Solar Concentration for Craft Practice and Sustainable Development

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Rasma Puspure, earrings, Random Treasures, 2019, Ginta Grūbe
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Solar Concentration for Craft Practice and Sustainable Development: Fusing Ancient and Modern Methods

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ABSTRACT

This paper presents opportunities created through an interdisciplinary collaboration between the fields of physics and craft. The research adopted a Fresnel lens to concentrate sunlight generating heat for craft purposes. Recursive methods were developed in relation to literature and past projects working at the intersection between science and craft. Outdoor experiments were conducted in Scotland following a Safe Operating Procedure to safely transport and use the Fresnel lens. Material identity was investigated during the creation of the *Sand Map of Scotland* and the 'Solar Enamelling' experiments indicated the potential of using this clean energy source for material processing. Findings highlight that the use of optics for material alteration adopted in ancient history are becoming increasingly relevant in society today with the demand for fabrication methods that can contribute to sustainable development. This research indicates the technical capabilities of using a $40cm^2$ Fresnel lens to heat, melt and vitrify a variety of materials and suggests future applications of this technology including the ability to digitise the process. This material processing technique offers an alternative to heat matter and is significant in geographical locations with ample sunlight, offering a cost-effective option to traditional heating methods and allows directional heating, which local craftspeople can exploit to their creative advantage.

INTRODUCTION

THE TRANSMUTATION OF MATTER THROUGH TIME WITH OPTICS AND PHOTONICS

Physics and Craft practices have a long-standing relationship: from the serendipitous manner by which a spectacle maker happened across a scientific instrument which later became the telescope (Galilei 1623), to scientific glassblowers creating apparatus through which 19th century scientists were able to demonstrate physical phenomenon (The Third Millennium 2021). Craft has played a vital role in developing technologies to aid scientific endeavours, yet in recent years, physics has informed technological capabilities in the craft field. Since the 1960s, photonics (technology concerned with the properties and transmission of photons: e.g. lasers, cameras, LEDs etc.) for manufacture has technologically transformed the jewellery industry in the UK: The London Assay Office for example have invested in X-ray fluorescence spectroscopy to assay items, laser marking to apply hallmarks and a fibre optic laser to manufacture the precise punches for traditional hand-punched hallmarking (Anon 2012). More broadly, photonics technologies are supporting the conservation of historical artworks and artefacts (PISTACHIO 2021), and laser welding, cutting, Selective Laser Sintering/Melting (SLS)(SLM) technologies have enabled craftspeople to design and create work to a high level of precision that was not previously technically or financially viable (KTN 2020)(Snyder 2013). New Crafts emerged in response to such technologies becoming accessible: with a trend for many to deviate away from a traditional craft studio, to embed computer aided design and manufacture into their craft process, as seen in *Digital Handmade: Craftsmanship and the new Industrial Revolution* by Lucy Johnston. Whilst technologies such as the 3D printer have enabled new ways of making, it can be said that objects made through these digital technologies feature aesthetic similarities, and are often energy intensive and wasteful fabrication processes by comparison to traditional craft methods.

Research to improve the power and reduce the size of lasers continues, yet controlling light to process materials dates back to ancient history. Solar energy is not a modern concept: solar rays have been harnessed through optical devices to illuminate darkened rooms, cut gemstones and for alchemical purposes throughout history. Convex lenses or 'burning glass' were used to concentrate sunlight to start fires in 7th century B.C.E.. 'Burning mirrors' were next to be invented in 212 B.C.E. where polished metal plates reflected the Sun's rays. This is famously illustrated in the Archimedes' 'death ray' fable which destroyed an entire Roman fleet (Chariot Energy 2021), as seen in Figure 1. I have identified two historical solar concentration methods that hold potential for modern application: 1, Sun Temples reflected sunlight using reflective metal panels to heat a central stone which then radiated the heat into a chamber to cook food, dry materials and fire ceramics, and 2, Parabolic mirrors ('burning mirrors') were used as weaponry and for alchemical purposes on gems, metal and stone. It is thought the mirrors were often used instead of a furnace to smelt and refine metals as the clean energy source burnt off oxides, leading to the 'solar forge' being a useful addition to the metallurgist's toolkit in addition to the furnace (Jordan 2014). These ancient methods of solar concentration for material processing have been mostly lost to time due to abundant fossil fuels, advances in equipment and technique, and the inconsistent availability of sunlight.

The development of optics however has continued: Augustin-Jean Fresnel invented the Fresnel lens in the 19th century to reduce the material weight of glass lenses by dividing the surface into concentric rings assembled on a flat surface (Hecht 1998). These lenses are now commonplace in lighthouses and searchlights to focus lamp light into a narrow beam. Furthermore, Fresnel lenses have been used in recent low-tech community projects to create 'solar ovens' in areas with limited electric supply: usually concentrating light onto a thermally conductive surface where cooking pots are then placed nearby to heat the contents, not

Figure 1: Artist's view of Archimedes of Syracuse (Sicily) operating his burning mirrors against Roman triremes during the siege of his city laid by consul Marcus Claudius Marcellus, at the time of the Second Punic War (214-2 BCE). Licensed by Science Photo Library.

dissimilar to the Sun temple premise (Solar Cookers International 2021). Recent research at Nottingham-Trent University has combined Fresnel Lenses for solar concentration with periscope instrumentation to allow solar ovens to be located indoors whilst the solar concentration occurs outdoors (Nottingham Trent University News. 2019) highlighting how more complex optical systems can be designed for increased user experience. Markus Kayser (2018) first created a 'Sun Cutter' (laser cutter alternative) using the Sun, a ball lens and xy-plotter before the 'Solar Sinter Project' in 2011, which combined a Fresnel lens with a photovoltaic powered x,y,z, axis printing bed filled with sand to sinter sand from the deserts of Egypt into glass objects using solar radiation. This project demonstrated how an abundant material in a remote location could be processed using clean energy. Scientific evidence of rapid climate change since the Anthropocene led to the emergence of the concept of sustainable development in the 1980s. Sustainable development is defined as economic development in the present day which does not deplete our natural resources to the detriment of future generations. The field of design is considered critical to changing our fabrication processes and energy usage, to reduce the rate of climate change and preserve our environment. In response, products and services are increasingly designed with social, environmental and economic impacts considered. Often, traditional craft practices and understanding indigenous philosophies have offered useful insights into how to engage with our surroundings through lived experience (Ferraro, 2019).

Craft has been embracing emergent technologies as previously mentioned in regard to laser applications, and jewellery craft practices continue to pioneer new methods despite the physical limitations. Traditional decorative vitreous enamelling has remained mostly unchanged since the third millennium B.C.E., yet craftspeople and researchers have adopted new methods for innovative results. This includes the work of Yinglong Li whom is applying plique-a-jour (enamel suspended between wires like stained glass) to SLM metal frames (Association of Contemporary Jewellery 2020); Arthur Hash (2021) who laser etches enamelled surfaces, a process which vaporises the targeted silica at around 1100^{o}C, and Jessica Turrell (2010) who enamelled 3D printed and electroformed structures using industrial enamels to explore the interface between contemporary practice and traditional enamel techniques during their research. Stemming from ancient and more recent practices and research in this area, this research study explored the intersection between physics and craft for material processing opportunities. The intent was to explore the potential of the Fresnel lens from the perspective of a craftsperson to understand how this tool could heat and melt materials for both sustainability and aesthetic purposes. The research, conducted by the author, explored the technical parameters of 'solar craft' using a 40cm^2 Fresnel lens and includes a *Sand Map of Scotland* and an investigation into 'solar enamelling': a technique not previously evidenced as an ancient craft. This article details the practice-based investigation of introducing solar concentrating technology for craft practices and suggests the future potential and significance of this activity and its potential contribution to sustainable development. The use of both first and third person have been utilised through this article: first person to convey the authors personal experience and observations during the research and third person to voice more objective, technical information and to contextualise the study within the craft field more broadly. All outdoor experiments were conducted in the UK following a Safe Operating Procedure to safely transport and use the Fresnel lens to reduce personal and environmental risks.

HOLDING SUNLIGHT

I do not often think about my physical interaction with sunlight: I know my body needs sunlight to produce essential vitamins and will experience sunburn if exposed to solar radiation for too long. Yet it was bizarre to experience holding a lightweight, $40cm^2$ acrylic lens, which if positioned perpendicular to the Sun can concentrate sunlight to an incredibly bright focus of approximately 4mm and reach temperatures in excess of 1200°C in the UK, as seen in Figure 2. As a silversmith, I have been conditioned to wield powerful tools and equipment, yet this solar craft practice felt distinctively different because it connected my hands to the Sun, positioned about 151.58 million km away and the high temperatures achieved with a relatively small lens highlighted the power of the distant light source transforming my target material. This immediacy of impact and utilisation of the Sun's rays that usually go unnoticed became an accessible and affordable heat source through the adoption of a lens. I had investigated other physics equipment for craft practices such as physical vapor deposition (depositing thin layers of metal to a surface in a vacuum) and tempering metal surfaces using a laser for decorative purposes, yet in my opinion neither had the mass-appeal or accessibility to the craftsperson like the Fresnel lens did: who can choose how they engage with the tool.

Figure 2: Karen Westland, Solar Enamelling copper tube on beach, 2019. Still from video.

The lens can be used in different ways: it can be hand-held, mounted in a tilting frame (an artist's easel works) or can be digitised to track the sun on a tripod; the divergent light exiting the Fresnel lens ranges in temperature allowing some control of where materials are positioned to alter their material state. The first stage in this research study explored solar craft through heating different materials to document the Fresnel lens parameters which included the creation of a *Sand Map of Scotland* based on Kayser's work with attention to the craftsperson's connection with material and place in the process. These initial tests were created holding the Fresnel lens by hand and bringing the focus down onto the material bed. Heating various materials including bullseye glass, silver and fabrics using the Fresnel lens enabled the documentation of thermal parameters to learn how materials reacted to the directional heat source as seen in Figure 3.

The glass frit fused effectively, samples needed turned over if the underside was also to be fused and did not break when cooling in outdoor ambient conditions. Flammable materials such as wood and fabrics were singed in a controlled manner as it was possible to introduce the focus to the desired area, then lifting away when the desired effect was achieved. Small metal samples such as fine silver wire were partially melted yet larger surfaces did not experience change, likely due to the thermal conductivity of the metal, spreading the heat absorbed across the entire material, preventing the metal from reaching melting point. It was also possible to sinter sand into glass in Scottish light intensities which indicated that materials with a melting point under 1200^{o}C would experience some thermally induced change. Care had to be taken not to bond materials onto the material bed (usually a refractive brick) even with kiln paper placed underneath to prevent adhesion, which indicated the focus of the Fresnel lens was more intense than the temperatures required for many of the materials tested. Building from Kayser's solar sinter research, glass was made with sands from various locations on the Scottish coastline to understand the geological and geographical characteristics of each sand sample. Sand was chosen to investigate if where the material was collected from influenced the glass material outcome. Sand samples were collected from 12 coastal locations in Scotland and each dry sample was exposed to the focus of the 40cm^2 Fresnel lens for 5 minutes for comparative analysis. The sand and glass samples in Figure 4 demonstrate the diverse range of aggregates collected and glasses created. Sand is defined as soil particles between 0.05mm and 2mm in diameter and is 85% sand and no more than 10% clay (Glinski 2011)(Agriculture Canada 1976), which suggests great variation is possible

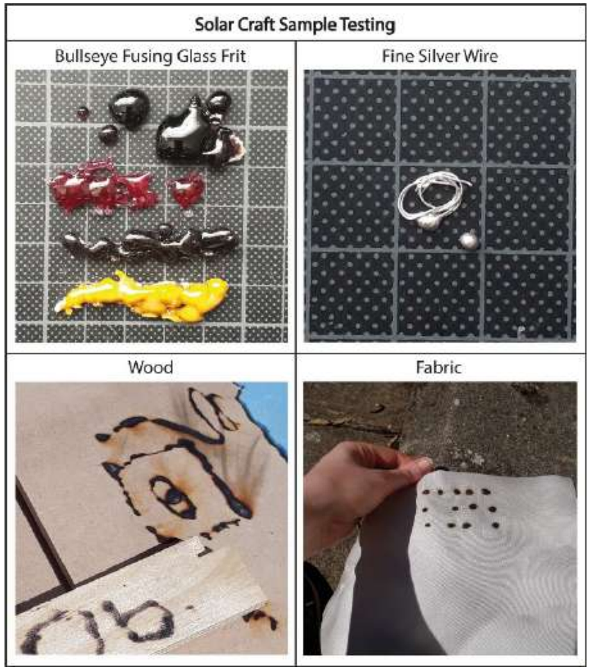

Figure 3: Karen Westland, Solar Craft Sample Testing, June & July 2018. Glass, silver, wood and fabric.

depending on local rock and soil types. The Egyptian desert sand from Kayser's work appeared a consistent shade of white in glass form whereas every sample in this study featured some colour variation, which likely relates to Scotland's diverse geological landscape as depicted in Figure 5. The samples from St. Andrews appeared to have a chalky content in the sand which was 'left behind' in the fusing process and it was clear that sands such as Shetland fused rather effectively whilst the sand from Crail proved more difficult. This research introduces the notion of solar sintered sand

objects holding a sense of place due to the sand being unique to the collection site and the sunlight intensities relative to the geographic and atmospheric location. Moreover, the map emphasises how natural resources in our local environment can be reconsidered with the view of developing fabrication methods that can contribute to sustainable development. The narrative has also been explored in the anthropological project *To See a World in a Grain of Sand* by Atelier NL (2022), which has to date melted sand from 809 locations globally into unique glass samples (using a kiln) to reveal the diverse colours and textures of the world.
I believe this connection between materiality, locality and sustainability will appeal to craftspeople wishing to pursue processes connected to the natural environment.

'Sustainability' in this context is referring to the clean energy source used to process the raw material and an indication of the local materials used. It does not however refer to the nature by which the raw material is acquired: which requires consent from whomever owns/is responsible for the local materials/land of choice, and using them in consideration to social, environmental and economic impacts. The sand samples collected in this research represent an exact place in time: as beach nourishment may be occurring at some of these locations due to coastal erosion, documenting the ever-changing Scottish coastline. As seen in the ancient craft techniques and unlike the works of Kayser and Atelier NL, the creation of the *Sand Map of Scotland* was a collaboration between the geologically unique material samples, the local atmosphere and winds, the Sun slowly rotating in the sky and the craftsperson carefully positioning the material and lens at the correct angles to optimise the light intensities concentrated through the lens to alter the target.
The samples altered through heat in this research study were co-created by nature and myself as the craftsperson: I felt directly engaged with my local environment and natural resources in a similar way to our ancient ancestors, despite the distance in time and technology.

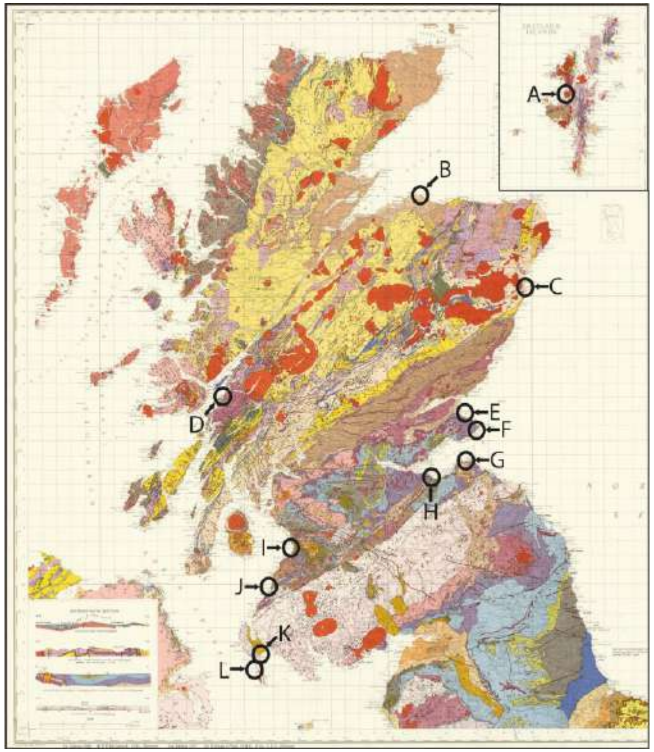

Figure 5: Geological Map of Scotland: superimposed locations of sand collection marked A-L correspond to Figure 4. Original map licensed by National Library of Scotland

Figure 4: Karen Westland, Sand Map of Scotland, Sand and sand glass (ruler dimensions in millimetres). Letters A-L correspond to the geographical locations indicated in Figure 5. Samples were exposed to Sun in Dundee for 5 minutes on the 25th April 2019 from 11:20am onward. Some stratus clouds were present.

SOLAR ENAMELLING

A potential hypothesis emerged after seeing the findings from the first experimental phase of the study: specifically, that solar concentration using the 40cm^2 Fresnel lens would be a sufficient heat source to 'solar enamel'. To test this, a series of samples were prepared indoors and transferred outside to enamel outdoors, each test building on the previous results. The solar enamel process deviates from kiln firing samples due to the directional nature of the heat source which may offer unique opportunities to raise the temperature of samples from different angles or to target local areas. The first enamel tests experimented with opaque and transparent enamels ground down from lump then wet-packed onto fine silver and copper substrates to understand how both the enamels and substrates would react in the directional heat. Samples were placed on a wire mesh tray - commonly used in traditional kiln enamelling – and the heat of the lens was introduced down onto one sample at a time. Image 1 in Figure 6 is a photograph of the successfully enamelled samples on both copper and silver substrates. It must be noted that the opaque cobalt blue (top right in image 1) was the most successful to bond to the substrates, yet the enamel partially changed from opaque to transparent in the process. The directional heat source caused the enamel to 'ball-up' with the heat, revealing the substrate before the metal then reached enamel temperatures where the enamel then sunk back down and bonded to the substrate. This can be seen with the opaque yellow (top left in image 1) samples which experienced difficulty in bonding the enamel and substrate due to this behaviour and oxides building on the substrate surface while exposed to the sunlight,

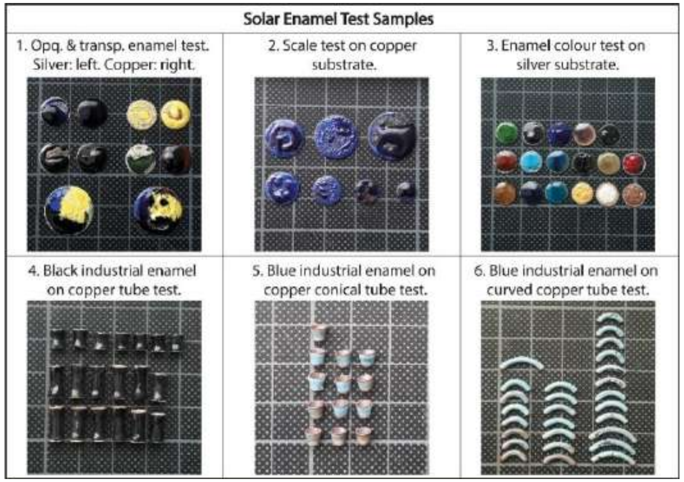

Figure 6: Karen Westland, Solar Enamel Samples, 2018-20. Enamel, copper, silver. (All samples photographed on a cm grid background for scale.) Samples were enamelled in UK summertime.

preventing the enamel from bonding to these areas once enamelling temperatures were met. The copper substrate samples appear to have enamelled all the colours more successfully than the fine silver substrate samples. The opaque black and transparent green did not appear to experience any significant changes. The overall aesthetic effect of these samples, particularly the larger mixed enamel samples were painterly: like the application of thick oil paint which may be of interest to enamellers interested in texture. The enamels were applied too thickly on the samples in this test and this was avoided in future experiments.
Secondly, copper disks ranging from 6mm to 16mm with the opaque blue enamel from step one were solar enamelled to gauge what scale the lens could heat to

enamelling temperatures before thermal conductivity began to negatively affect the samples. The results indicated that the smallest samples enamelled most effectively and the samples over 10mm diameter experienced difficulty in reaching enamelling temperatures with the given lens and light levels in Scotland, see image 2 in Figure 6. Here it is clearer to see the blue enamel partially losing its opacity through the process. Again, there were issues around where the focus of the lens was directed to on the sample: the enamel migrated away from and did not want to bond to those areas. Thirdly, a series of 8mm samples on fine silver substrate trialled the colour spectrum in vitreous enamels. The experimental set-up was changed for these tests as they were conducted inside a greenhouse to prevent the interference of wind on the wet-packed then dried enamel. The Fresnel lens was mounted in a tilting frame to allow each sample to be held in tweezers and the underside of each sample was introduced to the focus with the intent to prevent the lens focus from creating an oxidised area on the substrate surface where the enamel could no longer bond, leading to an even enamel layer across the sample. This strategy was very effective overall with a small chance that the dried enamel would detach from the substrate whilst being held at a downward angle when the substrate was absorbing the solar heat. Image 3 in Figure 6 shows the enamelled samples with even coverage yet there were some issues with cracking, and holes in the enamel, possibly caused by bubbling from the substrate absorbing the heat. There is also some blackening of the red and brown enamels, likely due to over-firing. In the process of enamelling in this set-up, there are issues with visibility: the user must blindly judge when the sample has enamelled. This is different to timing samples in a kiln which is set to a consistent even heat, as the intensity of the sun and the position of the sample in or near the focus is constantly changing leading to greater uncertainty. These results do however demonstrate the ability to solar enamel a range of enamel colours with reasonable success by directing the Sun’s rays to the underside of the substrate to protect the enamel surface. It is likely with practice; this process could be refined further to achieve the consistent results desired. After the enamel tests on flat surfaces, industrial enamel was tested on copper tube because it is more wind-resistant and easier to apply to three dimensional forms than vitreous enamels. The tube shape was altered by punching the ends into conical forms using basic tools and bending lengths of tube over curved surfaces by hand. This phase of research was designed to explore what was possible with little tools available and minimal enamel skills to allow the solar enamel practice to be easily replicated by others and particularly relevant for use in communities with ‘solar ovens’ but no specialist craft equipment. The tube samples were then threaded onto the wires of an upturned wire mesh rack or through a length of binding wire: allowing extra wire either side to hold by hand safely outside of the lens focus. Images 4-6 in Figure 6 depict the results of solar enamelling industrial opaque black and blue enamel onto the millimetre-scale copper tubes. There were issues with the enamel migrating away from the focal point of the concentrated light, particularly on the curved samples where there was nowhere to target that was not covered in enamel, unlike the tapered samples where it was possible to aim the heat internally. The opaque blue enamel appeared to go semi-transparent if heated for too long which created an appealing effect revealing the copper colour underneath, though inconsistent. Some of the larger samples had difficulty in reaching enamelling temperatures but overall, the industrial enamels bonded to the copper substrate more consistently than the vitreous enamels to both the copper and fine silver substrates. Lastly, some test samples were created to demonstrate how the solar enamelling process might be utilised in future work.

Figure 7: Karen Westland, Brooch with enamelled details, 2020. Fine silver, vitreous enamel. 7x7x1.5cm.

Small components may be solar enamelled before being integrated into larger jewellery items such as the brooch in Figure 7 where the solar enamelled hexagons are riveted to a parabolic silver form and will rotate as the wearer moves. The solar enamelled copper tube can be strung together like beads and combined with glass beads or decorative metal elements to add interest as seen in Figure 8. Overall, these experiments demonstrate that solar enamelling is possible and whilst there are environmental and technical challenges, the process creates unusual effects in the enamel, specifically altering the opacity, which offers new possibilities not presented by traditional kiln firing.

Figure 8: Karen Westland, Enamelled bead samples, 2019. Industrial enamelled copper, glass beads, brass and thread.

DISCUSSION & CONCLUSION

The aims of this experimental research were to investigate accessible scientific apparatus with the potential to aid craft practitioners interested in sustainability. The study outlined above has established that solar concentration can process materials in ways that potentially can contribute to sustainable development. A Fresnel lens at 40cm^2 was proven to be an accessible and affordable tool to heat and melt materials reaching temperatures over 1200^{o}C using natural sunlight as the energy source. Building on the literature, this solar craft process was proven to melt sand, a variety of glass, metals and burn wood and fabric in a controlled manner. The outcomes of this project connect the lens user to a low-tech craft practice which decreases control, compared to a digitised operation, but increases the level of human intuition and connection with the process. The results from this research reintroduce ancient craft methods and build on the techniques discussed and developed in the works of Kayser (2018) and Jordan (2014), yet solar enamelling on metal is something not seen before, presenting a new area of practice to expand upon. It must be noted that solar enamelling is not likely to replace reliable kiln enamelling: history has already validated this. However, in the sunniest locations on the planet where solar ovens are already used, this practice could be adopted and automated; solar processing technologies could also be integrated into solar farms to process materials. Moreover, whilst this research explored solar craft in outdoor and greenhouse conditions in Scotland, it is also possible to create a safe indoor workspace designed for solar craft practices in a location with consistent, high intensity sunlight, such as Portugal: where there is an indoor solar laser lab, to increase the reliability of this craft method.

It may be possible to develop a solar kiln or crucible, similar to the oven developed at Nottingham-Trent University (2019) to concentrate and retain higher temperatures for material processing purposes. An extensive review of current optics, solar concentration designs and solar-powered technologies would be required to engineer material processing technologies suited to the desired outcome. This study melted materials between 600^{o}C and 1200^{o}C which suggests that it may be easier to alter materials at lower melting points. Developing environmentally safe methods to recycle materials like aluminium and plastics through solar concentration may offer alternatives to a discipline which would benefit from innovative solutions that contribute to sustainable development. Further investigation into scientific apparatus in physics may reveal more areas which craftspeople can benefit from for developing innovative craft practices or can highlight the relevance of specific technologies outside their common use. Future research into this area from a craft perspective may act as a catalyst for innovation, diverse thinking and making connections between technologies and applications.

The experiments conducted in this study experienced varied results due to the changing Scottish weather conditions and the level of control the user had over the process and design choices of samples. The inconsistent light levels prevented understanding whether differences in outcome were due to the craftsperson's skill or environmental conditions. Experiments adopted cause-and-effect methods to respond to the process with limited scientific characterisation i.e., reliable evidence derived from quantifiable measurements. Future research may include characterising the process to better understand the relationship between ambient light intensities and the temperatures achieved through solar concentration, which would inform exactly what materials can be altered in which geographic locations or ambient light intensities. The Fresnel lens enables craftspeople to incorporate sand glass into their work, as enamelling kiln temperatures tend not to exceed 1100ºC, making this a useful tool if heating materials at high temperatures is required on a small scale. The *Sand Map of Scotland* highlighted the beauty and usefulness of local materials and the narratives that form between material, place and maker/end user. Expanding this material research to trial using solar concentration to fire locally-sourced clays, preserving wood with ‘shou sugi ban’, a Japanese technique which charrs wood surfaces with fire, and exploring solar lampwork may hold craft potential. From observations made during the solar enamelling stage, the process has the ability to deliberately melt different layers and types of enamels together in interesting ways due to the local application of heat which can impact the ‘flow’ of enamel. Exploring the transition from opaque to transparent, and creating different textures through firing enamels to wet sugar, orange peel or full gloss on a single surface could challenge the traditional enamel aesthetic and generally standardised process. Working with the migration of enamel to ones’ advantage may also stimulate serendipitous and creative work, using the process’s unpredictable characteristics. Investigating other heating methods; using the lens to prevent the directional nature of the solar heat source which impacts the solar enamel reliability may prove useful. For example, creating a solar ‘hot plate’ for the plate to consistently remain in the lens focus at a relatively consistent temperature, where flat enamel samples can be placed on the plate for the heat to transfer into the samples in an even manner, enabling small batch production. This causes the heat to reach the metal substrate first, yet the samples are facing upward so the enamel will melt down and vitrify onto the substrate without risk of the enamel dropping off and oxides forming as significantly. This strategy may require a considerably larger Fresnel lens concentration area to gain enough heat. Three-dimensional enamel samples could be designed with tabs to direct the lens focus to transfer the heat to local areas where enamel is present and the tabs could be later removed if desired. The plique-a-jour technique may lend itself toward this approach as the metal frame could be used to focus the light on to then transfer the heat into the surrounding enamel 'window' areas.

To conclude, this research will likely appeal to a variety of audiences and whilst this phase has taken a playful, ‘trial and error’ craft approach to the technology, with scientific thinking adopted but little scientific characterisation recorded of the process; the results are hoped to capture the imagination of craftspeople interested in sustainable development, such as recycling materials using this clean energy source, in addition to practitioners keen to explore a low energy enamelling process as an alternative to traditional kiln enamelling. This study demonstrates a key benefit of interdisciplinary collaboration; utilising scientific tools for craft practice. Furthermore, this paper notes a trend where scientific technologies such as laser processing are changing the identity of craft practice and the shift toward interdisciplinary and transdisciplinary collaboration to tackle the complex problems faced by society and the opportunities for innovation that are yet to be identified between the physics and craft disciplines specifically. This study has also successfully outlined a variety of ways that this approach can contribute to sustainable development through experimentation with optics in a craft context which offers scientists a new perspective for possible technological applications and provided craftspeople with a tool to thermally transmute materials. The findings from this study and literature studied advocate for research and practice beyond disciplinary boundaries, to form an alliance between applied physics and craft practice to advance technologies to benefit wider society.

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