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# The Art of the Maker – Craft, Design and Technology in the 21st Century

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## Abstract

*Invention, innovation and insight are keywords for any technologist and designer working in the academic or commercial sector. In the twenty-first century, a wealth of new and emerging materials, alongside digital methods for the manufacture of products and services are transforming and enhancing our lives. But there are also the age-old techniques and crafts traditions that demonstrate fundamental benchmarks in material culture that are the foundation for high-quality printing and fabrication today and in the future. And without these benchmarks in quality, we have no assurance as to diversity and quality over the ubiquitous and inadequate.*

*Exploring the future of printing and fabrication, new ways of thinking and working, alongside traditional methods of making, this paper sets out the shifting field of Homo Faber and the human condition, and how digital technologies are transforming craft and design.*

## Introduction

Over the last century, craft - a way of thinking about and making things - has been an important bridge between art, design and industrial design. Craft and making is fundamental human activity, and its applications can be seen both in the home, gallery, factory and in a hospital ward.

Oxford English Dictionary (OED), describes craft as skill, ingenuity in constructing and dexterity. Its etymology can be traced far back to 888, by King Alfred who exclaimed what wonders could be created through craft, "*Wundorlice cræfte þu hit hæfst gesceapen*". [1] Joseph Moxon in the 17th century, described the importance of good workmanship in the application of woodwork in his Encyclopædia on handy works, "It is counted… good workmanship in a Joyner, to have the craft of bearing his hand so curiously even, the whole length of a long Board." [2]

The term craft and making at the latter end of the 20th century was used pejoratively, but more recently craft has experienced a revival and critical academic scrutiny. According to Tanya Harrod, the term craft is a "contested concept, a word with almost too many associations." [3] We are so familiar with the term craft that we assume we know what it is. Julia Bryan-Wilson calls craft anachronistic, contradictory, outmoded yet utterly contemporary, edgy and radical. It is high art and vernacular, it is purposeful and mindful, yet hobbyist and decorative. In the digital age, it has maintained tactile materiality but also embraced and connected to new technologies. [4] In the UK, the disciplines associated with craft tend to be termed as applied arts, reinforcing the idea that craft is supplementary to other creative activities such as photography and sculpture. Yet as Adamson asserts, "craft is indeed always 'applied', always in motion towards some objective" [5] and what one could consider as a crucial aspect of craft.

Craft cuts across cultures, ages, disciplines, it is difficult to verbalise, and in order to thoroughly obtain a new skill, is dependent on the application of knowledge that is practised and developed over time.

## What is craft, why do we make things, and why does it matter?

In an exhibition series exploring the impact of craft, the V&A showcased and celebrated artists' relationship between material, hands, tools and tacit knowledge. [6] Daniel Charney describes making as critical for survival or a way of learning, [7] likewise, Thomas Thwaites, author of *The Toaster Project: Or a Heroic Attempt to Build a Simple Electric Appliance from Scratch* asks "do we know how things are made?". [8] Robert M. Pirsig, author of *Zen and the Art of Motorcycle Maintenance,* asks "how to fix things if they are broken?". [9] Furniture maker Peter Korn in his book *Why we make things and why it matters*, believes that "caring about what you do, is a moral imperative". [10] As Richard Sennett author of *The Craftsman*, suggests, "it is an enduring basic human impulse, the desire to do a job well for its own sake." [11] Of course, what Sennet is also implying is that to do a good job is not just related to craft but can be applied to any field. Korn's motivation for accomplishing a task "is to gain a sense of meaning and fulfilment". [10] It seems, therefore, making is also loaded with a range of human values, such as pride, self-transformation, desire to do well for its own sake, and problem-solving. And it is this problem solving, critical thinking, and reflection that moves the hobby or the amateur to skilled.

## Tools and making things by hand

Craft and technology are also framed by making things by hand, manipulating materials and the tools necessary to do the job, [12] as well as identifying problems, solving and critiquing.

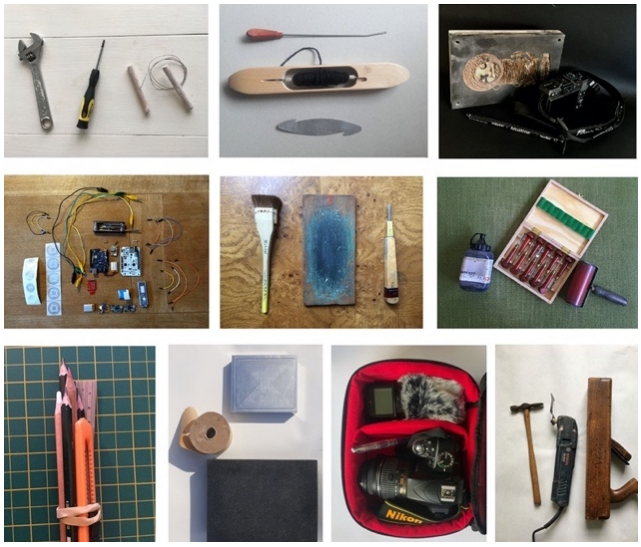

***Figure 1.*** *#letstalktools. Curated by Sofie Boons and Tom McDonah (2020), researchers were asked to choose three tools essential to their practice.*

Tools are crucial to making, but knowing how to use them is paramount. In the current age of things that are 'handmade', David Pye, attempts to distance the idea of things that are made by hand. Are objects made entirely by hand, or are tools involved, are these hand tools, power-driven, or in the case of this century computer controlled? Handmade could be considered as a historical term and not a technical. [13]

In a recent activity hosted by Sofie Boons and Tom McDonah at CFPR, [14] researchers were asked to reflect on a quote by Abraham Lincoln, "Give me six hours to chop down a tree, and I will spend the first four sharpening the axe", and to consider, what three tools are essential to their practice? It was interesting to note, although all of the group work with digital tools, their practice is still firmly embedded in the craft of making, using analogue tools alongside digital ones.

## A noble trade?

Manual labour in the pre-modern era was a life or death existence for the labourer, and making things was a necessity and not considered as a noble occupation. Whereas, traditional thinking and philosophy, influenced by Plato and Aristotle elevated the philosopher over the labourer.

The trade guilds of medieval Europe were similar to the ancient Roman *collegia*, [15] with which they may have been historically connected. In the German city of Augsburg, craft guilds are mentioned in the Town Charter of 1156. In the UK, by the 13th century, almost every town hosted a merchant gild, and by the 14th century, all the crafts were represented by a guild. Merchant and craft guilds were established in towns or regions of a city clustered around on their trades, or based on the relationship to a geographic location or allied trade (eg. weaving and wool, paper and water), and formed to protect and promote common interests.

By the end of the 14th century, a number of guilds received royal charters by which the King granted them special privileges and power. In 1436-7, Parliament passed legislation making it mandatory for all guilds to be legally registered. Guilds were also highly regulated, prescribing the quality and value of the work, and the hours of work. [16] In contrast to the regulated guilds the *ouvrier libre* or free artisan, posed an economic threat to the guilds. In Paris, where medieval rights of asylum were in place, artisans flocked to work in dubious working conditions and exchange for a high rent, avoiding guild fees and in the hope to make undercut competition. [17]

Training and the specialist transfer of skills and secrets of the trade evolved over centuries through guilds, workshops and studios, handed down by masters to apprentices, who largely served as technicians. Like the guilds, master painters such as Durer, Rubens and Titian oversaw large and busy workshops, where technicians ground pigments, prepared panels, painted the background for the masters to apply the finishing touches. Many apprentices traditionally remained anonymous. Studios and technicians working for international artists perform the same function today. In the so-called *post skill* era, ideas are more highly valued than the ability to make the artworks. Assistants make the work, but are not necessarily credited. [18] However, artists such as Ai Weiwei are careful to acknowledge how his works are made, because of their cultural, political and social implications. For example, Ai Weiwei's *Sunflower Seeds (*2010) were handmade in the city of Jingdezhen, a region of China south of Beijing. Historically famous for its kilns and the production of imperial porcelain, this region is still known for its high-quality porcelain production. Individual craftspeople made the sunflower seeds in a 'cottage-industry' setting, rather than in a large-scale factory. [19]

The introduction of the James Watt steam engine, at the end of the 18th century, meant new manufacturing methods, and mechanisation could be easily out-perform the efforts of craftspeople, leading to mass production of consumable and functional objects, including tableware and clothing, bricks and glass. As the machine age advanced through the centuries, the divide has increased between the makers – those who know how to make the things or indeed want to know how things are made, and the consumers of things; each of which can be categorised from the splendid and unique to mass-produced and utilitarian.

Walter Gropius's first manifesto of the *Staatliches Bauhaus* (1919) called for a vision that explored "research work for industrial production, speculative experiments in laboratory-workshops where the preparatory work of evolving and perfecting new type-forms will be done". Gropius vision had a significant impact on art historian Herbert Read, co-founder of the Institute of Contemporary Arts, who was a keen advocate for extending the model of the "craft workshop to productive industry, and applying hands-on making to research". [20] Sir Christopher Frayling, having held many positions including rector of the Royal College of Art, chairman of the Arts Council and Design Council, asserted that craft and practitioners needed to shed nostalgic connections with the past and to embrace the varied and versatile. [20 pg.33]

## Crafting as a nation – the amateur

In 1755, Denis Diderot (1685–1759) predicted that people in the future would not spend their time reading but rather 'devote themselves to investigation which will be new, or which they will believe to be new'. He further suggested that those unable to come up with their own ideas, 'will be busy night and day leafing through these books, taking out of them the fragments they consider worthy of being collected and preserved'. [21, 22] There are contemporary synergies, such as How-to-Books, YouTube and other online teaching platforms where a vast range of techniques are shared; from applying make-up to building a brick wall.

And, what have we been doing over these past few months? According to the Office of National Statistics (ONS), people confined to their homes during Covid-19, there has been a substantial increase of 147% in the time spent gardening and doing DIY. [23]

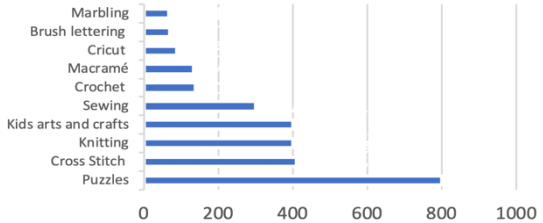


***Figure 2.*** *Source: search on Hobbycraft website and theguardian.com*[14]

We have also taken to a number of craft activities. According to the UK's largest arts and crafts retailer, online sales during Covid-19 increased by as much as 400% for some crafts projects, with total revenue increase by 8.9% to £193.6m for the year ending 16th February 2020. Online sales grew by 19% over the same period. [24] At the top of crafts were knitting and sewing, and other novel crafting activities such as amigurumi or Japanese crochet and macramé at more than 100% increase.

Of course, crafting is not new, otherwise termed as home-craft, handicrafts, defining people as a hobbyist, the Sunday painter, many generations both old and young have explored craft classes, how-to books, and summer schools in search of new techniques and inspiration. According to Stephen Knott in his book *Amateur Craft History and Theory*, we are entering a third industrial revolution. [25] Although amateur craft is more aligned to technique and less critique, the need for traditional, craft skills, analogue processes are still in demand and in-fact being reinvestigated and renewed. The French word amateur, is derived from the Latin *amā-re,* or to love, [26] and tends to be used pejoratively to describe a person who enjoys cultivating or dabbling in hobbies as a pastime without critical skills beyond superficial engagement. According to Josh Kaufman it takes 20 hours to learn a new skill, [27] experts working for a lifetime in their field would certainly disagree, but 20 hours - equivalent to a short summer course – is possibly enough to give the learner an appreciation of the complexities of making, and an appetite for learning. Making things is simple, but requires practise and knowledge of materials and process. However, hobbies can lead to extraordinary outcomes, blurring the boundaries between amateur and expert. How do we progress from hobbyist to expert?

## The art of being an expert

What do we mean by being skilled? Surely it must be a precondition for all making? As Adamson suggests, the skilled practitioner takes proficiency for granted. It is only through the complicated process of acquiring a skill that skill as such emerges. [5 pg.75] Can we become an expert simply by doing over and over? It is misleading to describe skill as the mere result of repetition. [28] However, Pye suggests that skill is not a word to be used and is a thought-preventer, [29] instead he states the quality of the result is not predetermined but depends on the judgement, care and dexterity which the maker exercises as he works." [28 pg.4]

***Figure 3.*** *Filmmaker and Printmaker, Wuon-Gean Ho (2020) "Mini Mokuhanga film" https://vimeo.com/412297888*

Here the critical factor is tacit knowledge – unspoken, acquiring an in-depth knowledge that cannot be explained, that is embodied through practice and efficiently responding to materials and tools. [30] Our understanding of materials, and the process of making is multisensory and built up as a library of cognition over time. [31] When we look at a material, we use different perceptions to gauge how it feels (sight, touch, audio), we can discriminate if something is wrong (change in vibration, the change in pitch of a drill bit when encountering resistance). Wuon-Gean Ho, Research Associate (CFPR), records the process of cutting and printing a woodblock in Mini Mokuhanga film (2020). The film focuses on the sound of rhythmic noises made by different tools working on the wood.

## Passing on skills

During the so-called *Age of Enlightenment* of the 18th century, there evolved a desire by the philosopher to gather and store knowledge and to bring a wider body of knowledge together by assembling the sciences, arts and manufacture into a dictionary of universal knowledge. From 1750, Diderot was employed to describe and illustrate all the arts and scientific advances, and publish as an Encyclopédie. However, the Guild's were firmly against Diderot's attempts to reveal their craft knowledge, and which could potentially undermine the Guilds' power. In order to complete the twenty-eight volume project, Diderot was forced to continue his work in hiding. [22]

As a grand *Enlightenment* enterprise of the 18th century, the Encyclopédie culture fuelled intellectual debate in the salons that brought together discursive activity from different social and cultural backgrounds. Diderot's observations in 1755 reflected a typical structure of society: skilled makers actively engaged in problem-solving and innovating, those involved in working and making, and lastly observers, philosophers and consumers. This structure or divide is certainly typical today. [22]

How are skills acquired and applied? Polyani explains: *An art which cannot be specified in detail cannot be transmitted by prescription, since no prescription for it exists. It can be passed on only by example from master to apprentice. This restricts the range of diffusion to that of personal contacts, and we find accordingly that craftsmanship tends to survive in closely circumscribed local traditions.* [27 pg.55]

In contrast to the closely guarded secrets of the guilds and studios, which is considered by Polyani as restrictive, the imperative is to not just to pass on artisanal skills in order to preserve a past, but a desire to provide new opportunities and insights for the future. At *Homo Faber* in 2019, hosted by The Michelangelo Foundation, [32] experts from around Europe discussed topics including the relationship between traditional skills and the digital world, the challenges of contemporary art restoration, ways to communicate about craftsmanship, and the importance of passing on artisanal skills to ensure their future.

How might skills be transferred between experts of different disciplines, and how might they learn from each other? Roger Kneebone, Professor of Surgical Education at Imperial College London, gained a two-year Welcome Foundation fellowship to explore the surgical overlaps between the fields of art, performance and craftsmanship. Filmed by the Crafts Council, he and Joshua Byrne of Tailors Byrne & Burge, explore the similarities between their very different professions. [33] The obvious connection is through sewing, but more importantly, the aesthetics and synergies of sewing garments and people together. A person recovering from reconstructive surgery, would not welcome ugly scar tissue; likewise, a person dressing for the day would prefer to wear clothes that fitted and enhanced their body. Therefore, the surgeon and tailor's aim are to ensure their clients feel and appear body confident. Both describe the function of their tools - straight needles for flexible fabric, and curved needles for a surgeon to reach a difficult area behind an organ. Their dialogue also considers the importance of achieving a balance between tension and flexibility of material or skin - how a material might react to different cuts, working with different fabrics, tension versus pliability of skin and organs, joining one material to another, and the limits of stretching and easing. [34]

Kneebone narrates another meeting between vascular surgeon Colin Bicknell and needle lace-maker Fleur Oates, both use thread, but in different ways. Both agree it is the connection between hands, materials and tools. During their first encounter, they explore tips on the unwanted twisting suture material or tangling of thread. They discuss tension: human tissue can be forgiving, but fabric exposes distortions. The lace-maker invites

the surgeon to stitch into fabric, which enables Bicknell to appraise his own practice and explore alternative methods. [35]

## Craft and technology in the 21st century

In the 21st century, the craftsperson has access to all the traditional skills and materials, and along with using computer-aided technologies, they have the opportunity to make something unique, personal and highly functional. But, how do notions of craft in the 21st century sit within an industrial and manufacturing context? When Neil Gershenfeld, of MIT's Centre for Bits and Atoms, was asked by his students, "What is digital fabrication good for?" His answer was the "ability to personalise – producing products for a market of one person." [36] Over the last decade, we have experienced new bespoke ways of functional digital workflow and mass-production methods for the single consumer. Today this has extended to specialist personalisation on a human level, for example, 3D scanning and printing for maxillofacial reconstruction, exoskeleton replacement of limbs, under development by Marine Shao and David Huson (CFPR) lifelike surgical training aids for surgeons, [37] or as exampled in the design process undertaken by Fabio D'Agnano (CFPR), who uses parametric modelling software and, more recently, machine learning to extrapolate details from a person's face to create better fitting and looking spectacles.

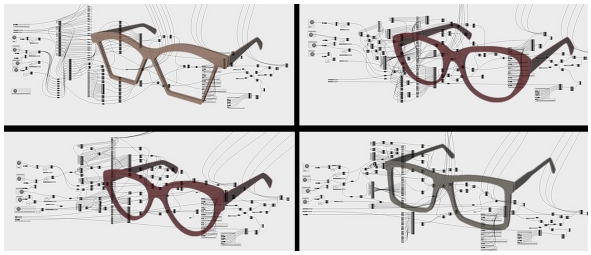

***Figure 4.*** *Bespoke 3D printed parametric glasses, Fabio D'Agnano*

In 2016, Google asked us to submit our doodles of objects via Quick Draw! It asked us to draw an image of a written word or phrase in under 20 seconds. Not only did the project provide a fascinating insight into the quality of people's drawings, but also the broader implications for how robots self-learn over time. It also demonstrated just how difficult it is to develop and train robots to draw. These new robots, Artificial intelligence, or AI - defined as algorithms that mimic human intelligence - authors have called into question the implications of robots and creativity. [38] The primary question is why would anyone want to use computers to make art? Is it for commercial gain, curiosity or as another tool to extend creativity? European craft manufacturers, from makers of luxury handbags, high-end furniture, to supercars, are exploring how 3D printing, robots and AI, can be combined with craft qualities, and yet, still maintain a craft identity. Furthermore, digital tools are not an antithesis to manual activity but can assist the development of artistic and craft production.

So far, it is the input of the artist as author to write the script and coding, and who masterminds the actions of the robot. All in all, the robot is still traceable back to the coded framework of the maker. However, computers, robotics and AI are beginning to present new ways and possibilities that can forge research and manufacture in novel directions, establishing alternative styles of creative expression. Can robots become painters or sculptors? That by through hours of training, as we do, learn how to create their own stylistic mark, which could be utterly different to a human's approach to painting and drawing. Returning to Sennett's, *The Craftsman*, where he compares the craftsman's desire to make by hand, incorporating variety and flaws, versus the anxiety of 'the rigorous perfection of the machine'. He describes two different types of machines, that of the replicant – that mimics human functions to best serve our needs (pacemakers, artificial limbs), or as a robot – a machine that is more of an extension of our physical self, but larger and stronger, which works faster but never tires (printing presses, paper mills, computers). And as Sennet explains, 'the replicant shows us as we are, the robot as we might be'. [11 pg.81]

## Case studies from the CFPR

The last section highlights further examples from the Centre for Fine Print Research (CFPR). As the name suggests, practitioners are exploring and researching new transformative technologies, working and communicating across disciplines and industries. They are at the forefront of craft and digital fabrication, combining knowledge of traditional and new tools, sustainable materials as part of the circular economy, robotics for practice-led design, exploring physical and tactile surfaces for human engagement, and historic methods for cultural reconstruction.

### *Glass and Ceramics*

There are many innovative opportunities for using digital design and fabrication technologies for the construction of new tools for the construction of glass and ceramic objects.

Working in collaboration with leading global companies including Arup, Wienerberger AG and Sibelco, Tavs Jorgensen's research includes low-cost 3D printing technologies. As the foundation for rapid and low-cost toolmaking, he works from customised visual scripts for the creation of functional extrusion profiles (dies). Extruded manufacturing was developed in the 19th century for the production of bricks and other ceramic architectural parts, and is still used extensively in the ceramic industry. However, the process has seen little innovation since then, and now 3D printing presents new methods for combining new tooling approaches for novel applications.

***Figure 5.*** *Smart Tooling for Ceramic Extrusion, Tavs Jorgensen*

*The Glassworks* project, initiated in 2018 by Jorgensen as an interdisciplinary workshop, investigated the use of low-cost 3D printers in combination with conventional glass casting methods to create hybrid production workflows. The weeklong workshop included experts from architecture, physics, engineering, chemistry, weaving, arts, pottery, ceramics, graphic design, and fashion design. While models and moulds for such workflows are single-use and disposable, such tools enable entirely new possibilities in the production of glass artefacts, from creative expressions to energy-saving applications such as urine powered fuel cells. The Bristol BioEnergy Centre at the Bristol Robotics Laboratory was interested in exploiting glass casting for more

efficient microbial fuel cells technology. MFCs are bio-electrochemical energy systems that convert the energy locked in organic matter such as urine, wastewater or detritus.

Jed Hammerman is working with Craven Dunnill & Co. which was established in 1872, to explore non-destructive 3D scanning and fabrication methods to restore ceramic glazed historic wall tiles. Current restoration methods involve removing glazed tiles from the walls, potentially damaging the work along with the surrounding area. By understanding how glaze behaves on a ceramic body, Hammerman uses 3D editing software to reverse engineer the original surface using data captured from a 3D scanner. The method will dramatically speed up the process of renovating heritage ceramics by bringing surveying and production techniques in line with 21st-century technology. The factory is part of the Ironbridge Gorge World Heritage Site, at the heart of Britain's Industrial Revolution.

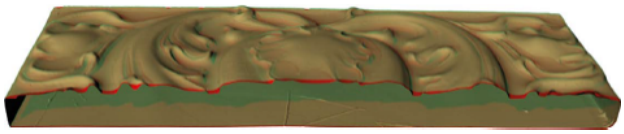

***Figure 6.*** *3D scanning technology used to accurately document colours, as well as the surface topography for use in reproduction, Jed Hammerman*

## Textiles

New materials and fabrics, and specifically e-textiles have been a focus of much attention due to their ability to make lives safer, healthier, and more comfortable. The extraordinary electronic, optical and mechanical properties of graphene, in combination with inkjet printing, presents a number of advantages over conventional manufacturing techniques including the deposition of controlled quantities of materials, whilst also reducing waste and water consumption.

With backgrounds in Graphene, Nazmul Karim and Shaila Afroj are researching Graphene inks for multifunctional wearable e-textiles that are breathable, comfortable and can provide real-time sensing for health. Printing a continuous conductive track on rough and porous textile surfaces is a challenge due to the low viscosity of inkjet inks. In order to overcome such challenges, they are exploring surface pre-treatment of textiles. The all-inkjet-printed graphene-based e-textile demonstrates good flexibility as repeatable change is resistance is observed in forward and backward bending direction. [39]

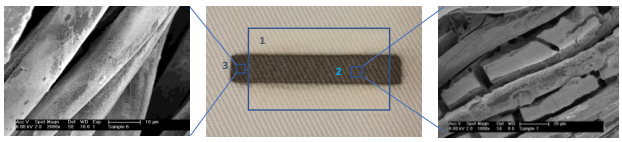


***Figure 7.*** *SEM image of inkjet printed ink (6 layers) onto (a) untreated cotton (×2000); (b) Inkjet-printed onto pre-treated area (1) conductive pattern onto pre-treated area (2) and Inkjet-printed onto untreated area (3); (c) SEM image of inkjet print (12 layers) onto NP1 cotton fabric (×1000).*

Laura Morgan's research specialises in digital surface treatments, including laser processing for coloration and 3D finishing of textiles and materials, laser shibori, laser peri-dyeing on textured wool, and laser patterning on linen. She is working on developing sustainable materials and processes within the circular economy by integrating craft, textile design and material science. She is also pursuing opportunities to integrate the sustainable profile of existing and emerging biomaterials with the precision and flexibility of digital technology, including bio-finishing, bio-coloration, regenerated materials.


***Figure 8.*** *Manipulation of materials using laser Shibori, Laura Morgan*

## Cultural Heritage

By combining old and new print technologies, inks and materials, and fabrication methods with embedded sensors, we are exploring novel ways for engaging with art, architecture and cultural heritage. We can reimagine and reconstruct objects that are lost; we can ensure greater interactivity between humans, objects and spaces, and enhance our appreciation of the history of things and how things were/are made.

Susanne Klein is leading a range of projects concerning structural colour, and the reappraisal and reinvention of historical photographic processes, including Woodburytype and Lippmann photography. The Woodburytype, invented by Walter B. Woodbury (patented in 1864), was the first commercially successful mechanical printing process for the permanent reproduction of photographic quality pictures, contrast and greyscale in a Woodburytype are generated by a relief of pigmented gelatine. Klein is also researching into structural colour, for example, how colour can be captured and reproduced, and how new colours can be generated, as exampled by layers of dieletric mirrors on glass (Lippmann photography), and on paper using red, green and blue pigment inks (Merck Spectraval).

A project underway with Bristol City Museum, and led by Abigail Trujillo Vazquez, is to reconstruct the appearance of the Maya frieze of the Palace of the Stuccoes in Acancéh Yucatán, dating from c. 350 BC to AD 850. The frieze is now destroyed but was documented in 1907 by Adela Breton. Her watercolours on drafting linen and black and white photographs taken by her at the same time are the basis of 2.5D prints which reconstruct the appearance of the frieze.

***Figure 9.*** *Reconstruction of the appearance of the Acancéh frieze, photopolymer gravure and embossing, Abigail Trujillo Vazquez*

Trained as an architect, Fabio D'Agnano has been working on computer-based modelling, rapid prototyping, and the incorporation of sensors and electronics embedded in 3D printed tactile objects, to assist visually impaired people to navigate and recall information about the history of the architecture or cultural object, or as an informative link to public spaces and cultural

institutions. Due to the impact of Covid-19, touching interactive exhibits in museums will be strictly off-limits. We are developing paper-based products and maps, designed for single use only, which then can be recycled, or taken away as a souvenir. This idea of a tactile memento offers new opportunities that can transform an inert replica into a smart object – that can connect to phones, computers, the museum, the internet of things, or other exhibits. It can be used as a container for storing or conveying information, or as a tactile replica which can include extrasensory experiences beyond touch, for example, smell and sound and stories.

## Conclusion

In the 21st century, we are experiencing a new creative shift in craft, design and technology. Just as other tools have been essential throughout the history of art and craft, we can exploit digital tools, new materials and new technologies, seeking ways to revive and reinvigorate the process of making and our rich material culture. As demonstrated throughout this paper, there are synergies between different professions that present opportunities for technological solutions and many possible overlaps and solutions that are yet to be found.

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