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Transferring Skill over 2,000 Years: A study of two disciplines

Introduction

This paper will look at the practical, technical and creative potential that is made possible when a traditional craftsperson who works with his hands and sketchbooks is given the opportunity to work full time in digital design. Over the last 12 months, I have worked with Computer-aided Design (CAD), incorporating *Rhino* and *Desktop Inventor*, and Computer- aided Manufacturing (CAM), using Computer Numerical Control (CNC) milling machines, laser cutters and 3D printing machines.

I have worked as a glassmaker and designer for 25 years, working from sketches and then developing my designs 'on the end of the iron' in a hot glass workshop. The glassmaking processes I have used have remained virtually unchanged for 2000 years. As a successful designer, I have had over 70 products go into production. I have worked for prestigious companies such as Habitat, Selfridges, Dartington Crystal and TVG and am currently on the design team at Caithness Glass. I never used digital technology and only used a PC as a word processor. Indeed, I was very much against the use of CAD, believing that although appropriate for product design, it could be detrimental to creative development within contemporary craft.

Last year I was given a new role at Plymouth College of Art within resource development. A major part of my work is to facilitate the use of our 3D printer, and to help plan our new Fab Lab. This has been a tremendously exciting time for me, and has completely changed my outlook on the use of digital technology in contemporary craft. I have used my past experience to work out ways of bypassing the limitations of working with a very simple 3D printing machine, achieving results that would be expected from a far more complex and expensive piece of equipment. I will use examples of the work that I have printed from my own designs, and those of PCA students, to provide evidence that very complex outcomes can be created from inexpensive, simple machines, using traditional modes of thinking, based on years of practical experience within the workshop. I would like to demonstrate that tacit skill is transferrable into the digital world and is just as relevant when working in front of a computer screen.

I hope that this paper will articulate the acquisition and application of practical and tacit skill and detail the importance of tacit understanding that enables the skills to be transferrable, including the vital transfer of the concept of quality.

I also hope to examine the possibility that, far from replacing traditional craft as I originally thought would be the case, the introduction of digital technology could actually save the endangered and, in some cases, dying traditional crafts from disappearing from public perception altogether. I will also discuss the notion of whether digital design can be regarded as craft.

As a master craftsman and researcher, I have published a number of papers on the subject of tacit skill, knowledge and understanding. As with this paper, my approach is somewhat personal and much of what I say can be described as conjecture, albeit informed conjecture. (For further information see Hankey 2011.) This is in fact, the heart of the matter. My thirty three years as a professional craftsperson is enough for my words to be taken seriously. Tacit knowledge is easily recognised and evident in the creative work that we produce, but is very hard to articulate explicitly our tacit understanding.

There is a necessity for the re-evaluation of tacit knowledge within administrative and political structures. In modern society with technical rationality as its dominant model of thinking, the working practitioner has very little credibility or voice. All my work is an attempt to square the circle: combining learning and making a living and history with the future; valuing the whole person; learning as much as writing. Designs and ideas for sustainable processes using ancient and traditional craft skills alongside modern technical innovation are an aspect of this determination to look to the past for what could be used in the future, just as I use a historical lens to view how tacit skills were valued in the past and how they could and should be valued again.

The transferral of skill

This paper describes the transfer of skill from one craft to another, and due to the nature of glassmaking, where techniques and processes have remained unchanged for centuries, the transfer of skill from one age to another. I have been incredibly fortunate to have had the opportunity to transfer my practical skills from one discipline to another in a professional working environment not once, but twice. As we are talking about practical skill it is important to see that the cognitive skills, design skills or cerebral skills embedded both within and outside of the practical, continue to develop and are actually enhanced by the experience of transferring from one discipline to another. In my case, I have moved from craft engineering to glassmaking, and then to a third discipline, CAD CAM, incorporating digital design and making.

In terms of historical processes, I was trained in the 1980s as an engineering craftsman within the traditional incremental apprentice system developed over hundreds of years. I later changed to work in a manner more akin to that of the ancient Roman glassmakers of 2000 years ago, and then once again, to work with cutting edge technologies including Cad Cam and 3D printing.

From Craft Engineering to Contemporary Glassmaking

Burners over molten float glass.

Clear cut glass at the end of the production line.

I was trained as an engineering craft apprentice on the installation and maintenance of glass furnaces at Pilkington Glass in St Helens. Even though the float glass process and furnaces were very new technology, the factories around them were hundreds of years old. Interestingly, due to the long history of the factories, and with working practices and attitudes handed down from craftsman to apprentice over the years, back in the mid-1980s the notion of the Journeyman was still prevalent within the workforce, particularly with the older engineers.

As you came out of your apprenticeship you were expected to spend at least two years gaining experience before the rest of the workforce accepted you as a craftsperson. Looking back into history, recently 'graduated' craftspeople would be expected to travel to other places of work, gaining experience in different working environments before returning to the original place of employment – hence the name – Journeyman.

This was explained to me by a gas engineer who I trained under for the first year of my apprenticeship, just before he retired. Even though the formal practice of journeymen ceased many years earlier, the workforce continued to regard a craftsperson that had just come out of his or her time as a 'Journeyman'. Indeed it took 10 years (a four-year apprenticeship followed by at least six years on the job) to be regarded by others as a master craftsman. That term is conferred on a craftsman by his or her peers, and should never be assumed by or attributed to ourselves.

This extra time, this 'journey into our craft' is the all-important time when we are still learning, without a tutor, having to think for ourselves and problem solving with nothing but our tools, our hands and our past experience to aid us. This is the time for the acquisition of tacit skill. This was recognised as a vital part, if not of the education, then of the *making* of a craftsperson.

Tacit skill

When we consider compression joints in domestic or industrial plumbing, they need to be tightened up to produce a water-tight or gas-safe joint. If you don't tighten the joint enough, it will leak. If you tighten the joint too much, it will leak. You have to get it just right; you judge it by how it 'feels'. This is tacit skill, implied but not stated. I found that this skill is directly transferrable to glassmaking. It's not that I understood the material, but rather that I knew that I had to look for and understand the 'feel' of the glass. Another vital factor is that it's not just the particular tacit skill that is transferrable, but the concept of 'quality' that goes along with it.

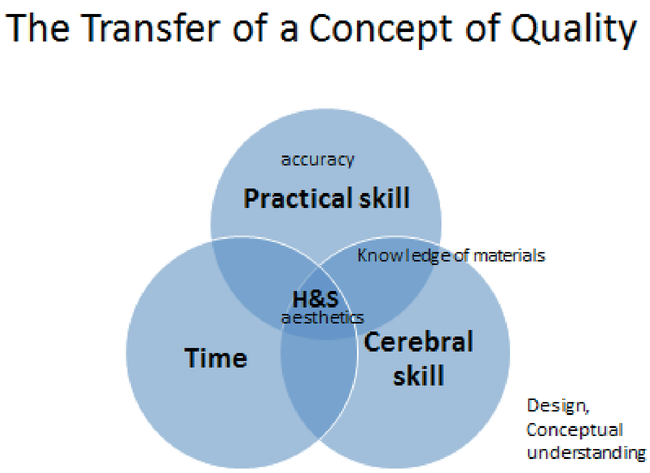
I have two examples of quality, the outcome of jobs that occurred within a week of each other when I worked as an apprentice craft engineer at Pilkington glass. In the first instance, a union joint on a water pipe above the glass furnace began to leak onto the hot float glass, causing the whole production line to be shut down. The resulting loss of income to the company would have equated to tens of thousands of pounds for an average unscheduled shutdown. Once I had arranged safe access to the area, I had the leak fixed in ten minutes and production was started again. The result was water tight but it looked awful. Both sections of pipe were out of line and there was jointing compound left on the pipe fittings. However the job was regarded as a great success as it was done quickly and safely, and I was congratulated on the quality of my work. Time was the most crucial issue with this job.

The very next job involved fitting a radiator in the MD's office. I must have spent three times the usual time fitting the radiator, checking and double checking, but above all, making sure it looked level in relation to the wall and floor. Again, the foreman congratulated me on a quality job, even though it took much longer than usual to achieve the outcome. In this case, the job looked perfect and there were no leaks, but time was not an issue.

My point here is that when we transfer advanced technical and tacit skills from one discipline to another, we also take with us the certain knowledge that what quality means can change from one job to the next, and there is not a fixed 'one solution fits all' answer to what quality represents within any discipline that involves autonomy of purpose.

Quality, in the performance of a practical skill, can be described as the correct selection and implementation of a number of criteria of fluctuating importance which vary depending on the job in hand. No two jobs are the same and we must therefore amend the nature of the quality needed for each one by choosing the correct criteria from which we implement the necessary ideals, tools and processes needed to achieve quality in the job at hand.

This concept of quality, the understanding that criteria change constantly depending on the job in hand, gained in any discipline, can easily be transferred and applied to another discipline, for example, from craft engineering to glassmaking.



Alongside the concept of quality, the move from craft engineering to glassmaking is made far easier when we consider the knowledge and tacit 'feel' of any material. For instance, in industrial or domestic pipework, copper is a soft metal that when over tightened will cause the fitting to leak. The actual pressure on a compression joint needed cannot be written down. It cannot be accurately measured. It has to be 'felt', with tacit knowledge gained from repetition and experience. Copper when worked becomes hard and brittle and needs to be annealed in order to soften it again. Molten glass also must be annealed, and has a 'feel' as well, a 'life' that can be recognised and acted upon with knowledge based on experience and repetition. The feel is different, but I am aware that any material has a 'life', certain attributes that apply to it and nothing else. A tacit 'feel' for one material allows the craftsperson to look for and be open to the unique characteristics of another. In this way the transfer of practical and tacit skill from one discipline to another becomes easier, alongside a concept of quality.

Perhaps the most significant criterion that needs to be addressed for the first time in the transfer of skills from craft engineering to contemporary design specialising in glassmaking, is that of autonomy of purpose. A craft engineer works unsupervised but under instruction from a managerial hierarchy, or from technical drawings and best working practices. A contemporary craftsperson is a designer, developing new ideas, perhaps using processes developed specifically for the job in hand. Autonomy of purpose enables a craftsperson who possesses tacit skill to experiment with the new, allowing the development of tacit knowledge and understanding.

Autonomy of Purpose separates the factory worker, following a pre-defined plan, from the contemporary craftsperson, who is free to experiment and develop even our greatest mistakes. A factory worker possesses tacit skill, but the contemporary craftsperson possesses tacit skill, knowledge and understanding.

Using Reflective rationality to develop a new glass furnace, using historical thinking to develop a new buisness model.

Before the development of complex admin systems, all decisions were made within the working environment, and the craftsman, in this case the glassmaker, also developed and built the furnace equipment, mixed the glass batch and produced the product. As a qualified gas engineer with experience in the installation and maintenance of large-scale glass furnaces, it seemed logical to build my own furnace, one that cuts the energy needed to run it by more than half. I designed a prototype design based on a 17th century furnace, and more complex systems are planned which use ideas first seen during the renaissance, although with modern materials and technology. (The design of the furnace is evident in Hankey 2009.) I have been working with glass since 1981 and spent eight years as technical instructor in hot glass at the RCA, and it was only recently that I first began to mix my own glass batch. This way of working is far more labour-intensive, but this is not a negative. With the glassmaker more in control of the materials and the process, the skills that previously were thought beyond modern knowledge are retrievable again. It is not that the skills were necessarily lost, but that the ideological insistence on a way of working (which values speed and a mechanistic heterogeneity over tacit knowledge and a thoughtful, cradle-to-grave approach to a process and a material) has made us blind to the possibility that a different way of working could give us the skills we thought we had lost.

The furnace was tested for the first time at the second Making Futures conference in 2011 and was situated at the Dartington Hall Trust site 'The shops at Dartington' for 12 months to prove its viability. It is a perfect example of the transfer of a concept of technical and tacit skill, knowledge and understanding from one discipline to another. Borrowing a business model from the 17th century and combining it with modern technology and materials, it has proved to be a very successful and reliable furnace that cuts the daily, hot-glass workshop gas bill, from £120 per day to less than £30 if run on natural gas.

The RGH1 glass furnace, developed on 17th century thinking with cutting-edge materials and computer-controlled high/low combustion system. It cuts down the cost of running a professional studio by 75% running on natural gas, while enabling excellent glass quality.

Transferring traditional craft skills to digital technologies

This third transfer of skill, from glassmaking to CAD CAM design, raises the very interesting question as to whether work undertaken using digital design and making is, could or should be regarded as craft. If we consider the new haptic tools, force feedback devices that allow us to 'feel' the surface of a 3D on-screen design, and the way in which we can now interact with 3D Autocad with a simple scanner such as *Microsoft Connect*, found on an *Xbox,* the answer is obvious. Anything that involves movement of the human hand to interact with material, whether solid, tangible or digital, in order to produce a 3D design, must be considered a craft. Anything that involves the performance of a practical skill is craft. We are already at a stage where we can manage without programming and even the keyboard itself. New interactive technologies, coupled with solid CAD programs such as *Solidworks,* provide a completely intuitive experience for the designer, where the hand dictates what happens to the on-screen material, without the use of traditional or digital tools. As the hand is guided by the mind and the eye, this very new development is extremely similar to one of the oldest ceramic processes, throwing a pot on a wheel.

As I have become used to working with a 3D *Touch* printer, I have found that I felt more comfortable using it after I stripped the printing heads down to replace components. It was as if I needed to get my hands involved with how it works in order to get to 'know' the machine. It seems rather informal to say that I can now 'feel' when the printer is 'happy'. Comfortable, know, feel, happy. These words seem too simple to be listing in a published paper, but they are what tacit skill is all about. Implied, but not stated; tacit knowledge and understanding deals with the feel of things. I can hear when the machines' motors are slowing slightly, indicating that the height of the build bed needs fine adjustment. I can also hear a slight juddering when there is a problem with the feed material. I can see when the raft appears either too hot or too cold and I understand the strange electronic glitches that only occur when the machine hasn't been left to cool for long enough before the next print is started.

It is important to recognise that a 3D printer, or CNC milling machine, is simply a complex tool and not creative in itself. The tools I use for glassmaking only become creative once they are in my hands. Only when a machine possesses autonomy of purpose will it become creative in itself.

As a musician I see parallels with designing and making, and composing and playing. In a literal performance of a skill, the musician has the ability to make the notes 'sing'. The gaps between the notes, the strength of each note as it is struck or played and the resulting sustain, are all variables that can make a piece of music excellent or dull. An acoustic guitar is played and the result is immediate – the hand strikes strings and presses down on frets resulting in an immediate outcome. This is very similar to throwing a pot or blowing glass. A simple cylinder can 'sing' or can be dull depending on the practical and tacit skill of the maker.

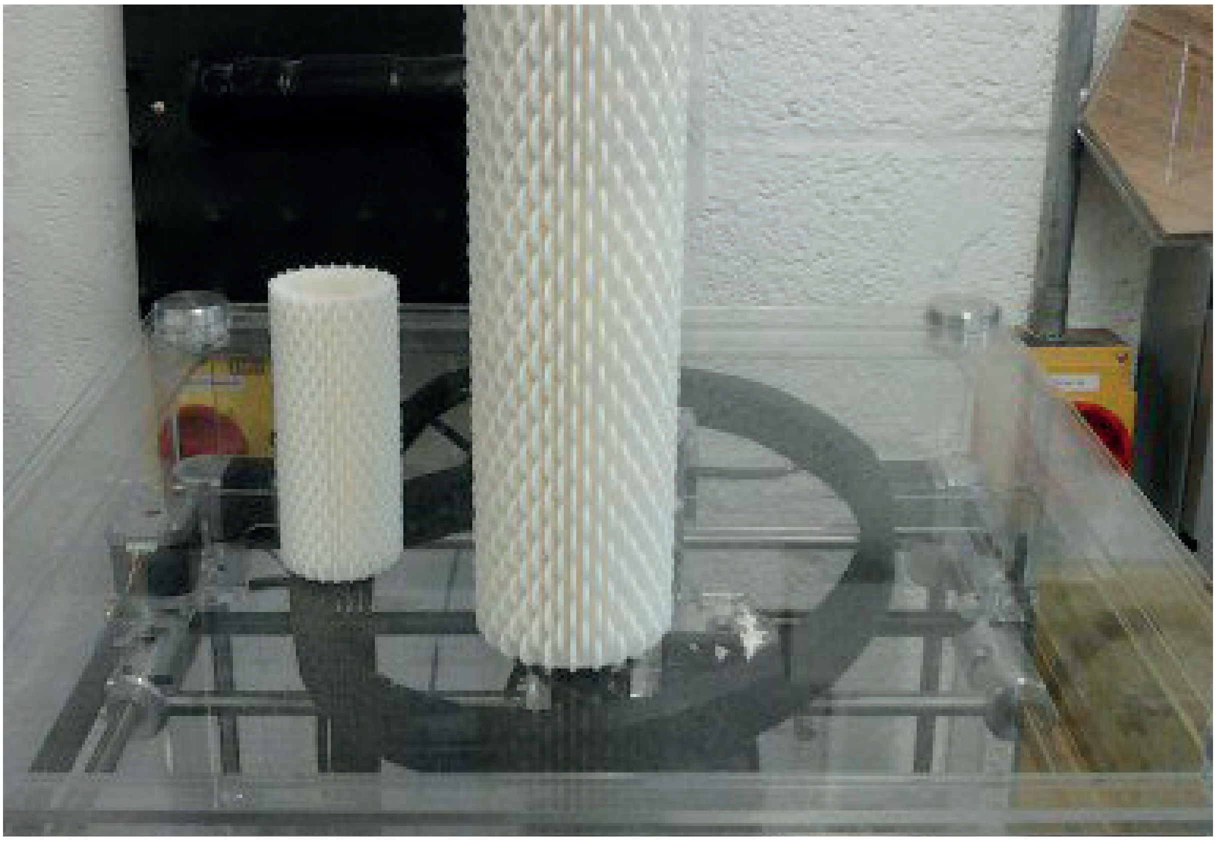
An electric guitar takes a signal from the strings to the pickups converts it via an electric signal to the amplifier. Interestingly, the result can be distorted to such an extent that the guitarist can 'play' feedback from the speakers as well as the strings. No-one would deny that the performance of music using distorted electric guitar can result in extremely creative outcomes – the influence of Jimi Hendrix in rock music is testament to this.

Similarly, the ability of a maker to influence the creation of computer-aided design using the hand and indeed the body enables a creative outcome which can be further 'distorted' using digital technology. The ways in which we can and will be able to creatively 'distort' and 'play', manipulating the original design will possibly enable the most exciting developments in creative CAD CAM.

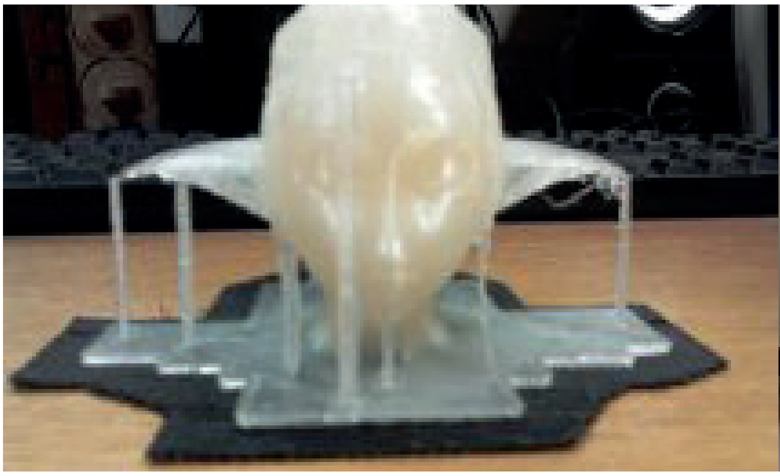
Using traditional craft skill to enable us to bypass limitations of the cheapest type of 3D printers

The most simple 3D printers, such as the 3D touch, build upwards from a base plate, making it easy to construct a simple form such as a cylinder, but impossible to build outwards as there is no support for the material. Much more expensive 3D printers incorporate supports that are generated from the original design. As a craftsperson, it was simplicity itself to design supports within the CAD file, which then enable any form to be printed. The results from a 3D printer costing £1,000 are extremely exciting, making 3D printing accessible and affordable.

It is common to see supports in 3D printers costing upwards of £10,000. They are programmed into the conversion software and are automatically generated from the CAD file. What I am doing is replicating that process, but building each prop 'by hand', that is, building individual props into the CAD file as the design is created. This is a natural thought process for a maker who has a practical craft background when faced with limitations. Problems can be solved many times with very basic traditional solutions.

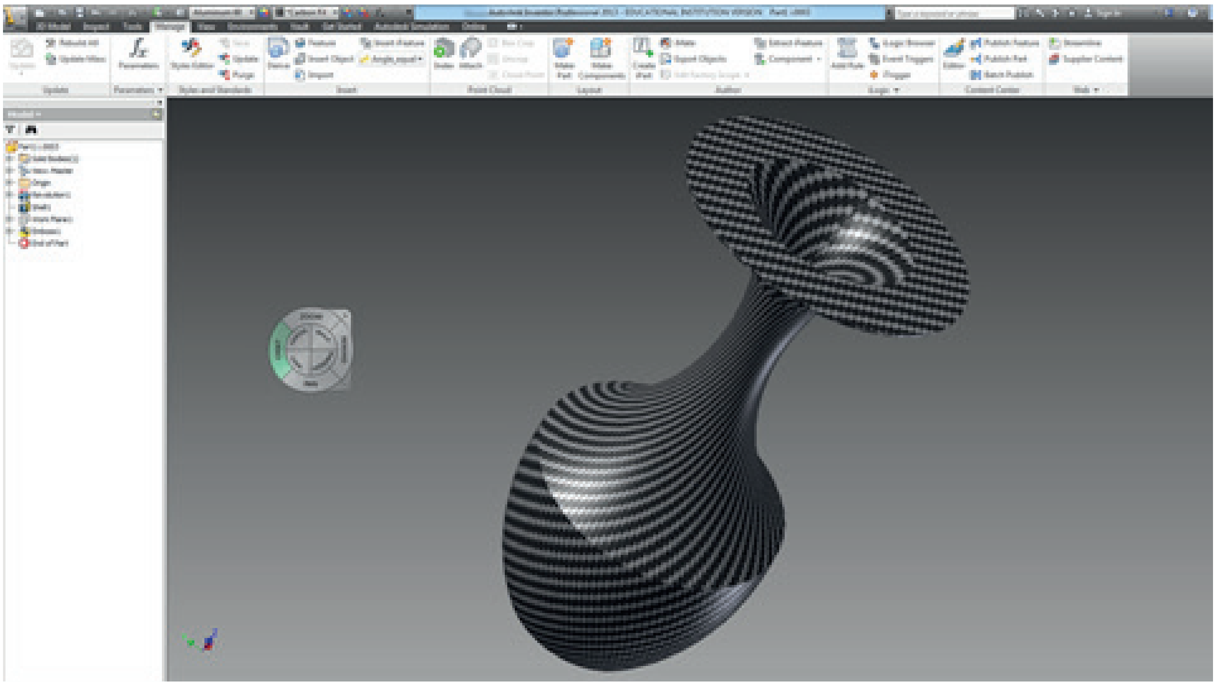


A simple cylinder with decorative pattern, designed on *Rhino* for PCA BA student, Ruth Harrison. The larger piece is far larger than the maximum making size and is made from two parts, glued together.



Top left – Pixie head, from a *Maya* animation file. The file caused glitches as it was imported into *Axon 2* to enable it to be printed. I imported it into *Rhino* first, constructing a secondary raft and built support posts to hold the structure while being built. Note the messy result on the right ear, where the support fell away during the printing process.

Top right – Dragonfly, incorporated flexible wings printed separately and then assembled.
Bottom – Train, designed on *Maya*, incorporated into *Rhino* and then into *Axon 2* ready for printing. The supports snap off easily rather like an *Airfix* model.

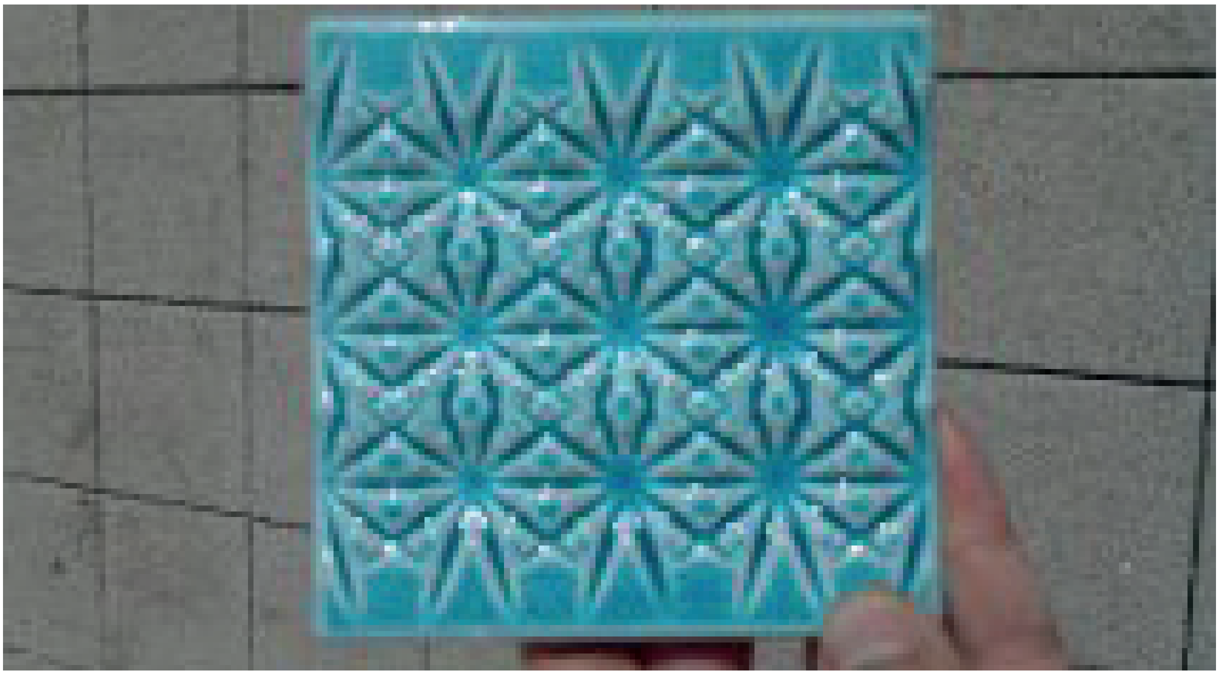


Above – Design on *Desktop Inventor*

Plymouth College of Art is about to incorporate new software into our Fab Lab, to be opened in 2014. We have examples of Mesh programmes (*Maya*), Surface programmes (*Rhino*) and solid programmes (*Desktop Inventor*) and will soon be working with the latest more intuitive software to go with a 3D scanner.

Using traditional and historical processes to generate new outcomes from CAD CAM

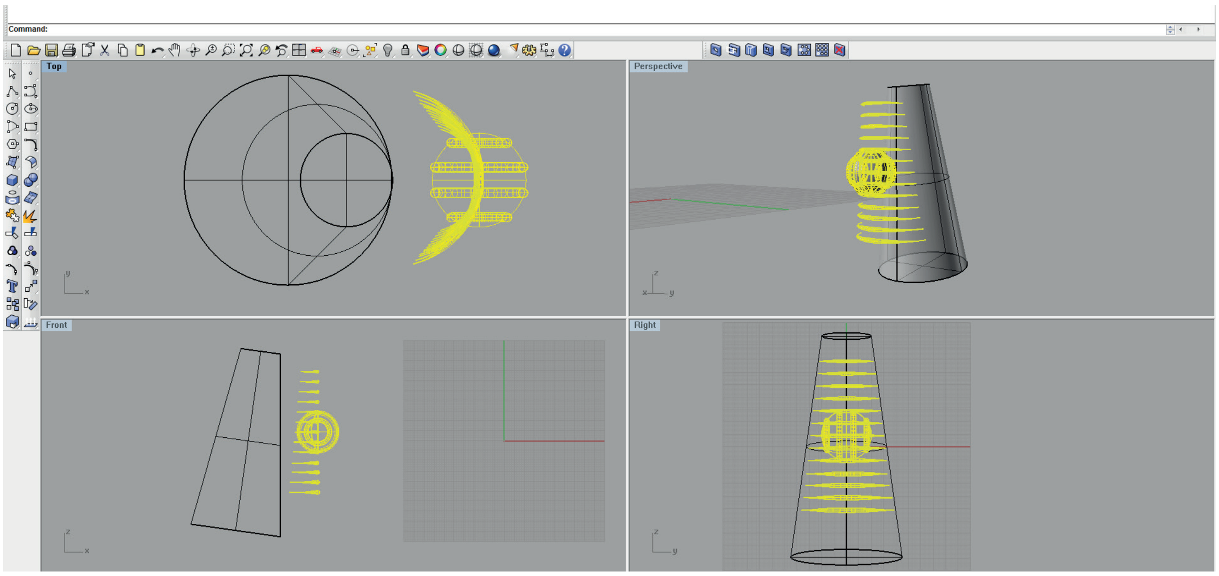
Above left – A roman cage bowl, carved from one piece of glass. An amazing, incredibly time- consuming and precious piece of work, that could only be recreated today using casting techniques. Above right – A 3D printed bowl that can be invested in plaster, burned out as in lost wax casting, and then cast in glass or metal.



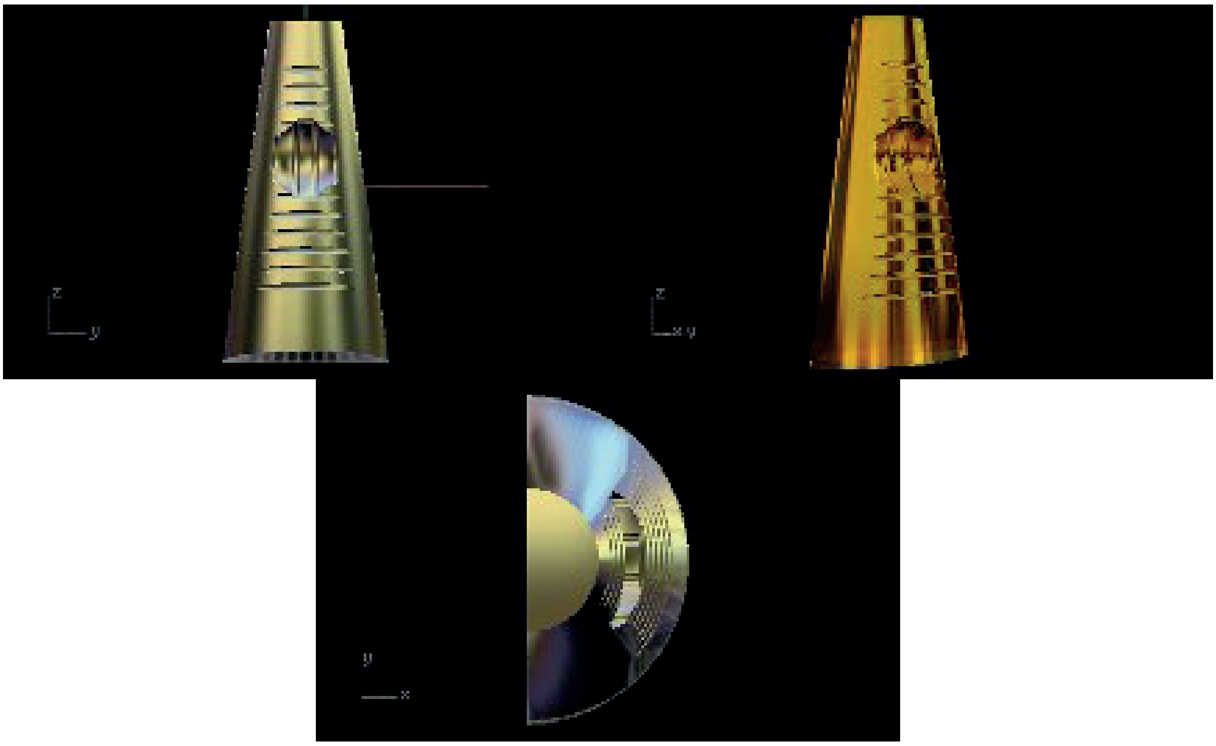
Above – A ceramic tile, slip cast in a plaster mould. The mould was originally produced in steel on a CNC milling machine. Gell flex was poured into the mould to create a template, which was then invested in plaster to create the mould. This traditional process can be used to produce, not prototypes but batch production pieces, capable of enabling detail of incredible fineness which could provide a sustainable business model enabling the re-introduction of traditional tile manufacturing to the UK.

Using a two thousand year old glass casting process with CAD CAM to produce the media innovation awards 2014

I was asked to assist glass artist, Amy Whittingham, to help to produce a steel mould from which her design could be made. Rather than investing 20 separate wax pieces in plaster, I convinced her that it would be easier and far quicker to cast the pieces directly from the furnace into a CNC-milled steel mould.
The first step was to construct her design as a *Rhino* 3D file



Once this was done, it was possible to produce renderings to see how the piece would look in a variety of materials.



The mould was made with a CNC milling machine and 20 glass awards were cast in less than four hours, each requiring minimal cold work (grinding and polishing). To achieve this result using lost-wax casting would takes weeks of work. What makes this process economical is the use of a hot casting technique, poured straight from a crucible, in the same way that glass was made 2,000 years ago.

Conclusion

The use of technical rationality as our preferred mode of thinking has resulted in a split that could be seen as between art and science, between what can be articulated and evidenced in words and what cannot. Over the years, the dominance of technical rationality has resulted in the downgrading of the tacit elements within work and as a result, the perception of craft is such that disciplines such as glass and ceramics are considered endangered subjects within art education establishments and in society as a whole.

We are living in a tremendously exciting time where we can bring together art and science, or rather more accurately art and technology, by combining traditional and historical craft processes with CAD CAM technologies. Not since the enlightenment has there been such an opportunity to bring together once more the combination of art and science, technical and reflective rationality, the implicit and the tacit. Indeed, the root word of technology, *techne,* originally meant 'art' in ancient Greek. What we are talking about here is a kind of 'Artology', perhaps not seen since the renaissance.

Skill, both tacit and implicit, is transferrable across disciplines including digital design but, also essential, is the concept of quality that is developed within the discipline, and the knowledge that there are a variety of ever changing criteria that need to be addressed in order to achieve it in individual and unique creative outcomes.

Rather than further threatening increasingly endangered subjects such as glassmaking, I now believe that new technologies will enable them not just to survive but to thrive. When combined with CAD CAM technology and processes, the traditional crafts may provide production manufacturing methods rather than the prototype development processes currently offered by 3D printing. Even if these methods are for smaller-scale batch production, there is now a real opportunity to make the traditional crafts viable again, not just economically, but as a very real and important part of our society. We can re-connect craft skills with a society which would clearly see the importance, viability and exciting potential when combined with CAD CAM technologies.

CAM on its own is not craft. It is just a series of very clever and complex tools. CAD however, allows us to manipulate virtual materials with our minds, hearts and bodies, with or without a keyboard as an interface. This is craft. As a guitarist 'plays' distorted and manipulated sounds in order to create art, it will be interesting to see the way in which artists and designers create, distort and manipulate their work in order to make it 'sing'.

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