques - mark making is often used to explore surface and texture, but not only useful for that
- it can be a very expressive, quick and responsive way of working
- can use it for representing objects, generating visual images, capturing feelings & impressions, looking at textures, etc.
- having less control, or a different level of control can free you up - it helps me when I get stuck sometimes. Also, marks can be interpreted in different ways, which is useful

Prompts

11:35 Explore a variety of techniques to make marks

Please respond using marks to:

11:55 - an object - suggest using a number of different techniques
12:10 - an object that you can touch / smell, but not see
12:25 - a piece of text / words from earlier workout

12:40 Using only marks, generate design ideas for an object to be worn [if you like, to celebrate a special personality (i.e. human, animal), place or event in your life]. (You can use marks both to generate ideas, and to represent the actual piece)

(90) Materials

2:00 Introduction

- designers use materials in a wide variety of ways: as 'content', to explore ideas, and as a medium
- benefits include: it's there in front of you to work with; it responds to what you do, not always in the way you expect; you can see the object in 3D in front of you; can use your hands and making skills to work with it...
- one designer's idea of a "living sketchbook"
- in my own experience, ideas often came to me when I was messing about with bits of stuff - especially useful if I wasn't having much joy with sketching, or couldn't get ideas out
- example of 'artefact' box: developed through a series of card 'sketches'; don't think I would have come up with that idea through drawing alone; but, is very dependent on the fact that I made it in card

Prompts

2:05 Exploring a variety of techniques and types of material, make some objects that appeal to you

Please respond using materials to:

2:25 - an object
2:40 - a piece of text / words from earlier workout
2:55 - one of your mark-making outcomes

3:10 Using only materials, generate design ideas for an object to be worn [if you like, to celebrate a special personality (i.e. human, animal), place or event in your life]. (You can use materials both to generate ideas, and to represent the actual piece)

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Appendix F: Artefact study - workshop exercises

This table lists the time allowed for each exercise in each of the four workshops (for workshops 2 to 4, specific times were allocated; these are indicated in column 2, with the actual times taken in each workshop in columns 3 to 5).

Artefact 'Mini-roundabout' – workshop outline	**W/s 1** (mins)	**w/s 2-4 times**	**W/s 2** (mins)	**W/s 3** (mins)	**W/s 4** (mins)
Words					
Please respond using words to:					
• an object that interests you	20	**15**	12	15	18
• an experience - eating a cake/cakes or fruit	15	**15**	11	15	15
• a person or animal that is significant to you	10	**15**	19	15	15
• a piece of text from the sheets provided	13	**15**	12	15	15
Using only words, generate design ideas for an object to be worn to celebrate a special personality (i.e. human, animal), place or event in your life. (You can use words both to generate ideas, and to represent the actual piece)	17	**25**	23	25	20
Mark Making					
Explore a variety of techniques to make marks	30	**20**	17	20	25
Please respond using marks to:					
• an object - suggest using a number of different techniques	20	**15**	15	15	15
• an object that you can touch, but not see	**n/a**	**15**	13	15	13
• a piece of text / words from earlier workout	12	**15**	15	14	12
Using only marks, generate design ideas for an object to be worn [if you like, to celebrate a special personality (i.e. human, animal), place or event in your life]. (You can use marks both to generate ideas, and to represent the actual piece)	23	**20**	20	16	20
Materials					
Exploring a variety of techniques and types of material, make some objects that appeal to you	30	**20**	22	23	20
Please respond using materials to:					
• an object	15	**15**	15	14	14
• a piece of text / words from earlier workout	10	**15**	14	14	11
• one of your mark-making outcomes	10	**15**	10	14	10
Using only materials, generate design ideas for an object to be worn [if you like, to celebrate a special personality (i.e. human, animal), place or event in your life]. (You can use materials both to generate ideas, and to represent the actual piece)	15	**20**	20	20	15

Appendix G: Artefact study - excerpts from texts

Willows whiten, aspens quiver,
Little breezes dusk and shiver
Through the wave that runs for ever
By the island in the river
    Flowing down to Camelot.
Four grey walls, and four grey towers,
Overlook a space of flowers,
And the silent isle imbowers
    The Lady of Shalott

From **The Lady of Shalott**, Tennyson

Our revels now are ended. These our actors,
As I foretold you, were all spirits and
Are melted into air, into thin air:
And, like the baseless fabric of this vision,
The cloud-capp'd towers, the gorgeous palaces,
The solemn temples, the great globe itself,
Yea, all of which it inherit, shall dissolve
And, like this insubstantial pageant faded,
Leave not a rack behind. We are such stuff
As dreams are made on, and our little life
Is rounded with a sleep.

From **The Tempest,** William Shakespeare

Had I the heavens' embroidered cloths,
Enwrought with golden and silver light,
The blue and the dim and the dark cloths
of night and light and the half light,
I would spread the cloths under your feet:
But I, being poor, have only my dreams;
I have spread my dreams under your feet;
Tread softly because you tread on my dreams.

He Wishes for the Cloths of Heaven, W.B. Yeats

I have a vision of the Songlines stretching across the continents and ages; that wherever men have trodden they have left a trail of song; and that these trails must reach back, in time and space, to an isolated pocket in the African savannah, were the First man shouted the opening stanza of the World Song, "I am!"

Bruce Chatwin, from **The Songlines**

Waterbarge

Your voice.
It makes a space I can step into
where there is room for me.
It is a journey which holds me,
like the arms of trees.
They bend, they shift slightly
with the weight, they rock
a little, to accommodate
the fingertips, pressing space
to mould the shapes of words.
When I heard your voice
I knew it was a boat
I could step into; there was
space for me to stretch
my limbs and words; not sink,
but float, on this slow
and gentle barge.

Morelle Smith

Lying on the Earth

The way the wind
fits the grass it blows across
my body
fits this earth. I lay my long
length down its slope. The grass
contains the sweetness
of the last rain, and below this
the odor of
humus - roots stems leaves blossoms
transforming themselves, going
all the way
down
to where the Cretaceous
keeps the imprint of the first
flowers. At my back
the stars,
my coordinates. I have found
my position, and tonight my hand
has the milky stench
of a cradle. I have
never been happier than I am
at this moment, held in this
lap, somewhere
between the first and final thought.

Marilyn Krysl

Winter Solstice

While others go gathering
Christmas trees
I bring dead-of-winter flowers
to a black vase
on this snow-white table.

They were golden rod
but the stalks are brown
and brittle, with paler sprays
of minute pompoms
furred for frosty nights

and tansy, with crisp curls
of charred leaves
and shelf-like seeds
packed on boot-button heads
matt and dark as ash buds.

The longest night descends
and winter-sized spiders
trickle from their flimsy canopy
like falling stars
but dark, on brightness

Valerie Thornton

1. **words**
Comments:
Please note that comments that are exercise- or section-specific will be found in the analysis tree in a 'Comments' space under the appropriate 'main' space
- 1.1 variations in response
Comments:
By this I mean variations between one student's responses to the different exercises, e.g. if there was a noticeable difference in the way they tackled a particular exercise, or if they found one exercise in the section particularly difficult.
  - 1.1.1 approach
variations in approach
  - 1.1.2 difficulty/ease
    - 1.1.2.1 difficulty/uncomfortable
changes in response due to difficulty or feeling uncomfortable
    - 1.1.2.2 ease/comfort
changes in response due to ease or feeling comfortable
- 1.2 'content' of words wrt source
  - 1.2.1 generative
  - 1.2.2 responsive
Comments:
For example, the person's emotional response to the source - things about them, rather than things about it. (Maybe not the best way of putting it! - but referring to internal things rather than external
  - 1.2.3 descriptive
    - 1.2.3.1 evocative
    - 1.2.3.2 functional
    - 1.2.3.3 associative
- 1.3 'concrete'
  - 1.3.1 sound/rhythm
  - 1.3.2 visual
  - 1.3.3 words as 'material'
- 1.4 placement of words
  - 1.4.1 organisational
  - 1.4.2 visual/pictorial
  - 1.4.3 'structural'
- 1.5 role of materials
Comments:
This category has to do with the extent to which the materials used are in the 'background' or the 'foreground' of the piece
  - 1.5.1 incidental
Comments:
In the sense that the materials do not play any particular role in the finished piece, other than as a 'background' for the words, in a sense.
  - 1.5.2 visual
  - 1.5.3 evocative?
Comments:
By this I mean like where one of the students had chosen the materials because they were like the source object, and said that in some ways her words were responding more to the materials than the object itself.
Would 'substitute' be a better way of putting it?
Am trying to distinguish between where people used the materials because it has attributes of the source object, and where it has other symbolism, e.g. using red paper for 'love', or blue material because blue has good associations
  - 1.5.4 emphasis
Comments:
Could be materials added, or modified e.g. where the paper has been torn, or otherwise 'worked on'
  - 1.5.5 symbolic
Comments:
For example, red material chosen for its associations with Valentines Day
  - 1.5.6 integral to piece
- 1.6 types of 'writing'
  - 1.6.1 single words
  - 1.6.2 short phrases
  - 1.6.3 narrative
Comments:
Might be 'finished' narrative, or like longer phrases, sort of 'stream of consciousness' thing
- 1.7 embellishment of words
  - 1.7.1 colour
    - 1.7.1.1 categorisation
Comments:
For example, where different colours are used to distinguish between different groups of words - could also be linked to association e.g. emotion, but in this case it is more to do with 'straight' use of colour
    - 1.7.1.2 association
Comments:
For example, the use of purple to suggest emotion
  - 1.7.2 emphasis
  - 1.7.3 visually expressive
  - 1.7.4 symbols
- 1.8 comments about using
  - 1.8.1 positive
Positive comments about using words...
  - 1.8.2 negative
Negative comments about using words...
  - 1.8.3 general
General comments about using words...
  - 1.8.4 familiarity
    - 1.8.4.1 familiar
Comments about familiarity with using words...
familiar techniques
    - 1.8.4.2 non-familiar
Comments about being unfamiliar with using words...
unfamiliarity

2. markmaking

- 2.1 variations in response
  - 2.1.1 approach
  - 2.1.2 difficulty/ease
    - 2.1.2.1 difficulty/uncomfortable
      changes in response due to difficulty or feeling uncomfortable
    - 2.1.2.2 ease/comfortable
      changes in response due to ease or feeling comfortable
- 2.2 'content' of marks
  Comments:
  To do with what people are responding to in the source material
  - 2.2.1 generative
  - 2.2.2 responsive
  - 2.2.3 descriptive
    - 2.2.3.1 visual
    - 2.2.3.2 evocative
    - 2.2.3.3 associative
- 2.3 (words category – 'concrete')
- 2.4 (words category – 'placement of words')
- 2.5 role of materials
  - 2.5.1 incidental
  - 2.5.2 visual
  - 2.5.3 evocative
    Comments:
    Am trying to distinguish between where people used the materials because it has attributes of the source object, and where it has other symbolism, e.g. using blue material because blue has good associations
  - 2.5.4 symbolic
  - 2.5.5 integral to piece
- 2.6 types of marks
  - 2.6.1 linear
  - 2.6.2 patterns
  - 2.6.3 textures
- 2.7 (words category – 'embellishment of words')
- 2.8 comments about using
  - 2.8.1 positive
    Positive comments about using markmaking...
  - 2.8.2 negative
    Negative comments about using markmaking...
  - 2.8.3 general
    General comments about using markmaking...
  - 2.8.4 familiarity
    - 2.8.4.1 familiar
    - 2.8.4.2 non-familiar
- 2.9 representational extent
  Comments:
  Whereas 'content of marks' takes to do with what people are responding to in the source, this is concerned with the extent to which the marks used are literal or abstract, illustrative or evocative.
  For example, in some student's exercises, the response is almost like traditional representational drawing, or design drawing
  - 2.9.1 illustrative (like drawing)
  - 2.9.2 convey/evoke
  - 2.9.3 associative
  - 2.9.4 symbolic
  - 2.9.5 marks
  - 2.9.6 abstract
  - 2.9.7 literal
- 2.10 adaptation of marks
  - 2.10.1 use as exist
  - 2.10.2 calligraphic
- 2.11 use of colour
  - 2.11.1 representational
  - 2.11.2 symbolic
  - 2.11.3 aesthetic
  - 2.11.4 other
- 2.12 techniques
  - 2.12.1 printing, dragging, rolling
  - 2.12.2 drawing/painting
  - 2.12.3 unusual use of 'traditional' tools
  - 2.12.4 unusual tools
  - 2.12.5 unusual methods
- 2.13 marks
  - 2.13.1 single
  - 2.13.2 combination
- 2.14 use of media
  - 2.14.1 'traditional'
  - 2.14.2 unusual
  - 2.14.3 visual
  - 2.14.4 material
    Comments:
    By this I mean that media were used e.g. for their 'shininess' in response to the shininess of the source object
- 2.15 control v. chance
- 2.16 'explorations'
  - 2.16.1 single
  - 2.16.2 multiple

3. materials

- 3.1 variations in response
  - 3.1.1 approach
  - 3.1.2 difficulty/ease
    - 3.1.2.1 difficulty/uncomfortable
    - 3.1.2.2 ease/comfortable
- 3.2 characteristics responded to
  Comments:
  The characteristics in the source object that are being responded to.
  But remember that source objects can be text, objects, markmaking...
  - 3.2.1 shape
  - 3.2.2 form
  - 3.2.3 structure
  - 3.2.4 texture/tactile
  - 3.2.5 function
  - 3.2.6 colour
  - 3.2.7 literal
  - 3.2.8 abstract
  - 3.2.9 associative
  - 3.2.10 responsive
  - 3.2.11 evocative
  - 3.2.12 visual
  - 3.2.13 material
  - 3.2.14 physical
- 3.3 (words category – 'concrete')
- 3.4 (words category – 'placement of words')
- 3.5 (words and markmaking categories – 'role of materials')
- 3.6 (words and markmaking categories – 'types of ...')
- 3.7 (words category – 'embellishment of words')
- 3.8 comments about using
  - 3.8.1 positive
    Positive comments about using materials...
  - 3.8.2 negative
    Negative comments about using materials...
  - 3.8.3 general
    General comments about using materials...
  - 3.8.4 familiarity
    - 3.8.4.1 familiar
      Comments about familiarity with using materials...
      familiar techniques
    - 3.8.4.2 non-familiar
      Comments about being unfamiliar with using materials...
- 3.9 representational extent
  - 3.9.1 illustrative (like a model)
  - 3.9.2 associative
  - 3.9.3 convey/evoke
  - 3.9.4 symbolic
  - 3.9.5 metaphorical
  - 3.9.6 abstract
  - 3.9.7 literal
  - 3.9.8 3D interpretation
- 3.10 adaptation of materials
  - 3.10.1 used 'as is'
  - 3.10.2 tailored to suit
- 3.11 techniques
  - 3.11.1 penetration
  - 3.11.2 joining
  - 3.11.3 threading
  - 3.11.4 colouring
  - 3.11.5 applying
  - 3.11.6 carving/breaking
  - 3.11.7 scoring/cutting
  - 3.11.8 burning
  - 3.11.9 wrapping
  - 3.11.10 knotting
  - 3.11.11 tying
  - 3.11.12 enclosing
  - 3.11.13 stuffing/padding
  - 3.11.14 binding/sewing
  - 3.11.15 gluing
- 3.12 control/opportunism
- 3.13 use of colour
  - 3.13.1 inherent in material
  - 3.13.2 applied
  - 3.13.3 representational
  - 3.13.4 symbolic
  - 3.13.5 aesthetic
- 3.14 creation of object
  - 3.14.1 assembly
  - 3.14.2 construction
  - 3.14.3 modelling/addition
  - 3.14.4 'taking away'
- 3.15 use of text or symbols
- 3.16 extent response due to materials
  Comments:
  By this I mean the extent to which the artefact created responds to the source object in question, and how much is due to the creative 'content' of the materials themselves.
- 3.17 main feature of artefact
  - 3.17.1 functional
  - 3.17.2 recognisable thing
    Comments:
    e.g. 'sock puppet' or 'doll'
  - 3.17.3 symbolic
  - 3.17.4 aesthetic
  - 3.17.5 visual
  - 3.17.6 structural
  - 3.17.7 form
  - 3.17.8 evocative
  - 3.17.9 technique
  - 3.17.10 material
- 3.18 driver
  - 3.18.1 idea
  - 3.18.2 material
    - 3.18.2.1 associative
      Comments:
      Thinking about materials making student think of Independence Day spaceship, and so building idea around that.
- 3.19 design objects
  - 3.19.1 object as 'design'
  - 3.19.2 object as 'finished piece
- 3.20 choice of material
  - 3.20.1 associative
  - 3.20.2 preference
    Comments:
    Where someone says they chose a material because they like circles, or liked the paper
  - 3.20.3 material/functional
  - 3.20.4 visual/aesthetic
  - 3.20.5 evocative
  - 3.20.6 symbolic
- 3.21 links to previous artefacts
  Comment:
  Perhaps this should go into the actual exercise sections...
  - 3.21.1 techniques
  - 3.21.2 materials
  - 3.21.3 artefacts
  - 3.21.4 visual
  - 3.21.5 ideas
  - 3.21.6 consistency throughout
    Comments:
    ...of technique, style, materials
- 3.22 aspects of materials used
  Comments:
  What aspects of the materials are being used in the creation of the artefact (linked to 'characteristics responded to', 'extent response due to materials', 'main feature of artefact created' and 'response')
  - 3.22.1 colour
  - 3.22.2 texture
  - 3.22.3 physical
  - 3.22.4 unconventional
    Comments:
    e.g. the use of glue to create texture
  - 3.22.5 form
  - 3.22.6 structure
  - 3.22.7 visual
  - 3.22.8 material
  - 3.22.9 symbolic
  - 3.22.10 associative
  - 3.22.11 evocative

4. approach to source
   Comments:
   This section is to do with how the person responded to the source.
   For example, in the 'text' exercise in the worlds section, some people 'dissected' the poems in a sense, going through them line by line, and seeing what their associations were. Other people dealt much more with how it made them feel, and that was the emphasis of their response.
   This is probably linked to the section dealing with the 'content' of the words, for example
   - 4.1 subjective
     Comments:
     By this I mean that the person's response concerned their feelings about the poem, rather than necessarily the 'surface' content of the poem itself.
     Similar in the markmaking, where the response was to qualities other than the visual or tactile?
   - 4.2 objective
     Comments:
     By this I mean that the person's response concerned the 'subject matter' of the poem itself
5. preferences
   - 5.1 words
   - 5.2 markmaking
   - 5.3 materials
   - 5.4 none
6. visualisation
   - 6.1 'internal'
   - 6.2 'external'
7. links to design
   Comments:
   By this I mean things that people said about their normal design processes, also how their approach to the exercises in this workshop related or didn't relate to their normal design processes.
   - 7.1 general comments
   - 7.2 similar
   - 7.3 different
8. differences in 'media'
   Comments:
   By this I mean the type of comments like using words is much more explicit that drawing, type thing

Interview Questions – Set 1

Practice (about the interviewee, the work itself, and the area it's in – not necessarily specific to this body of work)

- broadly, what is the nature of your work?
  - *what type of work are you producing?*
  - *how would you describe your practice, and yourself as a practitioner?*
- please could you tell me why you have chosen to work in this area/field?
  - *what attracted you to it*
  - *what do you like about this particular area/field?*
  - *related to interviewee's background? – esp. if working in digital and have a background in material practice*
  - *do you hope to achieve something particular by working in this area?*
- what is the broad focus/content of your work? (narrative, aesthetic, ...)
- in what ways do you think your work differs from others' in this group (or elsewhere)?
  - how would you characterise your work?

Approach (general, not specific to this body of work)

- how would you describe your approach to your work?
  - *particular features of way of working*
  - *(if background different, do you work differently in this environment?)*
- what are the most important characteristics/elements of this approach?
- in what ways do you think your approach differs from others' in this group (or elsewhere)?

Process (specific to this body of work)

- what are your aims this year?
  - *what do you hope to achieve this year?*
- how are you choosing to pursue these aims?
- what is it most important to you to achieve this year?

Outcome (creating this particular body of work)

- what drives your work? (e.g. goal, tacit aim?)
  - *how will you know when you've got where you want to be?*
- please could you describe/show me how you are developing/expect to develop your work/ideas?
  - *what media/techniques are you using/will you use?*
  - *how do/will each of these contribute to the process? where do your ideas come from?*
  - *what are you working on at the moment?*
- which features of your work are most important to you?
- what do you think will have the strongest influence on the direction of your work? (e.g. ideas, materials?)

Media

- what media do you/will you use in your work? (e.g. materials, elements of the software)
  - (also, processes and techniques)
  - *why have you chosen these?*
  - *what attracts you about them?*
  - *in what ways do you/will you use them?*
- what roles do/will these media (processes, techniques) play in your working process?
  - *(esp. if digital media – can be many different things)*
  - *what do/will they each contribute to your process?*
  - *e.g. used to communicate ideas, or dialogue with to develop ideas ?*

- what kind of relationship would you say you have with the media/material that you use?
  - *e.g. acting upon it, engaging with it?*
  - *what is the nature of your relationship with it?*
  - *what is the extent of your engagement with it?*
- do you experience any sense of 'dialogue' with your materials?

Anomalies

- do you anticipate/are you experiencing any difficulties or problems in your work, e.g. technical limitations, constraints?
  - *how do/will these affect/influence your work or your processes?*
- what do you think will be the major challenge for you in your work?

Other

- what are you looking forward to most about your work this year?
- is there anything you are concerned about your work this year?
- is there anything we haven't covered that you feel is important to your work?

Interview Questions – Set 2

Orientation (specific to this body of work)

- what are your aims this year? *what do you hope to achieve this year?*
- how are you pursuing these aims?
- what is it most important to you to achieve this year?

Work (creating this particular body of work)

- what is the broad focus/content of your work? (narrative, aesthetic, ...)
  - *how would you characterise your work?*
- in what ways do you think your work differs from others' in the group?
- what is driving the direction/development of your work? (e.g. goal, tacit aim?)
- what media/processes/techniques are you using to produce your work?
  - *why have you chosen these?*
  - *what attracts you about them?*
- what has had the strongest influence on the direction of your work so far?
  - *what has caused you most problems*
  - *what has caused you least problems*
- what has surprised you most about your work so far?

Approach (specific to this body of work)

- how would you describe your approach to your work?
  - *what are the most important characteristics/elements of this approach?*
- in what ways do you think your approach differs from others' in the group?
- is there anything that has surprised you about your approach/process this year?
- what has had the strongest influence on your approach/process this year
  - *internal/external*

Process

- what are the major elements of your working process in developing your ideas/work? (e.g. research, script, storyboard etc.)
  - *which are you most comfortable with*
  - *which are you least comfortable with*
- what is the relationship between these different elements?
  - *has this relationship changed over the year?*
- which has the strongest influence on the direction of your work?
- what media/processes/techniques are you using for each of these elements, and why?
- please could you describe/show me how you have been developing your work/ideas?
  - *what media/techniques are you using/will you use?*
  - *how do/will each of these contribute to the process? where do your ideas come from?*
  - *what are you working on at the moment?*

Media

- what roles do the media/processes/techniques play in your working processes?
- how would you compare your relationship with each of the media that you use?
  - *e.g. acting upon it, engaging with it?*
  - *what is the nature of your relationship with it?*
  - *what is the extent of your engagement with it?*
- do you experience any sense of 'dialogue' with your materials?

Anomalies

- are you experiencing/do you anticipate any difficulties or problems in your work?
  - *how have/will these affect/influence your work or your processes?*
- what is the major challenge for you in your work?

Other

- what have you found most satisfying so far this year?
- what have you found most frustrating so far this year?
- is there anything we haven't covered that you feel is important to your work?

Interview Questions – Set 3

Orientation (specific to this body of work)

- what were your aims this year? *what did you hope to achieve this year?*
  - *did these change? if so, why?*
- how have you pursued these aims?
  - *did this change? if so, why?*
- what has been most important to you to achieve this year?
  - *anything you haven't achieved that you'd wanted to/achieved that you didn't expect to?*

Work (creating this particular body of work)

- what is the broad focus/content of your work?
  - *has this changed? if so, why?*
- in what ways do you think your work differs from others' in the group?
- what has been the main driver in the development of your work? | what 'defines' the body of work?
- development of 'body' of work
  - *(clear idea/emerge)*
- relationship between pieces
  - *when (serial/overlap)*
  - *how they relate*
- what has had the strongest influence on the direction of your work?
- were there events or decisions you had to make that were particularly significant to the way your work developed?
  - *when did these occur?*
- what has surprised you most about your work?

Approach

- how would you describe your approach to your work?
  - *what you plan, what you let emerge*
  - *what you control, what you're willing to 'let happen'*
- in what ways do you think your approach differs from others' in the group?
- has your approach changed over the year?
  - *if so, why?*
- has your approach differed from previous years?
  - *if so, how?*
- has your perception of the way you work changed over the year?
  - *is there anything that has surprised you about your approach/process this year?*

Process

- what are the major elements of your working process?
- how do these elements work together in developing your work?
  - *has this relationship been different from what you expected?*
- what is the role of source in your process?
- where did the original idea come from?
- relationship between studio work and workbench
  - *has this changed over the year?*
- where does the main decision about what work will be take place (drawing <> workbench, storyboard <>?)
  - *has this changed over the year?*

Media

- what media/processes/techniques have you used in the development and production of your work?
  - *what are they each used for?*
- has your relationship with these media changed over the year?
  - *ways of learning about it?*
- how do you view the digital as a 'medium'?
- what role does the material/digital as a medium play in your working processes? (act upon <> engage)
  - *has this changed over the year?*
  - *internal/external – visual/ideas*
- what is the extent of your dialogue with the medium?
  - *has this changed over the year?*

Anomalies

- did you experience any difficulties or problems in your work?
  - *how did these affect/influence your work or your processes?*
- did anything unexpected occur in your work?
  - *how did these affect/influence your work or your processes?*
- what has been the major challenge for you in your work this year?
  - *what impact has this had on your work or your processes?*

Other

- what have you found most frustrating/disappointing this year?
- what have you found most satisfying/rewarding this year?
- what is the most important thing you've learned about yourself/your practice this year? (*that you are able to tell me!*)
- is there anything we haven't covered that you feel is important to your work?

Appendix J: Comparative study - example of completed analysis sheet

Interview no. 8 **Group:** M.Phil. / ~~Std~~ **Date:** 31 October 2002

Tapes used: (ser 4) 2+3
Questions: (start) 2.2 - 0.1 (end) 3.2 - 4.9

Indicators	'hard', distanced	strong		neutral		strong	'soft', situated	tape ref	quote
Orientation									
1. goals (how do you know when you've got what you want)	explicit goal	✓					tacit aim		
2. direction in work	conscious purpose	✓					open to experience		
3. process and product	emphasis on product	✓					equal or greater emphasis on process		
4. form and content	separate	✓					developed together		
5. constraints, limitations	working to go beyond constraints, freedom of choice		✓				working within constraints, choosing to work within constraints		
6. understanding, mastery through...	analysis & abstraction		✓				mastery of detail		
7. by...	break down, decompose, analyse	✓					reorganise, rearrange		
8. relationship to context	abstract, formal, remote	✓					situated, contextual		
Medium									
9. ends and means, 'medium and message'	medium is means to an end, means separate from end	✓					ends become means and vice versa, means becoming end, ends developed through means		
10. what is the role of the medium - tool or medium?	expressing, communicating ideas using medium, monologue	✓					developing ideas through dialogue with medium, medium as interlocutor		
11. how do you relate to the medium?	acting upon the medium	✓					engaging with the medium, being acted upon		
Process	control / distanced						negotiation / situated		
12. outcome - when you decide this	pre-planned, predetermined goals	✓					unforeseen consequences, discovery, goals emerge through work		
13. how is this accomplished, how does this exhibit (process)	planned in advance, premeditated?	✓					collaborative venture with medium, through dialogue with the materials and means of execution, repertoire		
14. decisions	pre-planned e.g. through abstractions	✓					keeping options open		
Work organisation									
15. organisation, form, structure	imposed, predefined, (premeditated, as in thought about before?)	✓					emergent, arranging, rearranging, playing with ideas, sculpting		
16. achieved by	e.g. hierarchy, abstraction	✓					finding "pattern", "rhythm", "form"		
17. level of engagement	abstract, with representations, models, metaphorical	✓					working with the medium, literal		
18. relationship to details, material	opacity, distancing from details	✓					transparency, keeping in touch with the details		
19. dealing with complexity	abstraction e.g. decomposition, design-by-drawing	✓					growing incrementally		
20. choice of materials	brought in as required by 'project'		✓				working with what's there, well-known materials, chosen previously, heterogeneous repertoire - not specific to project, brought in as need arises		
21. implications of this...		✓					speak through the medium of things		
22. use of materials	used for predetermined purpose	✓					used in "devious" ways, "truth to materials"		
Attitude to Events									
23. attitude to unexpected effects, surprise, risk	control	✓					"springboards for how to proceed"		
24. attitude to mistakes, problems	misstep, to be corrected		✓				essential part of process of negotiation		
Ways of relating to materials, objects	distal (distanced)						proximal (close)		
25. type of relationship	distant, objective		✓				intimate, 'connecting' with them, subjective		
26. boundaries	distancing yourself		✓				immersing yourself, placing yourself psychologically in their 'space' "down in there"		
27. awareness	selfconscious, conscious purpose		✓				unselfconscious, forgetting yourself, 'hear what the material has to say'		
28. experience, bodily participation	objects as formal, abstract?						experiencing objects as tangible, sensual and concrete		
Ways of seeing objects	formal						concrete		
29. attributes	formal properties ("what they are for")						concrete or tangible properties ("what they can do")		
30. physicality	as embodying abstract concepts (e.g. sprite – computational object with variables)						as material objects, esp. non-material objects (e.g. sprite – object attributed 'physical' properties – can cover one with another)		
31. relationship to context	abstract, in terms of properties, rules						situated, in terms of relationships, with each other		
32. transparency	working with concepts, abstract properties, transparent e.g. words being used to express an idea						working with signs, resonances, material e.g. words as textual objects		
Ways of thinking									
33. ways of explaining things, tackling problems	in terms of rules		✓				'reasoning from within', bodily thinking, putting yourself in the situation		
34. learning about things, understanding things	analytic, dissection, wanting to know how it's supposed to work, learning before interacting with it		✓				through its behaviour, learning through interacting with it		
35. what think with	thinking with rules of logic (abstract)		✓				thinking with objects (concrete)		
36. ways of understanding	formal, abstract		✓				sensible intuition, perception		
37. internal/external	mental		✓				bodily thinking e.g. writing as a way of thinking		
	mental revision						*physical revision*		
	composition takes place 'internally' then expressed						*writing to think, ideas come through the act of writing*		
	internalisation						*externalisation & spatialisation*		
Other Emerging Themes									
38. finding a 'voice'									

Interview Analysis (tweaked) MMcL October 2002

Appendix K: Comparative study - definitions of uses of materials

Technical sampling, technical samples

These terms refer to the process of producing (often small) samples to test materials, explore their capabilities, or refine techniques for working with the materials, such as ways of achieving different textures, finishes etc. I have distinguished it from the terms '3D sketch' and '3D drawing' as its main purpose is to test processes and techniques, rather than to generate or visualise 'designs' or the form of the work. Depending on the processes and techniques involved, this activity may be done using the 'final' materials themselves, but often substitute materials are used that have similar properties but are less 'precious', e.g. copper instead of silver to test etching techniques. (It is not necessarily monetary value that makes a piece precious in the context of this study – for example, having a very limited supply of found objects such as entire leaf skeletons can make them very valuable!)

3D sketching

While technical sampling is primarily concerned with exploring processes or techniques, students also worked directly with physical materials to generate and explore design ideas. I have termed this process '3D sketching': the idea generation is being done directly in 3D/physical materials (I have included making 3D visualisations from 2D sketches and drawings under the term '3D drawing', below). Again, this may be done with less 'precious' materials than would be used for the final piece.

3D drawing

Whereas 3D sketching is about generating ideas using physical materials, the term '3D drawing' describes the process of 'realising' or visualising an existing design idea in 3D physical materials. The purpose of 3D drawing is to see how the design idea actually looks in physical three dimensions. This idea may have been partially developed through 2D sketching or drawing, or through a more internal process:

> *"I can sit there and quite happily go through the motions of a page in a sketchbook in my head, drawing it down, I can sit and I can rotate things in my brain and I can see things from every different angle. And actually when I draw it down, it loses something that was up here, and actually I think I'm now better making it three-dimensionally, and then recording that on paper, and recording the bits that haven't gone wrong. Because if I draw things down, now, or if I go through pages in my*

sketchbook, I get lost half way, and it's that thing where you're reading a page in a book and you're at the bottom of the page and you realise you haven't actually read it. That's what I found I was doing. I rely far more on actually sitting down and making, and just letting things kind of inform me from that, and sketching while I'm doing that..."[81]

Physical model/mockup

I have used the term 'physical model' or 'mockup' to describe the process of modelling aspects of a piece to see practically how it will work, e.g. how a piece might be detached for cleaning, or how segments of a piece might join together. Whereas technical sampling is concerned with testing and refining techniques and processes for working with materials, or exploring the properties of materials, making a physical model or mockup is focused around testing aspects of function or design. This may be carried out in the actual materials, or again, substitute materials such as card or cheaper metal, depending on the purpose of the model:

"...another thing I've been doing recently is working in paper. Because with these ones, I need to work out where my rivets are going to go, so instead of going through a ton of copper just working out that I need holes here to go, for the rivets to go right through"[82]

Physical element

This term is used to describe a physical element which is, or is used to represent, part of an actual piece. The key feature of such elements is that they are 'predefined', like components: they will often have been made by the student, or be objects such as semi-precious stones, beads, pearls, and found objects such as shells.

Prototype

This term denotes a physical working replica of a final piece, often used to test its function, or how it will be made. Unlike a physical model or 3D drawing, which may not be to scale, or only focus on one part of a design or piece, a prototype is concerned with validating all aspects of the design and construction before making the final piece. In some cases if the student has used the 'final' materials, and the process is successful, then it will become a final piece. Alternatively, if a final piece does not work out for some reason, it may effectively become a prototype for a further piece.

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[81] Material student 5, interview 3

[82] Material student 6, interview 1

Practitioner Interview Schedule

[prompts in *italics*, background information in script]

Interview Details

Date:

Time:

Tapes:

Actions:

Preliminaries

- ☐ check consent letter signed and confirm permission to tape interview

- ☐ any questions on any of the arrangements before we begin?

Introduction – myself and my research

- ☐ My background is originally in computer science, and more recently in design/applied art (silversmithing and jewellery). My Ph.D. research is broadly concerned with designers' use of artefacts (sketches, models etc.) within their design processes and the implications for future digital environments for 3D design and modelling. A previous study I made of a number of designer-makers suggested that individual practitioners experience different relationships with the artefacts they create and work with in their processes. I believe that elements of these differences can be attributed to the nature and extent of a dialogue between designer and media, and this is the focus of my current research.

- ☐ I have chosen to examine this 'dialogue' by comparing design and making practices in the material environment with those in the virtual environment, as the similarities and differences between the two environments foreground those aspects of the relationship that I'm focusing on. As part of this study, I'm speaking to 3D practitioners who have worked in both material and virtual media – I'm interested in how their experience, perceptions, skills and working processes have transferred to the virtual environment, particularly in terms of their engagement with the medium.

- ☐ In this interview, I'd like to explore some of these aspects of your practice.

- ☐ *In the context of my Ph.D. research, the reason for examining these differences more closely is to assist, in a sense, in dissociating some of the ways in which different designer-makers/3D practitioners work from the physical artefacts that they use, and to gain insight into ways of working and knowing that are not embodied in the material context of the real world, and that could be usefully explored in the development of new ways of working in the virtual world of the digital design environment.*

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Practice

- ☐ how would you describe your practice, and yourself as a practitioner?
  - *material*
  - *digital*

- ☐ please could you tell me about your background, leading up to your current practice?

- ☐ how would you characterise your approach to practice?

- ☐ what are the key elements of this approach?

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Focus of work

- what types of work do you produce?
  - work itself
  - to commission, for exhibition, etc?

- what is the focus/content/aim/aesthetic of your work?
  - *material*

  - *digital*

- what characterises your work?

Digital practice [emphasis on 'medium', 'environment']

- what intrigues you about/attracted you to this area of work?

- what digital technologies/media do you use in your practice?
  - *how did you arrive at these ones?*
  - *what is the impact of these technologies on your practice/work? (relationship between 'vision' and 'crafting')*

- the nature of the 'digital' allows it to be viewed as many different things. What is its role in your practice?
  - *e.g. tool, medium, environment*
  - *'cyberspace'/digital medium or digital technologies as medium?*
  - *virtual/digital*
  - *functional use v creative engagement*
  - *origination/replication/simulation/realisation*
  - *what is the 'digital medium'?*

how do you engage with it? (if as medium, environment? what if tool?)

- *could be described as entirely passive, almost a 'non-medium', or a 'non-environment'*
- *can be anything you make it*
- *on the other hand, it currently requires very explicit, precise ways of working*
- *what is the impact of working in this context?*
- *role of surprise/opportunism*
- *what are the main challenges*
- *what have you found most exciting/unexpected?*

Relationship between digital and material practice [approach, work, etc.]

- ☐ how does your digital practice relate to your material practice? (in terms of work, aesthetic, approach, knowledge, skills, working practices, role of other media, etc.)
  - *how does your work/practice in the two environments compare?*
  - *focus, aesthetic*

  - *how does your material practice contribute to your digital practice?*
  - *direct? inform? have little to do with?*
  - *skills/knowledge (approach following…)*

  - *how does your working approach manifest itself in the digital environment?*
  - *similar? different? why?*
  - *working practices, experience*
  - *what distinguishes it from other approaches?*

  - *are you conscious of anything in particular that has appeared, disappeared, been retained, changed, developed in moving to your digital practice?*

- how does your relationship with the medium compare, and its role in your practice?
  - *what was the role of the materials in your material practice?*
  - *what was the role of other media?*

- what insights into your practice have you obtained from working in what are two very different media?
  - *has anything from your material practice been of special significance/especially valuable in your digital practice?*
  - *is there anything that your digital practice has made you conscious of that you weren't before?*
  - *has it thrown anything into relief?*
  - *does anything in particular surprise you?*
  - *anything you expected/didn't expect?*
  - *what is missing from the digital 'medium' that has or would have the most impact on your work?*

Digital practice in context

- in what ways do you feel your practice contributes to a 'digital aesthetic'?
  - *is there such a thing as a 'digital aesthetic'? if so, what?*
  - *impact of your work on the digital 'world'*

- what do you feel is the role of <description> in the digital arena generally?
  - *impact*
  - contribution

- what is the impact of your digital practice on <discipline>?

- in what ways would you distinguish your approach from other practitioners working in this area?

Emerging themes

- ☐ is there anything that you feel is important to your practice that we haven't covered?

- ☐ (arising from the interview)

Writing quotes

"In contrast to Planners, Discoverers regard instrumental definitions as reductionist, thinking of language as far *more than* a tool, and perhaps as inextricable from their sense of self. Language is here more like a *way of knowing*." (Chandler)

"For May Swenson, a poet: 'Language is *not only a tool* in poetry, it is its very being. In a poem, subject is not presented by means of language but language is the thing presented with the aid of subject'." (Chandler)

"Individuals differ strikingly in their responses to the notion of media transformation. They range from those who insist that they are in total control of the media which they 'use' to those who experience a profound sense of being shaped by the media which 'use' them." (Chandler)

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