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Glass: Technical and Reflective Rationality and the Implementation of a Sustainable Business Model.

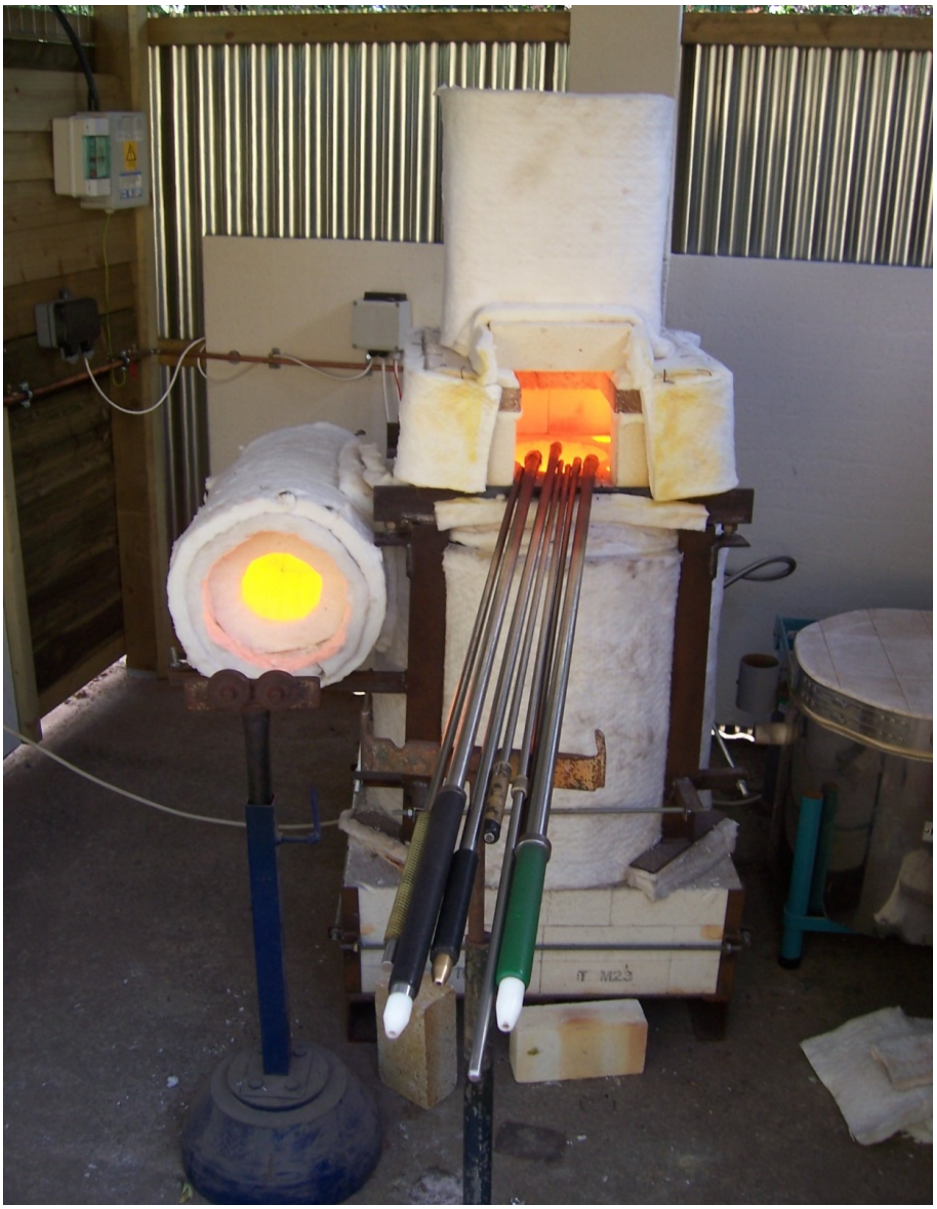
Abstract

This paper presents the research and development of pre-17th century kiln technology, which has led to the design of a new sustainable studio glass furnace with modern technology and materials. The aim of this research was to provide a breakthrough for sustainable studio glass technology. 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.

Underpinning this research is a deeper enquiry into the place and position of tacit knowledge. Comparing the technical rationality of today with pre-industrial revolution reflective rationality, I will suggest that our actual mode of thinking, the way we think as a society, actively undermines the importance and recognition of tacit skill. 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 – joining learning and making a living, history with the future, valuing the whole person – learning as much as writing – and the kiln design is 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 paper presents the findings of the first part of my research project, presented at the 2009 Making Futures conference, evidencing proof of concept from the first furnace designs, through the success of outcomes which were set out at the beginning of the project.
In collaboration with Dartington Crystal and the Shops at Dartington, I am building on my previous research with the design of a new type of glass furnace by placing a prototype into a professional environment in order to demonstrate that a sustainable and viable business model for graduates is possible.

The project will dramatically increase the capacity of PCA's glass facility and provide learning experiences for our students via WBL and internship opportunities and graduate start up schemes. During the next year, a larger furnace will be constructed for this site which will incorporate more than 1 crucible, a gloryhole and lehr. As with the current prototype, this new equipment will then be tested and evaluated in a professional and business context.



The RGH 1 prototype glass furnace, based on 17th century ideas of sustainable design, with the gloryhole used to reheat the products as an integral part of the furnace rather than a stand- alone unit which is expensive to run. This furnace was built without measured drawings, but uses the dimensions of standard refractory bricks and the size of the crucible and an oil drum as concise units of measurement. This ensures an extremely simple design with no bricks to cut, and is an example of the effective use of reflective rationality as a preferred mode of thinking when designing and building new or innovative equipment.

Glass: Technical and Reflective Rationality and the Implementation of a Sustainable Business Model.

I began my career at Pilkington Glass in St Helens 30 years ago. I served a craft engineering apprenticeship on the maintenance and installation of factory services. I later went on to go to art school, a BA in 3D Design and a Masters degree in glass at the RCA. Glass is in my blood. I worked for 8 years as technical instructor in hot glass at the RCA, have designed for Habitat, sold my own work to galleries and managed a medium size glassworks for 4 years before becoming a lecturer at Plymouth College of Art. I now teach glass, work based learning and professional practices and I am also on the design team for Dartington Crystal and Caithness Glass.

In this paper, I would like to present the findings of part one of my research, the building and evaluation of a new kind of test furnace using a combination of modern materials and technology alongside not only pre-17th century ideas, but the actual mode of thinking used at the time, that of reflective rationality. Underpinning this research is a deeper enquiry into the place and position of tacit knowledge. Comparing the technical rationality of today with pre-industrial revolution reflective rationality, I will suggest that our actual mode of thinking, the way we think as a society, actively undermines the importance and recognition of tacit skill.

It's interesting that I was drawn to glassmaking because of the use of hand tools that are needed for the production of studio glass. I'd spent 7 years as an engineering craftsman and felt at ease with any hand tools. When we consider compression joints in domestic or industrial plumbing, they need to be tightened up to produce a watertight or gas safe joint. If you don't tighten the joint enough, it will leak. If we 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 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 first came upon the subject of tacit knowledge during my Masters degree, through the work of Peter Dormer, whose book "The Art of the Maker" led me to the earlier work of Professor David Pye. In the 1990's, in order to find out more about the subject, I found on the internet a wealth of information within the scientific 'community', particularly in the area of research into artificial intelligence. The structure of tacit knowing was first introduced by Michael Polanyi in his book "Personal Knowledge: Towards a Post-Critical Philosophy" in 1958.

The word tacit means 'implied-not stated'. As such, it cannot adequately be defined in words. It applies to glassmaking perfectly because it's very hard to describe in words what we actually do. A simple example of tacit skill is how we recognise the face of a friend or colleague in a crowd of people. We can all do it. It's easy. But try writing down factually just how we go about this recognition process, without falling back on vague comments like "well I recognise the face". The result will be a complex document. Now magnify that complexity by a thousand and you'll get some idea what it's like to adequately define a tacit skill such as glassmaking. In fact, David Hamilton, who used to be professor of Ceramics and Glass at the RCA, once commented that glassmaking only occurs when hundreds of things fail to go wrong. Tacit skill is gained through experience and repetition of practical processes. In the factories, where ceramic products were

painted by hand, the workers would be talking about football or what was on telly last night while at the same time, demonstrating a high level of practical skill.

Tacit skill-in-action, reflection-in-action and *reflection-on-action* are increasingly complex aspects of tacit skill.

There is an assumption that because the craftsperson or practitioner cannot easily articulate what they are doing, that they are somehow lacking in intelligence. If somebody came up to me while I was working and asked, “How are you doing that?” I wouldn’t be able to answer. The thought processes involving the combination of memories of experiences that are needed to make a hypothesis, in order to implement a plan of action to deal with the task at hand, are far too complex to explain. The speed in which this thought process translates into action prevents such an explanation.

If, after I had finished the work, and the same person asked “How did you do that?” I still wouldn’t be able to answer because the action and thought process happens so fast that I can’t consciously remember accessing these memories of individual experiences.

While workmanship requires skill, craftsmanship, by definition requires tacit skill. A plumber is a craftsman. So too is a welder, fabricator or painter and decorator. My City and Guilds certificates refer to my Craft apprenticeship. I also have a certificate of Engineering Craftsmanship. In fact, it can be argued that the performance of any practical skill can be described as craft. What elevates the intellectual thinking of the contemporary craftsperson working in the applied arts is the introduction of reflection during the making process. A craftsperson in a factory is producing the same object each time during the making process. Any diversion from the norm is discarded and results in a loss of time. In contrast, the contemporary craftsperson is dealing with new situations, and a different form of intellectual thinking is required. It is relatively easy for a glassmaker to blow into a mould or produce lots of the same object because of the familiarity with the process. When I am asked to interpret a fine artists’ or a sculptors’ ideas, I have only a vague idea of how I’m going to make it. When I am working the glass, I am considering a range of problems that I have to solve. I use my past experiences in order to come up with a hypothesis to enable me to form a plan of action. I use my tacit skill to implement this plan and reflect on the outcome. What I am describing is ***reflection-in-action***.

“When someone reflects-in-action, he becomes a researcher in the practice context. He is not dependent on the categories of established theory and technique, but constructs a new theory of the unique case. His inquiry is not limited to a deliberation about means which depends on a prior agreement about ends. He does not keep means and ends separate, but defines them interactively as he frames a problematic situation. He does not separate thinking from doing, ratiocinating his way to a decision which he must later convert into action. Because his experimenting is a kind of action, implementation is built into this inquiry.”

Schon, D.A. 1983

When we are working on new designs, we are indeed researchers in the practice context. As we are constantly reacting to the material and processes involved, we are working on a higher intellectual mode of thinking than that required of tacit skill and are acquiring tacit knowledge. “But”, you may say, “this is just conjecture, albeit informed conjecture”, and quite right, too. I need to articulate explicitly, in words, in black and

white, exactly what I mean and prove my point. In doing so, I will be engaging in an even more complex level of intellectual thinking, that of ***reflection on action.***

"It takes considerable diligence to be in a position to be able to articulate a situation in working life – and this is crucial – to the point where we can grasp why it eludes precise description."

Janik A. 1988

Tacit skill requires craftsmanship, tacit knowledge requires reflection in action and tacit understanding requires reflection on action. I don't have a reference for this. I do know in my heart that it's right though, and this is enough for me. This isn't a guess, clutching at something that is ethereal, but a fact backed up by 30 years of the acquisition and application of tacit skill, knowledge and understanding.

"Tacit (silent) knowledge (Polanyi,1958) and implicit learning have in common the idea of not knowing what you do know or have learnt…. Originally, Polanyis' interest was in the kind of knowledge which we routinely use and take for granted, such as the ability to recognise the face of a friend: it is irreducible to explicit proportional knowledge and cannot be articulated. It cannot therefore be taught, although of course there is obvious evidence that it can be learned or acquired"

Atherton J S. 2002

Any argument involving a true craftsperson that possesses tacit skill is difficult, because our argument is 'silent'. We can only usually successfully articulate through the quality of our work.

I suppose I should say that I fell into research 'by accident'. When I worked at the RCA I was approached by Dr Sarah Fearn of Imperial Colege and Reinho Liefkes of the V&A to facilitate the practical aspects of recreating a 17th century venetian glass recipe. The scientists at Imperial College found that they couldn't melt the glass successfully as it was so aggressively corrosive. Indeed, our first attempt of melting the glass resulted in a dramatic failure of the crucible, which was selected for its ability to withstand corrosive glass and was supplied to us by experts in refractory crucibles.

Fig 1. The crucible was supplied by experts after matching the material to the aggressive glass recipe. The glass - or rather the 'scum ' on the surface of the glass, simply ate through the wall with ease.

It occurred to me that the Venetian glassmakers used clay pots which would have to have been 'glazed' using a small amount of pre-melted 'cullet' which would then be ladled around the walls of the crucible, thereby protecting the pot from damage. Using this knowledge, I developed a way of melting the Venetian glass and worked with it. The results astonished me. This 17th century glass has tremendous working characteristics and is a joy to work when compared to our modern glass recipes. When I experienced working with the 17th C glass formula, I knew instinctively that this glass was developed by a glassmaker. Back then the craftsperson had the same credibility as the scientist or technologist. In fact, if we go further back in history we see Leonardo painting the Mona Lisa, producing analytical drawings of the workings of the human body and designing helicopters in his spare time. There was no difference in the credibility of the artist, scientist or craftsperson because they could well be disciplines practiced by the same person. In terms of conceptual understanding, ***reflective rationality*** was the only mode of thinking available. This results in a 'try it and see' kind of research. Since then, art and science have separated and become two very different disciplines, which in turn require equally different kinds of rationality.

Modern glass is not made to recipes developed by glassmakers but rather developed by technicians looking at chemical compositions. What is important in these recipes is the clarity required in batch production under rapid conditions. In other words glass recipes are designed to support industrial conditions, but they are not set up to be sympathetic to the maker. The problems of industrialisation are systemic: as industry became more dominant, society required an increasingly complex structure. Administrative and political systems became more and more specialised, with a corresponding negative effect on the craftsperson. Once the link between the recipe and the process was broken in glassmaking the craftsperson could only specialise more. This way of conceptualising administrative intervention in educational and administrative systems is known as **technical rationality** and follows three main assumptions.

"There are general solutions to practical problems.

These solutions can be developed outside practical situations (in research or administrative centres).

The solutions can be translated into teachers' actions by means of publications, training administrative orders etc."

Altrichter H, Posch P, Somekh B. 1993

The most crucial aspect of modern technical rationality is that administrative and political change is decided outside of the working environment and handed down the chain of management to the practitioner in the form of instruction or training. The most significant aspect of reflective rationality was that any change was made within the practitioners' working environment. Solutions to problems were found in the glassmakers working environment, inside the context in which the problem arises.

These days every person who works in a large organisation has to have their role defined. It is very easy to define the role of the scientist or technologist in words

because the nature of these disciplines concern definitions and proven facts. But as we know, tacit skills such as those belonging to the glassmaker cannot be articulated into words. As such, it is impossible to define the glassmakers' role (or that of any practitioner) adequately. The problem is that once we attempt to make a system transparent, we must try to define it in order for it to be understood. As it is impossible to articulate the tacit elements, what is left is only what can be adequately described. The tacit elements, those vital ingredients that are needed to achieve quality in anything that we do are lost.

Before the industrial revolution and the complex explicit administrative systems that accompanied it, the preferred mode of thinking was that of **reflective rationality.**

"Reflective rationality, in contrast follows three very different assumptions: -

Complex practical problems demand specific solutions.

These solutions can be developed only inside the context in which the problem arises and in which the practitioner is a crucial and determining element.

The solutions cannot be successfully applied to other contexts but they can be made accessible to other practitioners as hypotheses to be tested."

Altrichter H, Posch P, Somekh B. 1993

What else can we learn from the 17th Century? I began to wonder how the reflective rationality which was dominant before the industrial revolution could be used to address some of the problems we face today as craft practitioners. After all, the early glass furnaces had to be fairly sustainable as it took a lot of trees to make a small amount of glass. Every ounce of energy was used in some way or another in reheating and annealing the products made.

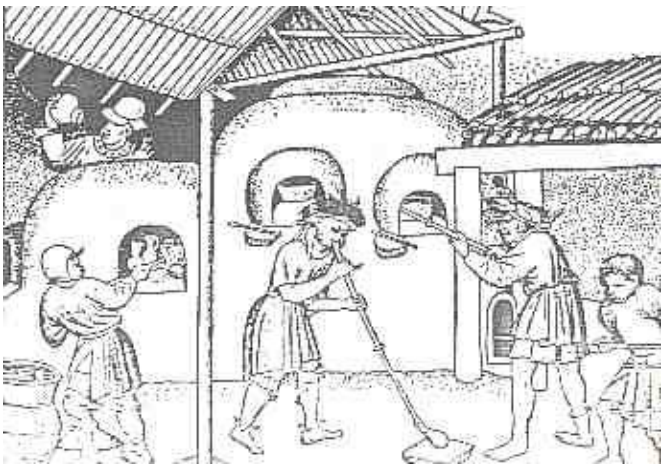


Fig 2. In this image, we see that the furnace is used to reheat glass and to provide energy for the annealing oven

There are many problems facing the glass practitioner. Increasing gas prices and cost of materials and massive competition from cheaper imports has resulted in most of our blown glass manufacturers closing down production and importing from overseas.

Dartington Crystal is the last major blown glass manufacturer in the country and have been a great supporter of my research. Smaller studios are beginning to close as glassmakers look to hire facilities rather than invest in their own workshops. (I really feel that cooperatives are the future for the studio glass sector). Conventional furnaces need to be on all the time, even when not in use by glassmakers. It can take between 3 days and a week to get furnaces up to temperature and ready to work from depending on their size and design. What is needed is a furnace that can be turned on and off only when needed resulting in a more viable business model, refractory materials and crucibles that can withstand rapid heating and cooling, and a new way of thinking when designing the furnace, using a combination of new technologies and reflective rationality.

In part one of my research, my main objectives were to dramatically reduce the cost of running a glass workshop, to reduce emissions and to provide the opportunity for further research and funding. I set out to design and produce a prototype test furnace that would reduce the energy needed (and emissions) to melt and work glass by between 1/3 and 1/2 in comparison with a conventional furnace. When the fact that it can be turned off when not in use is taken into consideration, fuel costs for a small business can be halved at least. Due to the lightweight refractory materials used in the design, it would cost much less to build than a conventional furnace and would pave the way for a viable, sustainable business model. At the forefront of my thinking at all times was to base my mode of thinking primarily in reflective rationality.

In order to evaluate the success of the test furnace, I worked with The Shops at Dartington to build a workshop in collaboration with Dartington Crystal and Plymouth College of Art. I lit the furnace for the first time on August 30th and have been making glass and demonstrating three days a week since then. Now that the furnace is in a professional working environment it can be tested over a longer period of time.

Initial findings show that the furnace can be lit with cullet in the crucible and can reach 1200 degrees C in 2 hours, in comparison with conventional furnaces which take days to reach working temperatures. It can be taken from cold with the crucible 1/3 full of pre melted glass and worked in just over 3 hours and can be crash cooled over the same time.

It is fitted with a control system and in the eventuality of disruption of electric supply or gas, the burner will automatically check and go through a purging process before re-lighting (something I haven't experienced in small furnaces before).

It can run on natural gas or propane without the need to carry out changes by engineers.

It runs from a standard single phase electric plug and attaches to the gas main via a standard gas cooker bayonet fitting, or to propane using standard fittings.

The gloryhole runs between 100 and 200 degrees hotter than the furnace mouth without any extra flame or energy required.

It cost me £400 to build (excluding burner and controller*) and costs less than £40 per day to run on large propane bottles. This is the most expensive method but results in a 'pay as you go' system that keeps you aware of the running costs. If the furnace is run on natural gas I estimate an average below £25 per day for the furnace and incorporated gloryhole.

I decided at an early stage in the project that I will share the first stage of my research, the basic test furnace, with glassmakers and graduates as it is only through the free disclosure of information that we can reverse the decline in glassblowing in this country. This term, students from Plymouth College of Art will be working in the workshop as part of their work based learning, and graduates will be using it to start their own micro businesses learning how to maintain and build their own furnaces before moving on to build their own workshops.

At this point I would like to mention the influence of a conversation I had nearly 10 years ago with Paul Chevelou of Dyson Refractories. He made a remark, concerning the crucible I'm using, that he tests them by taking them up to working temperature in only 4 hours, whereas the company recommends taking them up to temperature over a much longer time. This was the starting point for me, to determine just how quickly a thin walled crucible can be taken up to temperature and how long would it survive constant working conditions. The design of the furnace is one thing, but as I found when our most sophisticated refractory material was 'eaten' by a 17th century glass, the design of the crucible is just as important. Over the next year I will be putting as much effort into the design of crucibles as to the design of the furnace. The aim now is to produce a larger capacity multi crucible furnace that incorporates a gloryhole and annealing oven, costs far less to run and offers the possibility of a large clear pot of about 50kg and 2 smaller colour pots of about 25 kg each. The furnace will be able to melt batch in the larger crucible and will use reclaimed glass from that batch in the smaller crucibles. The furnace will be designed to be user friendly with gathering ports lower than the test furnace.

The scale of reduction in costs is so great, we have to ask, "What's the catch?" Of course with a 25kg crucible, glass quality will suffer although using an old trick of putting a potato into the glass breaks up chord very successfully – another great trick from the past. It must be remembered that this is a test furnace and the larger crucible furnaces will ensure adequate glass quality for a studio.

The main issue with these new furnaces is that of maintenance. In order to make these savings, I have swopped a conventional high cost, low maintenance design for a low cost, high maintenance design. This way of working is far more labour-intensive, but this is not a negative. I can turn the furnace off, crash cool it, take out the crucible, replace it and have the furnace back on in just under 2 hours. If the pot is empty, I have taken it from 1250 degrees to room temperature in only one hour without damage to the crucible.

Of course, in the event of a run out, there will be more work to do. However the furnace has a large amount of sand at its base and even if I have a total disaster and have to completely rebuild it, it will cost about £60 in ceramic fibre and about £40 in fire bricks and would take about half a day to complete.

It is this way of thinking that is producing such exiting results. The whole project uses reflective rationality, thinking outside of our technical rationality 'box'. Why do we have a gloryhole using up as much energy as the furnace and yet in only used between 5 and 10% of the making process? Why do we have the expense of running an annealing oven when we could easily use the waste heat from the furnace? We know it's possible, it was done in the 17th century.

The answer is because in industry, scale of production demand specific processes and equipment was designed around those processes. If you are producing hundreds of items, you need separate annealing ovens and gloryholes that run much hotter than the furnace, so that items are made and reheated faster. Speed is king on the production line and when it comes to studio glass, we seem to have accepted smaller versions of the industrial model.

As the influence of science and technology has been enhanced over the years, the influence and therefore the **credibility** of the craftsman has diminished. Within the conceptual framework of technical rationality, craftspeople within manufacturing industry are perceived to be working on a low level of theoretical knowledge and are merely following instruction from the managerial and administrative power structure above them. The introduction of technical rationality into modern society has created a complex hierarchy of managerial responsibility. The trouble is that within these power structures of large companies and organisations, we confuse this hierarchy of responsibility with a hierarchy of credibility.

Technical Rationality, society's preferred mode of thinking, encourages a hierarchy of responsibility and undermines the importance and credibility of the craftsperson, and therefore of tacit skill.

"This hierarchy expresses a genuine mistrust of practitioners. Within the conceptual framework of technical rationality, they are working on a low level of theoretical knowledge and are merely applying what has been predefined in the academic and administrative power structure above them."

Altrichter H, Posch P, Somekh B. 1993

This hierarchy of authority is so strong within our society that credibility and tacit knowledge has very little influence in some of our established complex administrative systems. The fact that something is written down overrides the vital knowledge of practitioners.

Before the development of complex administrative 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. I have been working with glass since 1981 and spent 8 years as technical instructor in hot glass at the RCA, and it was only last year when I first began to mix my own glass batch. Again, 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.

I'm incredibly lucky to be fortunate enough to become expert in craft engineering and glassmaking. I have built and maintained furnaces and have the skill and knowledge to be able to construct the test furnace, and will be constructing larger, more complex furnaces containing multiple crucibles and incorporating a gloryhole and annealing chamber.

We are very fortunate as creative practitioners that we differ from the majority of society in that we use reflective rationality within our practice as our preferred mode of thinking. I believe that far from being an outdated way of making and knowing, as much of public perception views the crafts, creative practices and reflective rationality point the way ahead for the future of manufacturing in this country.

Technical rationality encourages a hierarchy of responsibility rather than credibility, and complex written administrative systems far outweigh the local systems developed by practitioners, undermining the importance of tacit skills. Not only does society mistrust what can't be written down, but it is increasingly failing to recognise the importance of tacit skill, knowledge and understanding. Our actual mode of thinking actively undermines tacit skill and knowledge and therefore craft itself.

For this reason it hasn't been easy to persuade building managers to allow something like an experimental glass furnace to be constructed and worked in public places, and it is a credit to Plymouth College of Art that they have accommodated my research and supported this project. I don't believe that I could have built and installed the furnace anywhere else. As craftspeople we simply don't have the credibility or influence to be taken seriously without having organisations such as PCA, Saflame and Dartington Crystal behind us. In a society that values technical rationality over reflective rationality as its preferred mode of thinking, the craftsperson or practitioner becomes an increasingly less credible voice within our administrative and political systems. Yet we have an ability to get things done, to take risks and develop new sustainable ways of doing things. In a country that has very little manufacturing, we are in a unique position where we can demonstrate not only that we can produce quality work, but that we can lead the way in developing new entrepreneurial business models. Imagine trying to run a large factory using experimental energy sources such as hydrogen fuel cell technology. The scale makes it impractical. But we could fun a small furnace, kiln or forge. In this way we could bring together applied art and applied science in a way that truly reconnects craft with society.

"There should be a symmetry, rather than a hierarchy of power- a more dynamic learning culture, based on the understanding that local initiatives exist already, and that their growth process should be supported rather than being ruptured and thwarted by imposed change."

Altrichter H, Posch P Somekh B. 1993

Using the prototype furnace to demonstrate and engage with the public at the new glass studio at Dartington

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