Craft Thinking & Digital Making

*The role of the architect in the digital era.*

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I

Introduction
“Computer-assisted design might serve as an emblem of a large challenge faced by modern society: how to think like craftsmen in making good use of technology.” (Sennett, *The Craftsman* 2008:44)

When the Austrian architect Adolf Loos lambasted his readers in 1898, for failing to recognise the merit of true craftsmanship, he compared nation to nation in the hope of shaming his Austrian readers into agreement. Over the following one hundred years transport and communication became quicker and more reliable. The production of goods continued its progression from individual 'crafting' into 'manufacturing', crossing borders in a way that replaced the state with the corporation as the point of reference for the quality of goods (Bakan, 2004). Then the casting of the world wide web connected buyers, sellers, designers, makers and thinkers in every nation and the comparisons were no longer national or international but something even more all-encompassing: global.

The idea of craftsmanship - making, techné, mastering material – has looped through architectural theory since long before Loos and moved on into Modernism and beyond. Its meaning and pertinence, particularly with reference to architecture, has changed with the times. What is 'craftsmanship' to the 'Global Age'? It might be said that the Global Age is
synonymous with the 'Digital Age'. A time when computerization of design processes, as well as making processes, would seem to be eliminating 'hand-on' craftsmanship for good. Digital tools – computers, software, imaging, modelling – are stretching the boundaries of architecture both in terms of form and design process. In turn, these are having an effect on the role of the architect. In trying to interpret these changes it can be difficult not to let the astounding technological abilities of the tools (the hardware and software) overshadow a critical understanding of the influence of the human operators and designers. One way of looking at these developments is to consider the similarities in the thinking and making processes of digital architects – architects and researchers using digital technology - with a craft approach. Traditional techniques, materials and ways of working are experiencing a resurgence as one solution to the massive energy consumption of modern buildings which is implicated in global climate change. However, the two approaches of high-tech-digital and materially-biased-craft need not be seen as mutually exclusive. Could an interpretation of digital processes as a 'craft' be a way of understanding the latest digital architectural methods? What does such an interpretation reveal about the changes and the consistencies of the role of the architect in the digital era?

An investigation of the concept of craftsmanship and how its
definition moves through the different architectural theories and movements will inform a contemporary interpretation. What attributes, techniques and relationships might be said to be craft-like? These can then be taken into consideration when examining the work of 'digital architects' – architects like Greg Lynn who, through his teaching, research and practice, are expanding the uses of computers in design, or SHoP Architects, who combine digital design capabilities with manufacturing methods. The processes employed by such architects can then be compared to craft processes. Finally, contemporary architectural theory addressing the application of computers in architecture will be considered to see if similar ideas pertaining to a 'digital-craft' exist.
II
Craft
The word 'craft' is associated with skill and making. Such a broad definition incorporates the Classical potters, Venetian Glass-makers, Medieval stonemasons and modern day lace-makers. For the purpose of this investigation the crafts and craft techniques considered will be those relating to building. For example: the mason, the carpenter, the plasterer, the roofer, the blacksmith, the weaver, the glass-maker and many more skilled men and women\(^1\) whose combined work historically went into making buildings, with or without an architect to oversee the work. Each discipline was a master of its respective material. In Medieval Europe the greatest undertaking of these craftsmen and women were the cathedrals. In the eleventh and twelfth centuries these buildings were fuelled not only by religious fervour but a spirit of invention and ambition which permeated society. There was a high degree of social movement through the working classes and a powerful group of merchants and traders was emerging. Thus the master mason, though most likely of a peasant background, could find himself in the company of kings and bishops (Gimpel, 1983).

\(^1\) In the Middle Ages several women's names appear in the accounts for construction of cathedrals, for example plasterers, mortar mixers and some stone masons. Wives often managed the finances and a widow might continue to run her husbands affairs after his death. (Gimpel, 1983). In this paper “craftsman” will refer to craftsmen and craftswomen.
For every skilled craftsman there would be at least one apprentice or assistant as well as great numbers of labourers. When the work was done, or more often when the money had run out, the workmen moved to another town with another church or cathedral to be built. Sometimes they might be drawn to a particularly ambitious new building or follow a respected master craftsman to the next project. Their skills, ideas and experience travelled with them. Masons in particular, whose work was seasonal and less easy to find in towns once large building projects were completed, were known to travel to every corner of Europe with their pattern books (ibid).

With the urge to produce ever more impressive structures and details the technology of each craft was advanced. One craft would feed off the developments of another. For example, when the smiths learned to forge stronger steel then the tools of the mason and sculptor become more refined, the clamps to lift the stones became stronger and the skills of these craftsmen expanded accordingly. Experimentation with the built form itself may have been risky but it did not deter the medieval craftsmen from pushing their skills and knowledge to their limits, sometimes with catastrophic results.  

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2 Low to freezing temperatures damage the setting of lime mortar
3 There are numerous examples of towers over crossings collapsing. At Beauvais Cathedral in 1593 the masonry tower built over the crossing collapsed, just moments after the clergy and congregations had left the church in procession. (Heyman, 1968)
Fig. 1 Medieval Builders
The whole event was managed and directed by the master mason. He was called on to oversee the vast workforce, designs, workmanship, supplies as well as the associated costs of the building project. Drawings were made on the floors of the cathedral, often at full size, by the master mason and his pattern book carried sketches and geometrical diagrams to assist the builders. Although the role moved from being 'hands-on' to a more directorial one, the master mason was nevertheless on site at all times. Some cathedrals took centuries to complete however and generations of churchmen and workers were involved. The building grew in parts, some began with a transept, others with the choir (Kraus, 1979). Changes in style and technique can be traced through these components of the church. The thinking and resolving by the craftsmen, including the master mason, took place as the building evolved: during the 'making' process itself.

In the fifteenth century, the beginning of the Renaissance, a key change to the process of building was the development of drawing. Increasing sophistication, as well the new use of perspective, enabled buildings to be designed and communicated via paper and pen. Designs could be visualized and developed at a distance from the making and the craftsmen. While such Renaissance men as Leon Battista Alberti
acknowledged the difficulties of achieving the same quality of workmanship in this way, Alberti also believed this distinction allowed architecture to be elevated to its true status as an art (Anstey, 2007). This change in status meant not only a change in the tools and skills of the architect who had previously been so closely associated with the craftsmen, but also a greater social separation between the two. What is more, there was now a distance in time between the thinking (or designing) by the architect and the making (or building) by the craftsman. This notion of completing a design, albeit through different stages, before beginning to build has been absorbed into the legal and commercial processes of architects today.

Fig.2  perspective drawing of Santo Spirito by Brunelleschi
A focus on the merits of craft and craftsmanship re-emerged as the Industrial Revolution surged through Europe. Intellectuals and artists in England such as John Ruskin and William Morris railed against the loss of traditional craftsmanship to factory based mass production (Gombrich, 1986). Morris set up his own workshops to preserve the individual techniques of weaving, dyeing and printing. His reaction to the industrialization of making-processes was as much social as aesthetic. Morris fixed on the appalling conditions for factory workers and, with a degree of nostalgia, championed the idea of the 'workshop' as the healthier, safer environment where people would be happy to work for work's sake. Economically however, the crafted furniture and natural dyed fabrics could not compete with the new 'efficiency' of mass produced goods. The Arts and Crafts movement strove for a simplicity in form and honesty of materials yet they produced luxury items, available only to the well-off. The notion of craft was becoming associated with the romantic past and specialized techniques for individual pieces.

The call to uphold traditional crafts was taken up in Germany where the Deutscher Werkbund was founded in 1907. Unlike the English movement, this aimed to combine craft expertise with mass production in the hope of well designed and internationally competitive, industrial products.
These ideas were taken on by the Bauhaus ten years later – a school whose aim, according to Walter Gropius, was “to produce designers who were able, by their intimate knowledge of materials and working processes, to influence the industrial production of our time.” (Gropius, 1955:15)

In the Bauhaus, curriculum students worked for a period in a workshop of their choice overseen by both a master of the craft and a designer or artist. Physical experience of working with materials was deemed essential. Furthermore, Gropius recognised the value to a craftsman's apprentice of working on actual orders with the master. With this in mind he worked to procure practical commissions for the Bauhaus students, an enterprise which proved lucrative for both the school and the successful students.

Writing twenty years before the foundation of the Bauhaus, a fierce critic of the Werkbund yet a champion of the craftsman was the architect Adolf Loos. Loos' essays describe a definite separation in skills and ethos between the architect and the craftsman. He believed the integrity of the craftsman had been lost through designers and artists telling them what to do. Loos drew attention to a conflict between practicality and beauty in the eyes of his contemporaries. He felt many every day objects were over decorated to the detriment of their function and used examples from crafts in fields not
connected to architecture to illustrate the point. The Werkbund's quest for a new 'style' was misplaced, according to Loos, who admired the English Arts and Crafts' simplicity. The most damaging influences hindering the production of beautiful, functional objects were those of the artist and architect over the craftsman:

“It is high time our craftworkers tried to throw off this un-called-for tutelage and started to rely on their own good sense. Anyone who wants to collaborate is welcome. All credit to anyone who is willing to don an apron and take his place at the humming potter's wheel, or strip to the waist and help at the furnace. But those dilettantes who want to dictate their designs to the creative artist from the comfort of their studios should stick to their own field, namely graphic art.” (Loos, 1898)

and even more damning, twenty years later:

“...if you want craftsmen in touch with the style of the times, poison the architects.” (Loos, 1917)
Fig. 3 Bauhaus Metal workshop, Weimar, 1923

Fig. 4 tea infuser and strainer by Marianne Brandt, Bauhaus Student, 1924
Perhaps rising to the challenge, Loos' admiration for the pure object or form - its practicality and functionality and honesty of materials - became the focus of the Modern Movement in architecture that followed. New technological possibilities inspired the next generation of architects. This era of architectural experimentation and technological advances in construction contained within it some of the verve of the medieval cathedral builders. The idea of a craft in the early twentieth century had become associated with applied arts, decorative skills from which the modernists wanted to distance themselves. Craftsmanship, on the other hand, with an emphasis on mastering new building tools (technology) and new materials, remained key. Elizabeth Shotton has documented Le Corbusier's journey in working with the idiosyncrasies of materials like concrete. She shows how, by his later work such as La Tourette, he incorporates the material's moments of imperfection into his buildings much as a stone-mason might work with the seams and folds of stone. (Shotton, 2007).

While the dictionary definitions of “craft” and “craftsmanship” are broad, some conclusions from this short historical investigation can be drawn from the point of view of architecture and the building process. Firstly the theme of material and the mastering of its applications remain consistent.
What is meant by 'material'? Thanks to its apparent historical status a craft material is often thought of as a “traditional building material” - wood, stone, thatch, lime. It is not so difficult to see how the same term might include things like steel or glass or even combinations like curtain walling. In the twenty-first century, however, must material be physical? Elizabeth Grosz’s philosophical investigation (2002) will help to interpret the relationship between the material and the virtual in the last section of this paper.

Secondly, there is making, learning to make and collective recognition versus the individual. It is evident that craftsmanship includes
learning by doing, practical experimentation and apprenticeship. Some of the social mobility of craftsmen described in the early Middle Ages changed with the advent of guilds and a more protective, sometimes secretive attitude to specialist knowledge became common. In terms of authorship, while the master mason of Notre Dame may have had his name engraved eight metres long on the South transept, most craftsmen worked anonymously. The medieval stone-cutter's mark was a method of quality control and stones were laid with these marks to the inside of the wall where they would be covered by the frescoes (Gimpel, 1983). A craft does not carry the recognition or accolades of the artist. Its performers work anonymously and in groups, leaving only small personal indentations.

Lastly, there is the connection of skills, technology and social relationships between different crafts. Improvements in the quality of steel could have direct effects on the workmanship of those using steel tools. Such developments in the crafts are also reflected directly in the architecture: techniques to produce flat panes of glass developed by 13th century Venetian glass-makers enabled the glazing of the huge cathedral windows for example. Whilst there is a mobility ascribed to craftsmen, any network of cooperation or knowledge transfer would appear to operate through the production of architecture, where skills are combined towards one aim – the
building. One could speculate, therefore, that this knowledge transfer might also be facilitated by the architect. As the overseer of the whole, as well as the parts, the architect is well placed to use the latest developments in one craft to stretch the capabilities of another.

Fig. 6 Medieval Stone-cutter’s mark
III
Digital Design Processes
The computer tools used by architects and associated professions have evolved in the last ten years from graphic, representational tools to have complex three dimensional, animated, self generating capabilities. The built-in problem solving and evolving algorithms of some software today appear to have moved the computer beyond the role of tool and into that of designer. What are the digital design, work and development processes being employed by architects and researchers?

Computers first had their widest impact in design professions in the form of two dimensional CAD (Computer Aided Design) drawing. The possibilities they offered were most actively pursued by mechanical and component designers. Cross-overs were made into component manufacture comparatively early in the life of CAD with CADCAM (Computer Aided Design and Computer Aided Manufacturing) developing alongside each other. Today, the new timber Gothic vaults for the crossing tower at Bury St Edmunds' Cathedral are modelled in fine detail by a joiner using computer software. That digital information is then fed directly to the wood cutting and carving machine (a CNC4 cutter) before proceeding to site to be assembled.5

4 CNC – computerized numerical control
5 personal communication with cathedral architect Henry Freeland, 2009
As with the medieval craftsmen, the technological advance of one field has affected another. In the early stages of computer design development the methods of data input and manipulation had a mathematical and engineering slant that lead some architects to find it less intuitive than their engineering counterparts. With less concern for minute tolerances and a limited requirement for calculations, the advantages of the computer over the drawing-board were not always clear to practising architects. Nevertheless, although many practices still use a combination of hand-drawing and CAD, computer drawings have become the medium of choice for the detail drawing stage of the commercial architectural practice.

As the capabilities of the computers increased, so did the scope for three dimensional modelling, visualizations and animated presentations. Many large practices now use the improved three-dimensional capabilities of CAD software to take design and construction information through from the initial proposal to detailing. In the competitive global market computer visualizations and animations are becoming commonplace for every size of job. The parallel developments in popular culture of computer games graphics, cinema special effects and advertising may be leading to the general public – including clients and planners - being computer image literate at the expense of being able to read traditional plans and elevations.
Fig. 7 & 8  CAD drawings for new vaults at Bury St Edmunds Cathedral (2009)
The pace of these technological developments in the last century is far beyond the speed of changes in craft techniques of the Middle Ages. The initial digital possibilities seemed limited to replacing the traditional architectural tools of pen and drawing board. Three-dimensional co-ordinate representations meant computers could also replicate physical models. As a digital alternative to manual tools the computer did not immediately affect the working processes of the architect. However, as described earlier, the architect can be well placed for an exchange of technological ideas. The capitalization of computer techniques by architects began when they looked, as Le Corbusier had, to the automobile and aircraft industry. The digital forms being produced in these industries required not only new ways of 'making' but also of 'thinking', or designing. As well as providing commercially viable ways of producing new forms digital technology started to alter the way an architectural project might be conceived, developed and communicated. These ideas are not only explored but actively celebrated by the much cited contemporary New York architects SHoP.

SHoP's close work with component fabricators through CADCAM software

6 The Guggenheim Museum at Bilbao by Frank Gehry is a famous example
is, argue the principle architects Coren and William Sharples, “blurring the distinction between the architect's design drawings and the contractor's shop drawings.” (2007:29) Through the computer the architect's details are translated directly into materiality. This way of working acknowledges a continuation of the design process right through fabrication and construction. Traditional contract drawings are an artificially (although legally) frozen moment of the design before construction processes alter the design further. SHoP believe a time will certainly come when a building design can be issued to a contractor in the form of a three dimensional computer model to be broken down into elements and fed into respective fabrication computers to assemble the building. This moment of assembly is a part of the design process which is also changing. SHoP believe that the parallel development of the form for their Camera Obscura in Greenport, New York using standard manufacturing processes for non-standard building elements, allows individual designs to be economically competitive when compared to conventional designs which use “off the shelf” components. In their interior fit-out for the Virgin Atlantic Clubhouse at JFK Airport, New York there was a decision between parts arriving on site in pre-cut sheets (like model kits) or as detached pieces. The Millworkers assembling the screens
Fig. 9  computer rendering of Camera Obscura by SHoP Architects

Fig. 10  Camera Obscura under construction, Greenport, Long Island USA
felt there would be less confusion in locating the parts if they remained attached although this was later abandoned in favour of a numbering system (Ibid). This project illustrates that the manual side of the mechanized system requires equal consideration. This inclusion of the constraints and possibilities of the construction and fabrication stages at design stage represents a revived integration between the 'thinking' of the architect and the 'making' of the builders.

Meanwhile, the ability of computers to conceive forms in virtual space has surpassed human comprehension. In the same way that the I-Pod can hold more songs than one humanly has time to listen to, a computer is able to generate an infinite number of forms from a set of parameters – that is: defined or varying restrictions mathematically translated into the software. These forms are without human scale and any context must be fed into the model via the same codes as the design data. Unlike physical models they incorporate the variable of time through the nature of their animation and their own growth or metamorphosis. The architects working and researching with these techniques suspend expectations of the outcome and work with the ‘unexpected’ as part of the design process.
The application and development of this software is being investigated by researchers all over the world. There are a number of approaches. One of them is environmental testing through computer modelling to inform design solutions and material development. The relevance and interest in this research has increased with a raised awareness of climate change issues and its relationship to building construction, energy use and embodied energy. For example, computer software can test specific data relating to a proposed building such as its heat requirements. Material qualities are simulated by the computer and testing in a virtual world greatly reduces the risks and cost of testing in the physical one. This is a form of learning-by-doing which is close to those of the craftsmen. Small adjustments can be made with each experiment enabling a thinking/making process not usually possible on the scale of a building.

Other approaches are less governed by data from the physical world, preferring to explore the virtual possibilities first. Once again, the refinements of the software tools made for other industries have governed the direction some of these experiments have taken. In the aerodynamic industries there was a call for ways of describing splines and the complex mathematics of curves have subsequently been incorporated into most CAD
Fig. 11 thermal building analysis

Fig. 12 Biomimetic Butterflies
programmes. This has superseded triangular polygon meshes previously used for describing surfaces (Hesselgren, 2006). This technology has allowed the modelling of highly complex geometrical shapes created by a coordinate system entered by the designer and it can now be programmed to generate its own forms in response to codes or algorithms entered by an operator. The curved and coded nature of the resultant models has lead to biological analogies. Some research uses the technology to understand and interpret existing biological models, such as the shell of a lobster. This testing and interpreting might be seen to be a similar process to that of the digital environmental researchers who take physical models and develop them further through the use of the computer. Others, however, look to incorporate ideas of DNA, selection and cell reproduction so that the software builds the model itself: self-generating architecture.

Generative design tools generate concepts and stimulate solutions based on “robust and rigorous models of design conditions, design languages and design performances,” according to Kristina Shea (2006). The scope and application of such technology is the topic of research for post-graduate architects around the world and software programmes are already employed by mainstream architects like Fosters in London.

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7 also known as biomimetic architectural research
Whereas the environmental and biomimetic digital architects start with forms which are then manipulated via other data, the generative digital architect inputs data that then supplies the form. Their role is one of data gatherer, transmitter, manipulator and assessor.

In her book “Abstract Space, beneath the media surface”, Tierney (2007) describes the digital design process using generative software as: definition of the problem of the field. For the computer to generate the form the digital architect must chose what data to input upon which the form will be based. This choice represents the first stage of the process. How this data is then manipulated is determined by the software. Defining and modifying the rules by which the software responds to this data is the second stage. The third stage is the production, by the computer, of any number of models or proto-types. These must then be evaluated by the digital architect with the potential then to return to Stage 2 (Tierney, 2007). The skills required throughout this process include computer programming and an ability to collate and translate statistical data. It also includes skills more commonly associated with architects such as formal perception, interpretation and application. However, unlike the traditional architectural processes, these skills are less about imagining and deciding what to make and more about imagining and
deciding how to make something – where the 'something' is yet to be determined.

'The unexpected' is a term often used in the context of self generating software. Working with it has presented architects with a change to their role as design-originator. However, in an interview in Architectural Design magazine in 2006 (Rocker, 2006), Greg Lynn explains that the era of what he called the “happy accident” is over. Lynn is an international proponent of digital technology and exhibited in the 2008 Venice Biennale “Out There, Architecture Beyond Building”. He is an architect and teacher associated with the University of Applied Arts, Vienna, the Department of Architecture & Urban Design California and the Yale School of Architecture. He also runs his own practice. Lynn talks of the transition of skills from those evolved through the appropriation of existing software – usually developed in other industries – to programming architectural software. He stresses the need to incorporate design skill with programming skill for manipulating the medium. Lynn feels the strength of the digital medium is in its ability to work with components that go to making up a whole. This, he feels, is a key difference of architectural design over other areas of design.

“The relationship between parts and whole is essential to the
evaluation of quality, meaning and experience of any architectural
design.” (Ibid:92)

He suggests a problem with experimental digital design has been a
tendency to see the parametric product as the whole rather than the
component. This “bottom-up” way of thinking as Lynn puts it, is a change
to an architect's more usual method of “top-down” i.e. conceiving the whole
and then designing the elements that go into making it. This method bears
some resemblance to the collaborative work of craftsmen constructing
separate elements of one building. However, as Lynn argues, the architect
can bring an holistic over-view to this approach whilst still working from the
parts towards the whole.

Fig. 13 A series from the Embryological House by Greg Lynn
For the Embryological House, Lynn's practice FORM produced a series of one-of-a-kind houses. The houses are customised for individual clients and adaptable to a full range of sites and climates. To Lynn what is important is the series as the solution rather than the search for the ideal house. This acceptance of using series, through which “identity, signature and meaning tend to move” (Ibid:93), Lynn finds more readily accepted by product designers than architects.

“Most architects want to understand the Embryological House experiment as a search for an ideal house – as if the whole collection of houses was a conceit to then select the best one. They are all equivalent. I love them all equally as if they were my children. The design problem was not the house, but the series, the entire infinitesimally extensive and intensive group.”(Ibid:92)

Digital processes would appear to illustrate a closing of the distance between the architect-thinker and craft-maker. Architects are learning from mechanical engineers, fabricators, computer programmers and each other in a collaborative fashion which is at odds with the singling out and authorship of the architect-the-artist. Digital processes also embody a shift in the design approach of digital architects – thinking and making appear closely linked
both through the incorporation of the fabrication process into the design and learning through testing and experimentation. However, as alluded to by Greg Lynn, there are still requirements on the digital architect which go beyond that of craftsman. While the digital processes are masters of components, the architect must guide these processes towards the conception of the whole. Skills of interpretation, refinement and application of the computer data (models) are required. The role of the architect in the digital era continues to be one of co-ordinator and director although the methods of inception and development are different.
IV
Virtual & Material
This investigation into the digital processes and craftsmanship has tended to concentrate on the physical manifestations of craft and architecture. Yet digital processes, though they may be translated into material and fabrication, deal primarily within the 'virtual' realm. Elizabeth Grosz (2002) has written about the implications of the ideas surrounding computers, virtual reality and architecture. Drawing on the philosophy of Gilles Deleuze, Grosz argues that the virtual exists alongside every-day reality and is not a concept exclusive to computers. The same space, she writes, exists in writing, reading, drawing and even thinking:

“the virtual is the space of emergence of the new, the un-thought, the unrealized, which at every moment loads the presence of the present with supplementarity, redoubling a world through parallel universes”. (Grosz, 2002:78)

According to Grosz, architecture can approach the concept of virtuality in two ways: as a new technology developed through the use of computers, or as a new way of “seeing, inhabiting and designing space” (Ibid:89). This second approach is less about the computer as a tool and more about a re-conceptualizing of the virtual and the real within each other. It incorporates an open-ended and indeterminate quality which relates
to working with the “unexpected” as described in the digital processes.
Applying Deleuze's ideas of “the outside” to architecture also leads Grosz to
question whether architecture can be thought of in terms of series or
assemblages – a notion raised by Lynn through the digital production of
multiple architectural solutions.

For Grosz the question of the outside of architecture, the
unthought, the unbuilt must be asked whenever formulaic solutions take
over from experimental and innovative ones. Andrew Benjamin
(Benjamin, 2006) argues for a material theory of architecture but includes
that of the immaterial or digital, within it. Benjamin recognises an
approach of experimentation and research, either materially or digitally
as a basis of design practice and hence architectural theory. While he
acknowledges that there is a fear that moving to a material understanding
of architecture could result in slipping into pragmatism, making
architectural theory irrelevant, he assures us that as criticality is internal
to architecture, innovation and experimentation will remain possibilities.
Benjamin draws a distinction between a history of architecture as “the
history of the plan” and the history of architecture as “the history of
material possibilities”. He acknowledges neither is completely
independent of the other but suggests that a shift of emphasis to the
history of the material possibilities allows a natural re-thinking of the understanding of both the plan and the materials. This, in turn, implies a relationship between history and design. The philosophical questions relating to matter -How do we identify the material possibility? What does material possibility involve? Is possibility the same as potentiality? (Ibid)- are equally pertinent when material is not reducible to matter, as is the case with digital architecture. Benjamin proposes an empirical link between the material and digital, or virtual – that is knowledge based on experience and observation (the learning-by-doing of the craftsman). Through their theories both Benjamin and Grosz eschew questions of the virtual as representation or imitation of the material. These theories suggest the digital processes discussed are craft-like not simply because they mimic craft techniques applied to material but because they tap into craft ways of thinking and problem solving.

Experimentation may be a useful approach but another writer investigating digital experimentation, Susannah Hagan, wonders what it is for in architecture, what the point is and who's got it? (Hagan, 2008) Hagan proposes environmental design theories as the resolution between digital and material architecture by looking at the concept and history of the 'avant-garde'. She sees the need for greater understanding of the direction
and application of digital architecture as pressing and is perhaps echoing Lynn's thoughts that the time of the “happy accident” in digital experiments is over. Environmental design, she argues, has been the silent under-dog to the novel forms and innovative design procedures developed since the 1970s. Parametric models can be formulated to respond to specific environmental constraints such as prevailing wind direction, temperature ranges, solar heat gain. Computer innovations are giving these theories and proposals new kudos because of an increased ability to both test them and realise them. A global consciousness of environmental issues makes this digital application appealing to both material and digital architects, conscious of embodied energy to take just one example.

For Hagan the virtual is a direct link to the material and digital media is the key to access it. As a guide to any changes in the role of the digital architect, however, this approach gives few clues. Therese Tierney(2007) uses the “media surface” as a way into the theory of digital architecture. She draws a connection between art and architecture through the (modern) use of abstraction and a rise of the importance of the object over the representation. Although she details the digital design process - acknowledging a change in tools has necessitated a change in
design process - she refuses to be drawn on its application. She suggests that digital processes are not applicable to all design problems and leaves it to others to define its use within architecture.

*Fig. 14 Interior by Sarah Schneider, Studio Lynn graduate, 2008*
V
Conclusion
To decide whether digital architectural processes can be labelled a craft it must be decided what, in light of this investigation, is the definition of craft. A number of aspects have been shown to be key. These include: an anonymity amongst craft-workers in the work they produce, a collaboration and knowledge transfer between associated disciplines and learning within the craft through apprenticeship and experimentation. These broad categories could be applied to many types of work. A craftsman works with material but what that material is varies greatly. The immaterial may be considered to be part of the material and thus is not helpful in narrowing down the understanding of craft. In his book 'The Craftsman', the sociologist Richard Sennett believes that any activity, from parenting to software programming, can be seen as a craft. A more specific and useful criterion might be that a craft involves thinking during making.

The testing of technological solutions by digital architects draws them into close allegiance today with engineers and fabricators, other designers and researchers. The internet enables near instant transfer of information and in the case of both research and design this allows the testing of models across the world. Learning and development of the medium takes place through a circular repetition of small modifications and
experimentation. Access and communication via the internet means expertise is dispersed and not reserved to any centres of excellence. The craft model of master and apprentice is not evident, although if digital processes are to be defined as a craft this might present a useful paradigm on which to build a knowledge-base. Experimentation is evidence of learning-by-doing but doing is not the same as making. Is there a process of thinking during making within digital architecture?

For architects like SHoP, whose digital design codes are the cutting instrument of their buildings' components there can be little argument that their thinking and designing processes are linked directly to making. Close simulations of biological and environmental models parallel the physical world as a way of making without making. Where the architecture remains primarily in the digital realm, deciding whether these processes constitute making depends on one's understanding of the virtual.

If digital design processes are to be defined as a craft what then for the architect? The circular sequencing and collaboration between other players in the creation of architecture through digital processes are an upset to the traditional linear process spear-headed by the architect. This is reflected in a change in the digital architect's role from one of authority and exclusivity to one of positive social and intellectual exchange. Where the
process of drawing and the status of architect as artist once separated the architect from the craftsman, working in the craft world of digital design puts the architect on a level footing with other thinkers and makers. Up to this point an architect may be defined as one whose thinking was distanced from the making. Through digital processes, an architect can be seen to be thinking during making as a craftsman does. Yet there is still a call for something else from the architect. Greg Lynn speaks of components and the whole within architecture. Where crafts build components and push individual potentialities, their coordination and development into a whole has been facilitated by an overseer: an architect. The pursuit of the whole over the part continues to separate the architect from the craftsman. Through digital-craft and common work processes this separation is less divisive than previously but the coordinating and driving role of the architect continues. In the digital era the architect is not a craftsman but is one able to apply craft thinking to digital making.
VI
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VII
Illustration Sources
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Fig 1: Medieval Builders www.lessons-from-history.com

Fig.2 perspective drawing of Santo Spirito by Brunelleschi
http://veronicawaisberg.blogspot.com

Fig.3 Bauhaus Metal workshop, Weimar, 1923 www.bahaus.de

Fig.4 tea infuser and strainer by Marianne Brandt, Bauhaus Student, 1924

Fig.5 Couvent de La Torette by Le Corbusier, 1960
www.flickr.com/photos/jmtp/2720120416/in/set-72157612282167527/

Fig.6 Medieval Stone-cutter’s mark

Fig.7 & 8 CAD drawings for new vaults at Bury St Edmunds Cathedral (2009)
courtesy of Taylor Made Joinery Interiors, Manor Wood, Ipswich Road, Bildeston, Ipswich, Suffolk IP7 7BH

Fig.9 computer rendering of Camera Obscura by SHoP Architects

Fig.10 Camera Obscura under construction, Greenport, Long Island USA
www.flickr.com/photos/fedenegro/259729478/

Fig.11 thermal building analysis www.neh-berlin.de/neh_en/konzept/analyse.php

Fig.12 Biomimetic Butterflies www.processingblogs.org/2007/06/

Fig.13 A series from the Embryological House by Greg Lynn
www.flickr.com/photos/12951443@N07/2090558659/

Fig.14 Interior by Sarah Schneider, Studio Lynn graduate, 2008
www.dezeen.com/2008/08/16/asemic-scapes-by-sarah-schneider/