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## **Crafting innovation: The intersection of craft and technology in the production of contemporary textiles**

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### **Abstract**

This article has grown from a programme of practice-led research entitled 'Structural Textiles: Adaptable Form and Surface in Three-Dimensions'. In this research traditional textile craft practices centred on hand making have provided an essential foundation from which to develop deployable textile structures that have customizable behavioural properties. The article investigates the importance of touch in acquiring understanding of textile artefacts and the significance of this tactile acquisition of knowledge in the process of textile production. In such practice, innovation is generated through the maker's creative responses to unforeseen behaviours of both process and material. However, the research also has also drawn on CAD/CAM technologies that enable the creation of designs and products with increased accuracy and complexity but reduce or remove instances of handcrafting in the making process. The article considers how sensory information gained through touch and the embodied knowledge that this generates can be preserved as part of contemporary textile practice whilst exploiting the potential of CAD/CAM and other automated processes to create complex and innovative outcomes.

### **Keywords**

practice-led research, textiles, hand making, embodied knowledge, CAD/CAM, innovation

### **Introduction**

This article has grown from a programme of practice-led research entitled 'Structural Textiles: Adaptable Form and Surface in Three-Dimensions' that has focused on the physical and conceptual processes of folding as well as the generation of folded textile outcomes. I found that the project, although essentially design research, operated at the interstices between many areas. In this research traditional textile craft practices centred on hand making have provided an essential foundation from which to develop my work. However, the research also draws on CAD/CAM technologies to evolve novel, hybrid production processes to create deployable textile structures with customizable behavioural properties (Figures 1 and 2). This article specifically investigates how these disembodied, digital technologies can be used as tools that compliment and further advance the embodied insights achieved through the process of hand making.

The meaning of the word 'craft' embodies a distinct set of ideas and approaches to the production of artefacts. Glen Adamson describes it as 'an amalgamation of core principles, which are put into relation with one another through the overarching idea of "craft"' (2007: 4). This article focuses on craft's emphasis of material experience and the skilled manipulation of materials, touching briefly on its predisposition to local variation but does not discuss its implicit associations with collective, cultural experience.

Traditional craft, particularly when discussed in comparison to the fine arts, sometimes seems to be seen as 'a ghetto of technique' (Adamson 2007: 71), divorced from innovative practice and the generation of ideas but I think that such attitudes ignore the cognitive and conceptual development that takes place as an intrinsic part of the process of physical manipulation of materials. The skill developed through hand making in craft practice gives the maker 'control within the productive operation... [and is a] purposefully constrained physical action' (Adamson 2007: 73). This bodily action is constrained by more than just the pragmatic technical knowledge of the 'right' way to carry out a task. Informed decisions are also exercised that enable the craft practitioner to attain the desired effect, a subjective position that foregrounds the personal style and taste of the maker as well as their implicit understanding of the materials of their craft. In this article particular consideration is given to the significance of touch in the discipline of textiles and its importance in the acquisition and transmission of knowledge in the making process.



Left: Figure 1: Rachel Philpott (2007). Deployable textile structure, silk-screen printed and hand-folded woven polyester. Photograph: Rachel Philpott. © Rachel Philpott.

Right: Figure 2: Rachel Philpott (2008). Deployable textile structure with shape-memory, composite material formed using laser cutting and hand making techniques. Photograph: Rachel Philpott. © Rachel Philpott.

Traditional handcrafting methods require great manual dexterity and are often labour intensive but they allow the practitioner to develop embodied knowledge that informs the creation of artefacts. In such practice innovation is generated through the maker's creative responses to unforeseen behaviours of both process and material. The introduction of automated machine production and CAD/CAM technology alters the relationship between maker and material, reducing or removing the direct physical link between the practitioner and the processes and materials of their practice. However, these technologies offer many benefits, including the ability to create work of increased accuracy and complexity. This article considers how these distinct approaches can be intertwined to best exploit the opportunities presented by both methods for the production of new work.

Material innovations, married with advances in mechanical and CAD/CAM technologies have enabled the development of processes for the production of pleated and folded textiles that either replace or reduce instances of handcrafting in the making process. Two different industrial approaches are outlined: one, a small-scale pleating workshop in the United Kingdom, the other a large-scale industrial plant in Japan. These are discussed in relation to traditional hand making processes to demonstrate ways in which practitioners, through the informed selection of specific processes, might make use of the advantages offered by semi and fully automated technologies whilst still retaining opportunities for innovation by employing the 'workmanship of risk' (Pye 1968: 4).

### **Tactility and the intelligent hand**

People have been folding and pleating textiles for millennia, using laborious hand manipulation techniques on natural fabrics. Examples of pleated Egyptian clothing found in tombs and depicted in statuary date as far back as 2000 bc (Richards 2000: 30). Fabric patterning and shaping using manipulation methods including stitching, binding, tying and clamping can be seen to the present day in countries including Japan, Malaysia, Indonesia, Thailand, India, China, Norway and England. Common to these textile-folding techniques is the close physical proximity of the craft practitioner to the stuff of their craft, a tactile interaction between the body, particularly the hand, and the textile.

The sensorial aspect of materiality is prominent in the discipline of textiles. Textiles enfold us throughout our lives, embedded in our daily experience through their intimate, whole-body contact with our skin, to the point where 'Textiles are a second skin, which prodigiously enhances our pleasure in the first' (Graves 2003: 49).

Our understanding of textiles is mediated by touch in an interaction not limited to the hand. Touch makes us aware of our physical body and its interaction with others and the environment, a somatic intelligence that engenders a fusion of our surroundings and ourselves. There is no distance or separation between the touching and the touched. Through touch, one is 'amidst rather than standing before the world' (Connor 2004: 322).

The folds of draped and pleated textiles and our manipulation of cloth plays an important role in our acquisition of knowledge regarding environments external to ourselves. Creased cloth constantly leaves imprints on our skin, embossing its history on our impressionable boundary with the external world. This liminal folding plays a significant part in our development of embodied knowledge. Serres notes,

'Consciousness resides in this contact... It is often hidden in a fold of tissue, lip against lip... a hand clenched into a fist, fingers pressed against each other, the back of one thigh crossed over the front of the other, or one foot resting on the other. I wager that the small, monstrous homunculus, each part of which is proportional to the magnitude of the sensation it feels, increases in size and swells at these automorphic points, when the skin tissue folds in on itself. Skin on skin becomes conscious... Without this folding, without the contact of the self on itself, there would truly be no internal sense, no body properly speaking, *cœnaesthesia* even less so, no real image of the body; we would live without consciousness; slippery smooth and on the point of fading away.' (2008: 20)

Our proprioceptive and kinaesthetic senses play a part in tactility as touch encompasses an element of motion, stroking and rubbing the skin against surfaces to stimulate our senses, but touch working in isolation is an inaccurate sense.

It should be noted that although haptic experience is grounded in the physical sensation of touch, like abstract and symbolic verbal language, it is ambiguous, subjective and open to differing interpretation. It is duplicitous; an identical touch can appear safe or aggressive, attractive or repulsive, intimate or alienating, nurturing or destroying to different individuals. Kozel notes, 'When interaction is dependent upon one sense, it becomes inherently fragile' (2005: 444). Touch is evocative but not discerning, working more efficiently in combination with other senses.

'In the academic world touch has often passed under the radar. Like the air that we breathe, it has been taken for granted as a fundamental fact of life, a medium for the production of meaningful acts, rather than meaningful in itself.' (Classen 2005b: 2)

Historically, western culture has denigrated touch and other bodily knowledge, regarding it as a primitive lower form of knowing. 'Aristotle... considered sight as the most noble of the senses "because it approximates the intellect most closely by virtue of the relative immateriality of its knowing"' (Pallasmaa 2007: 15). The senses and sensuality are often conflated with pre-verbal stages of development, femininity and sexuality and as a result considered unsophisticated, irrational, emotionally driven and an embarrassing, slightly shameful aspect of our beings to be repressed (Howes 2004: 6).

The denial of bodily knowledge as a valid and valuable way of knowing has led to a detrimental separation of hand and head where 'both understanding and expression are impaired' (Sennett 2009: 20). It is necessary to exist in and to interact with our environment on many non-visual levels before we can truly be said to understand its nature. As Benjamin points out,

'... the tasks which face the human apparatus at the turning points of history cannot be solved by optical means, that is, by contemplation, alone. They are mastered gradually by habit, under the guidance of tactile appropriation.' ([1936] 1999: 233)

Whilst vision gives a detailed description of the surface features of our environment, a superficial mapping of the landscape, touch provides insight as to how these elements are interrelated. 'Whereas topography is visual, "topology is tactile"' (Connor 2004: 323).

The effect of synaesthesia and other less extreme overlaps between the senses encourages a whole body knowing of the material. This crossover of the senses allows one to feel an object without touching it. Textiles imply bodily contact even if none occurs. We each build a personal 'vocabulary' of touch over our lifetime, developed alongside our acquisition of verbal language and influenced by our cultural background (Classen 2005a). Memory aroused by visual stimulus awakens this haptic consciousness, as Pallasmaa says 'Vision reveals what touch already knows' (2007: 42). Our senses cooperate to construct a complete physical and emotional conception of an object from the feelings that are generated in the body. Dorinne Kondo talking of the Japanese tea ceremony states: 'The interaction of various sensory media creates a multiple layering of meanings that "all add up to one message"' (Leach 1976: 41). Though there may be qualitative and significant differences among the various sensory modes... the gathering of these elements into a single ceremony tends to highlight the similarities among them' (Kondo 2004: 207).

This unconceptualized proficiency rooted in physical sensation, gained through bodily experience and guiding the making process, is embodied knowledge. The maker unconsciously reacts to the sensory feedback of hand making, using their embodied knowledge of both the making process and the properties of the material to guide the forms created. Observation of films documenting my own practice shows my hands in constant motion, instinctively modifying and evaluating the work. Through this exploratory action the hand becomes intellectual, as Tallis (2003: 243) asserts, the hand is the most highly developed pre-lingual part of the body, acquiring valuable sensory knowledge through the manipulation of materials.

Driscoll (2009) has identified two discrete types of touch. The first, manipulative or functional touch is a subconscious action employed, for example, when folding clothes or doing up a shoelace. The second, sensual touch is a conscious action, a purposeful search for information that notes not only the pleasure or pain given by the contact between hand and object but also information regarding the nature and behaviour of the materials. In the process of making both these types of touch have a role to play in developing what Sennett describes as 'material consciousness' (2009: 119), an embodied understanding of both the technical limitations of processes and physical properties of materials. Each sensory encounter provides us with new information that can, over time, become incorporated into our sensual vocabulary as embodied knowledge or practical wisdom.

Skill in making, which lies at the heart of all craft practice, is attained through the integration of embodied knowledge with technical understanding, injected with imagination. Whilst consciously rationalized technical knowledge informs the preparation of the task, at the moment of making touch guides my actions allowing me to work intuitively to the strengths of the inherent qualities of the material. This could be described as 'the intuition of the un-thought known' (Bollas 1987). Exploitation of the profound haptic knowledge of the materiality of textiles, gained unconsciously throughout our lives can significantly impact on the process of making. To be guided by touch is to put conscious action aside in favour of intuition and emotion, but how is it possible to nurture this sensory catalyst for the development of knowledge and invention in situations that take advantage of semi or even fully automated processes of making?

### **The impact of CAD/CAM on the making process**

As technologies progress 'artists and artisans are... embracing two opposites – hand and technology' (Wada 2002: 145). Two and a half centuries ago the industrial revolution distanced the craft practitioner from the physical processes of production with the introduction of automated

machinery. More recently, this physical detachment has expanded to include the design process as CAD/CAM has become increasingly prevalent in many disciplines. In much contemporary textile practice this has subtly shifted the focus of the means of production from experiential craft to design engineering. This presents the modern day practitioner with the challenge of finding ways to exploit the advantages given by automated production processes and CAD/CAM technologies, whilst still retaining the valuable embodied knowledge gained through hand making and the opportunities for innovation that this hands-on practice affords.

Malcolm McCullough (2009: 314) sees practitioners' use of CAD/CAM technologies is analogous to craft practice, arguing that manipulation of the digital interface uses a similar range of skills, e.g. manual dexterity, hand-to-eye coordination, an understanding of cause and effect and pattern identification. It is true that tacit knowledge of the computer interface is developed through regular and extensive practice, one does not consciously think about all the individual steps required to operate familiar software but instead concentrates on achieving the desired outcome. However, processes that rely wholly on CAD/CAM often omit opportunities for the generation of embodied knowledge given by the intimacy of touch. Although the visual and aural elements of a physical entity can now be adequately reproduced in the virtual world, usually the tactility and materiality of the mimicked medium is missing.

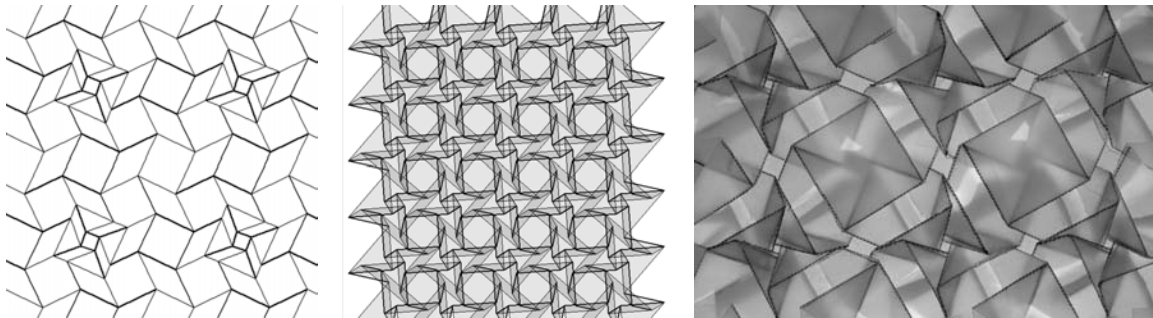
CAD technologies are rapidly evolving to simulate haptic experience. For example, the Logitech WingMan Force Feedback mouse based on FEELit technology helps the user to 'feel' the computer interface. FreeForm Concept and PHANTOM devices allow the maker to quickly and intuitively develop 3D digital models using their sense of touch to 'sculpt' form in a way that assists the crossover of embodied knowledge into virtual environments. These models can be easily adjusted without remaking, allowing each stage of an iterative design process to be saved and reworked numerous times. As these technologies are compatible with other CAD/CAM packages, the digital designs can be produced straightforwardly in the physical world. However, these technologies are not yet able to fully engage all of our senses in the exploration of an object or an environment. McCullough himself acknowledges that, 'Touch technology... remains far behind other aspects of human-computer interaction' (2009: 313). This has significant impact in instances in production where computational techniques are used in place of processes previously founded on the direct physical experience.

When engaged in physical making the practitioner is part of a three-way dialogue with the materials and tools of their craft. In this 'real' situation the materials used will invariably have imperfections and foibles that have to be assimilated into the overall design. These inconsistencies can act as an agent of change, stimulating innovation and driving the evolution of process. This opportunity is absent in the virtual world as these materials are consistent and unvarying (Dormer 1997: 147).

Making processes that rely entirely on CAD/CAM not only remove opportunities to develop embodied knowledge of the materials of the craft but also reduce practitioners' chances to gain embodied and tacit knowledge of aspects of the making process. This can have a negative impact on the development of a comprehensive understanding of methods used. For example, in my own research it was necessary to develop original folding patterns to create deployable textile structures (Philpott 2010). I evolved my first designs through computer modelling using Tess 1.2, an origami tessellation-generating programme developed by Alex Bateman. The software enabled me to adapt generic folding patterns, to control the basic pattern structure and to adjust complex patterns quickly (Figures 3a and b). It also allowed me to move seamlessly between a display of the folding net and a graphic representation of the finished, folded pattern, removing the need for time-consuming, physical folding of the paper to see the result. However, although the software enabled me to develop a series of complex folding patterns, without an underpinning tacit knowledge of physically folding origami designs I was unable to acquire a practical understanding of the relationship between the two-dimensional folding diagram and the three-dimensional folded form. This limited my control over the design process. Joseph Lim observes,

'When the representational means becomes the media in which the design process operates, then the construction/material system is constrained by the representational means. (2009: 9)'

My use of the computer software simplified the design process, however, this came at the cost of a full, embodied understanding of the relationship between the two-dimensional representation of the origami pattern and its three-dimensional folded form (Figure 4).



Left: Figure 3a: Rachel Philpott (2006). Origami net designed using Tess 2.1 software. © Rachel Philpott.

Centre: Figure 3b: Rachel Philpott (2006). Fold pattern designed using Tess 2.1 software. © Rachel Philpott.

Right: Figure 4: Rachel Philpott (2006). Origami folded tracing paper using fold pattern illustrated in Figures 3a and 3b. Photograph: Rachel Philpott. © Rachel Philpott.

Usually I construct physical models intuitively, employing my understanding of the relationship between materials, process and form to create complex geometries without needing to fully understand the abstract mathematical principles that govern them. Using CAD to create designs allowed no opportunity for the development of such embodied understanding, leaving me unable to predict how adjustments would affect the outcome. I found that without this understanding I was unable to adapt the CAD designs in any systematic way.

In order to address this I began to work directly on paper, folding models that allowed me to assimilate the 3D structure into the design process from the outset. Yet while folding with no pre-designed net was initially liberating, being more in tune with my natural way of working, my lack of knowledge of traditional origami techniques severely constrained my output. Working through a comprehensive series of exercises outlined in Lang (2003) I expanded my vocabulary of folding through tactile engagement with the paper, learning how to customize and adjust classic bases to create novel designs. This meant that I could experiment more intuitively with structure and pattern and by developing a greater understanding of traditional origami bases through physically folding paper I was able to better understand the relationship between an origami net and the finished folded form. Once I had developed this tacit understanding I was able subsequently to usefully apply this knowledge to design origami nets in the medium of CAD.

Being able to integrate the different types of knowledge developed through these two distinct approaches allows one to capitalize on the advantages of both. Although much useful knowledge can be developed through hand making, some hand making is extremely repetitive and time-consuming and can be usefully outsourced to semi-automated or fully automated processes to maximize production volumes or to limit cost. Designers who possess both practical material knowledge and CAD/CAM expertise are ideally placed to evolve innovative hybrid practices through the amalgamation of their complimentary skills. Dormer (1997: 145–46) describes this happy marriage of digital and tactile knowledge as 'middle-aged wisdom' as the further we progress into the digital age the more traditional handcraft skills are being lost.

### **Integrating hand and machine: The need for astute selection of appropriate methods**

Contemporary pleating and shibori practices have been transformed by the advent in the mid-twentieth century of thermoplastic materials like polyester, which have shape memory capabilities allowing permanent folds to be created. Prior to the twentieth century pleated textiles would have always been composed of natural fibres and would either have to have their folds set by stitching or they would have to be stored very carefully. Intricately pleated textiles were difficult to clean and needed reshaping on a regular basis. Even as late as the early twentieth century Fortuny gowns of micro-pleated silk had to be sent back to the couture house on an annual basis in order to be re-pleated. As material advances made it possible to create easily washable pleated textiles the demand for such fabrics increased. This in turn led to an increase in the range of available making methods from solely handcrafted techniques to include semi- and fully automated production processes, each with its own distinct characteristics.

'Shibori', an ancient method of creating texture and pattern on cloth has been used across the world for centuries. A Japanese word that literally translates 'to wring, squeeze or press', shibori is used to refer to a number of different ways of resist dyeing and shaping material by wrapping, tying, clamping and stitching (Wada et al. 1999: 7). Traditional shibori practice uses a number of different hand tools to assist the process. For example, the 'yokobiki dai', a tying stand comprising an upright post with a protruding metal hook helps the practitioner tension and tie the cloth. A more common tool is the sewing needle, used to stitch lines of thread that can be drawn up to gather the cloth into a variety of forms e.g. soft, regular, parallel accordion pleats. In an experienced hand Michel Serres notes these hand-tool becomes unified with the body in the practice, acting as an extension of the body and allowing the maker to gain tactile feedback throughout the process of making (Connor 2004: 321). The outcomes of making with such tools are heavily dependent on the skill of the maker and quality is not guaranteed. This aligns with David Pye's concept of craftsmanship as,

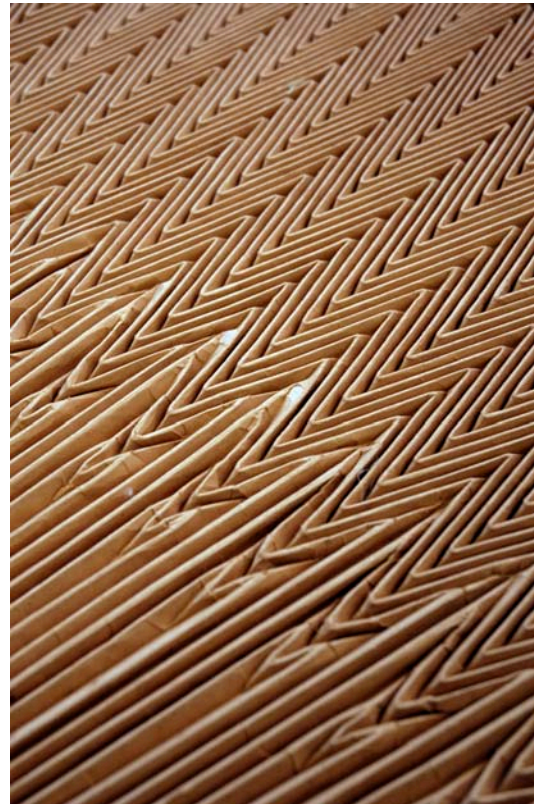
'... workmanship using any kind of technique or apparatus, in which the quality of the result is not predetermined, but depends on the judgement, dexterity and care which the maker exercises as he works. The essential idea is that the quality of the result is continually at risk during the process of making; and so I shall call this kind of workmanship 'The workmanship of risk'.' (1968: 4)

Over time more sophisticated machinery has been developed to speed up production. The princess pleater is a hand-operated machine comprising a row of needles and multiple rollers that feed the fabric through at an even tension. As the practitioner turns a wheel that revolves the rollers, the princess pleater simultaneously stitches numerous, parallel threads across widths of approximately 30cm. This produces far more regular smocking and accordion pleating effects and at a much greater speed than could be achieved by hand stitching. The use of such hand-operated machines gives a limited amount of tactile feedback throughout the process that, with practice can be equated to the sensory feedback gained from hand-stitching practices. This allows that practitioner to draw on the embodied knowledge gained from one type of activity to inform another. However, the limited scale of output from such hand-operated machines is not suitable for large-scale production of fabrics. My visits to F. Ciment (Pleating) Ltd, Potters Bar, UK and Inoue Pleats Co. Ltd, Tokyo, Japan in 2005 and 2008, respectively have provided an invaluable insight into the industrial production of such fabrics. For many years these companies have pleated textiles by machine and hand, predominantly for apparel but also for interior design applications.

In both companies simple folds such as accordion, box and crinkle pleats are machine made using a fully automated process. Capable of pleating fabrics up to 150cm wide, these electrically powered pleating machines use a roller system to feed the fabric, sandwiched between two sheets of paper, through the machine in a continuous length (Figure 5). Instead of needles a blunt blade traps the paper and cloth layers onto a heated metal plate while a wedge slides across the plate behind the blade, pushing the fabric up into a pleat. These machines can fold whole bolts of



cloth in a fraction of the time it would take to carry out the operation by hand. Here the results of the process are highly predictable, a 'workmanship of certainty' (Pye 1968: 5) where the machine operator has little physical interaction with the material throughout the process and little impact on the quality of the outcome.



Left: Figure 5: Inoue Pleats Co. Ltd (2008). Automated princess pleating machine. Photograph: Rachel Philpott. © Rachel Philpott.

Right: Figure 6: F. Ciment (Pleating) Ltd (2005). Card mould for pleating textiles. Photograph: Rachel Philpott. © Rachel Philpott.

Such machine work is excellent for situations in which high volumes of products of reliable and uniform quality are required, as Pye notes, 'The workmanship of risk has no exclusive prerogative of quality' (1968: 7). However, the unvarying nature of such automated production limits opportunities for either the process or the outcomes to advance and evolve, as can occur spontaneously as a result of the natural deviations of the hand making process. While an experienced craft-practitioner is well equipped to revise and amend their practice to accommodate the unexpected, machines are not so flexible. 'Machines break down when they lose control, whereas people make discoveries' (Sennett 2009: 112).

It is the 'workmanship of risk' that sparks creativity and innovation, the drive towards constant evolution perhaps lying in 'the disparity between idea and achievement in free workmanship' (Pye 1968: 30). Furthermore, these fully automated processes cannot undertake many of the more complex folding patterns, which require extreme dexterity involving fine motor skills that cannot yet be replicated by a machine.

A technique common to both industrial facilities for transposing elaborate tessellating origami patterns onto cloth is by clamping the textile substrate between two identically folded moulds of paper, card or foam before heating or steaming (Figure 6). The folding process is so complex that

it can only be carried out by hand. However, the production of the moulds offer more flexibility in choice of method and the two companies' approaches are very different. At F. Ciment (Pleating) Ltd these complex pleat moulds are entirely handmade, each taking up to six weeks to complete in an extremely labour-intensive process. Two layers of identically sized card are laid out together and pin marked to register them correctly. The design is then scored with a tool resembling a bent bradawl that bruises the card before it is folded along the scored lines. The high degree of accuracy required is wholly dependent on the skill of the maker, who carries out the task using a number of hand tools. However, parameters of the activity are so constrained that it might be argued that the task could be far more effectively and efficiently carried out by a machine.

The significantly larger scale of production at Inoue Pleats Co. Ltd, has led to differences in the manufacturing process. This Japanese company takes advantage of CAD/CAM technologies that enable the production of complex structures directly from computer modelled or scanned designs in ways impossible even just a decade ago. Here card moulds are computer designed and laser scored, guaranteeing accuracy and limiting opportunities for error as well as speeding up the production process considerably. However, the fabric and card packages are still folded by hand as at F. Ciment (Pleating) Ltd, with complex designs taking up to three days to fold (Figure 7 and 8). Designs can be relatively easily created or altered and moulds quickly produced using CAD/CAM technologies, while the maker retains a connection to the tactility of the material in the making process at the point of folding. This considered adoption of technology as one of a range of production methods not only speeds production, improves accuracy and lowers production costs but also conceivably expands the potential for experimentation.

By combining both hand and machine processes practitioners are able to draw on their embodied knowledge at the same time as taking advantage of disembodied technologies. Through the use of such integrated practice they can also retain an element of unpredictability in the work that can drive innovation.



Left: Figure 7: F. Ciment (Pleating) Ltd (2005). Worker hand pleating textiles using card moulds. Photograph: Rachel Philpott. © Rachel Philpott.

Right: Figure 8: Rachel Philpott (2006). Transfer-printed cotton lawn, hand-folded from a CAD-designed origami net. Photograph: Rachel Philpott. © Rachel Philpott.

## Conclusion

I am inclined to agree with Adamson who suggests, 'Craft only exists in motion. It is a way of doing things, not a classification of objects, institutions or people' (2007: 4). The skill base of craft practice is still predominantly gained through physical, hands-on engagement with materials that enables the practitioner to gain embodied and tacit knowledge of their craft. However, as technology has progressed it has become more prevalent and accepted as part of craft practice.

CAD/CAM technologies in particular have transformed the processes of craft. While these methods remove or limit the direct physical contact with the materials in the making process they

give the capability to make more complex objects with greater accuracy than is possible by hand making alone (Figures 9a, b and c). Computers are affordable to individual craft practitioners, allowing personal access to industrial process as well as giving the potential for mass customization of objects.

'This reverses perhaps the greatest blow against the artisan two centuries ago, namely the establishment of a means of production too large and complex for any individual to afford.' (McCullough 2009: 315)

In my own making, as for many contemporary craft and design practitioners, both hand and CAD/CAM practices are inextricably entwined. This has been illustrated by the journey of my practice from physical origami folding, to computer generation and representation of origami folding patterns, translation of these results through the process of laser-cutting and hand construction techniques before returning to a different iteration of the physical folding. I believe that this spiralling evolution, moving from hand manipulation to machine and back again can advance the design process and progressively develop the physical outcomes of the practice to a greater extent than by using either method in isolation.



Left, Right and Centre: Figures 9a, 9b and 9c: Rachel Philpott (2010). Deployable textile structures with shape-memory, composite materials formed using laser cutting and hand making techniques. Photograph: Rachel Philpott. © Rachel Philpott.

'Traditional' craft is rooted in the development of technical and conceptual skills through hand making. In such practice the relationship of the touching hand to the materiality of the making is particularly important, as knowledge gained through such interactions can be unconsciously internalized in a way which guides future making activity. In my experience, provided enough time and attention is given to this stage of skill acquisition this knowledge can provide a solid foundation for innovative practice that uses hand making in combination with other mechanized means of production.

Embodied knowledge, once acquired through close physical contact with materials, can subsequently be applied in situations such as CAD/CAM design and making processes, even when direct physical contact does not occur. Decisions made when engaged in these disembodied making processes can reference the knowledge developed when encountering the materials using the touch of the hand. In this way equivalent but different processes of conceptual development and dexterity and be nurtured and evolved in the operation of CAD/CAM tools. Both

hand and machine processes offer the maker opportunities for the development of innovative practice but when used in combination these opportunities are amplified.

People have the capacity for creativity and imagination. Machines, when astutely used, can be efficient tools to cultivate these attributes. Individual human mastery of automated processes can create evolution and innovation in a way that a fully automated system cannot. McCullough suggests, 'partnerships with technology are better than autonomous technology' (2009: 311). I believe that contemporary craft and design practitioners are well positioned to be at the forefront of shaping innovative methods through such complimentary partnerships.

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