Dyeing SLS Parts

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Interaction Research Studio

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Assembling research prototypes, 2010

The Interaction Research Studio has pursued a practice-based approach for almost ten years now. We explore new technologies and the ways they can reveal and extend people's values and activities, and we do this by designing new kinds of digital devices for them to try in their everyday lives.

Making things is fundamental to our research on a number of levels. To begin with, it is by giving people things to try that we learn how technology's potential can be realised in practice, and how our conceptual understandings of people play out in real life. Moreover, making things well, with care and attention to detail, is important, as it means we can present people with fully finished, carefully considered designs rather than relatively unrefined and poorly executed prototypes. Finished designs have a kind of presence and authority that creates trust and a willingness to engage.

Beyond serving as a means to an end, however, making is in itself a process of learning and discovery. Producing a finished physical artefact, even from relatively complete specifications, involves tens or hundreds of detailed decisions along the way. Many of these involve issues that don't surface in developing proposals, but which are crucial in determining the character and eventual role of the artefact in question. Making makes explicit the implicit.

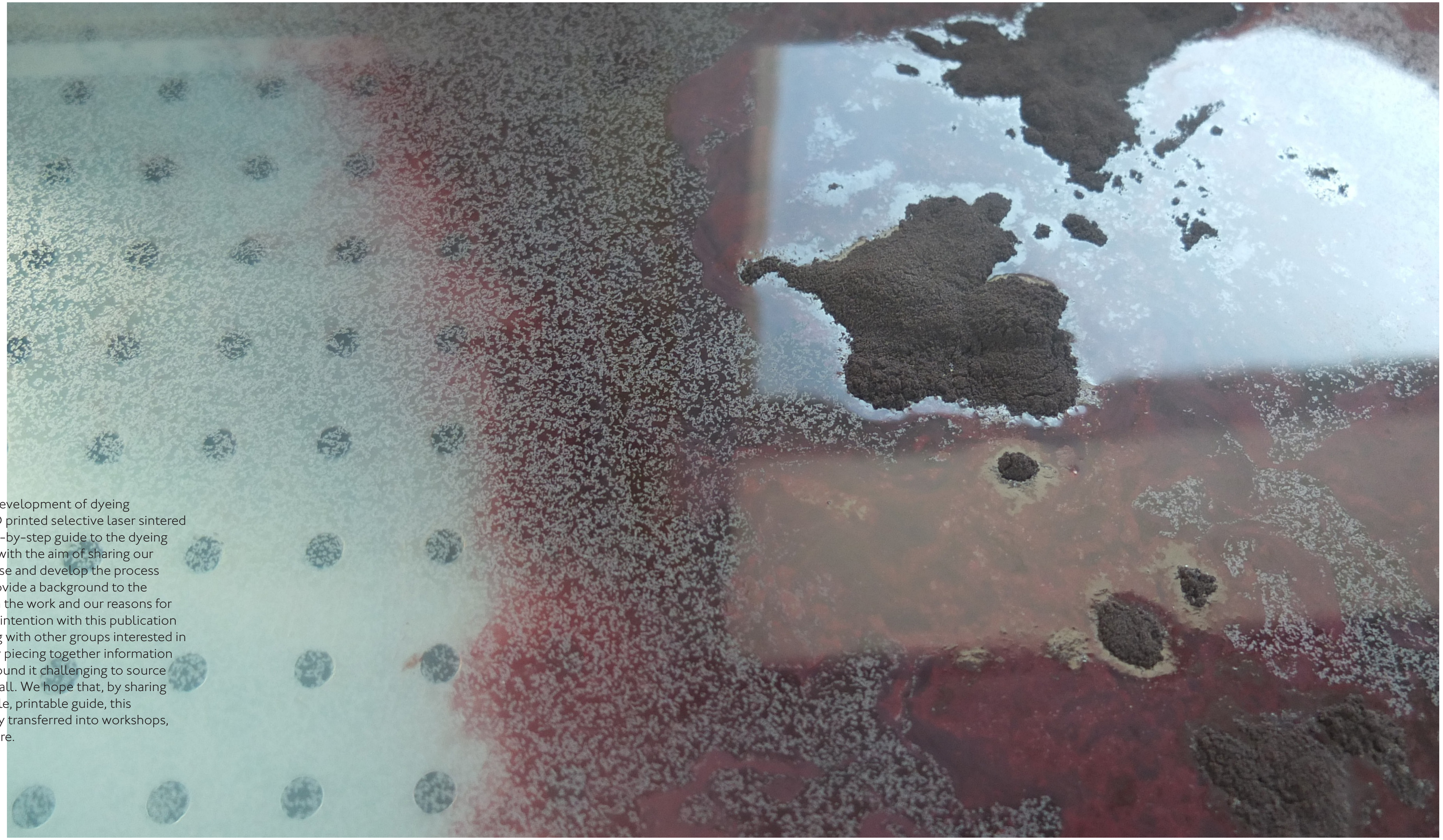
Making also forces decisions about values and priorities for designs. Final designs almost always represent a hard-fought positioning between conceptual ideals and physical and pragmatic constraints. Far from forcing compromises, constraints and the ways they are addressed force an enacted commitment to the values one holds most important, leading to depth and gravity in a final design.

Finally, making illuminates the materials and processes that are at the heart of the design process. It is through trying to craft a finished artefact that the affordances and constraints of the design materials speak most loudly. Developing new skills and processes of working with materials both opens up new potential for the entire design process and teaches us what the materials with which we work are and might be.

Detailed making is seldom given much attention in the research literature, however. Instead, we tend to tell the 'big story' of the things we make -- their conceptual framing, their technical novelty, their reception by volunteers. This is a shame, because much of what we learn in our research goes unreported. The primary purpose of publications such as this one is to redress this imbalance, and to tell the 'little stories' of making -- for they are every bit as fundamental to our research as the grand narratives.

Bill Gaver, 2014

Introduction



Nylon dye dispersed in a heated water tank

This booklet reports on the development of dyeing techniques used to colour 3D printed selective laser sintered [SLS] parts. We present a step-by-step guide to the dyeing process we have developed, with the aim of sharing our learning so that others may use and develop the process further. Preceding this, we provide a background to the people and studio involved in the work and our reasons for developing this process. Our intention with this publication is simply to share our learning with other groups interested in dyeing SLS. We learnt a lot by piecing together information from disparate sources, but found it challenging to source knowledge of this process at all. We hope that, by sharing our practice in a downloadable, printable guide, this knowledge can be more easily transferred into workshops, studios and makers everywhere.

The Interaction Research Studio is an academic research studio based at Goldsmiths, University of London. Our work explores the design of computational systems for everyday life through practice-based research. Part of our work involves designing and fabricating research prototypes embodying new concepts for interaction, which are then given to our project participants to live with and experience over time. We don't pursue design as problem solving, but rather design products to create situations that encourage playfulness, exploration and insight. The outcomes of our work include articles and exhibitions that represent our philosophies, methods and empirical work to academic, industrial and general publics.

Examples of past research projects can be seen on the opposite page. This includes [clockwise from the top left], Plane Tracker, 2008; Photostroller, 2011; Prayer Companion, 2010; and Home Health Horoscope, 2007.

A recent project, the Datacatcher, led us to develop and batch produce 130 interactive mobile devices. The Datacatcher displays social, political and environmental data about its locale. At the time of publication, the devices are ready for deployment to research participants located across Greater London. Further publications will report the broader aims and outcome of the research, but, here, we will focus only on part of our production process.

The studio developed the form, interaction and electronic hardware for the Datacatcher. The two-part casing houses electronic hardware and is secured by a single screw. A dial is glued onto the final assembly, resulting in three separate components for each device. The production of the casing and dial were outsourced to a UK manufacturer, leaving us with nearly 400 white SLS components.

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The Interaction Research Studio

A selection of projects by the Interaction Research Studio

Datacatchers, 2014

The team explored various production methods for the Datacatcher. Our original intention was to use injection moulding, but we eventually moved to Selective laser sintering [SLS] rapid prototyping as a production method. SLS is a form of rapid prototyping, producing polymer parts in a chamber of nylon powder. Thin layers of powder are sintered, or melted, layer-by-layer to produce a three-dimensional form. The solid sintered material is surrounded by powder, enabling the production of intricate and complex geometries. Once the parts have been built and cooled, the surrounding loose powder is cleaned away through bead blasting.

There were three benefits to using SLS; firstly, this method was a cheaper option than injection moulding for low-batch production. Secondly, rapid prototyping offered freedom in designing the form, without the restrictions of the draft angles, material shrinkage and split lines inherent in injection moulding. The self-supporting nature of an SLS build enabled us to design the outer casing as one piece, with a single complex form for the inner core. Finally, the lead-time for production was considerably shorter than other manufacturing options, easing time pressures.

The freedom in form and finish of rapid prototyping was important to us. Our intention was to produce a research prototype, an object designed for enquiry and something significantly different to a consumer product. We wanted to avoid some of the qualities of existing consumer goods, including glossy finishes and split lines, and produce a well-finished object in an intriguing material.

The SLS components were finished using a vibro-polishing machine, tumbling the parts with ceramic stones to soften the material. This helped to produce a unique paper-like material, with a subtle grain and smooth fibrous texture. Our next step was to explore methods to colour the SLS parts without hiding the texture and visual quality of the material. Dyeing processes seemed the logical option.

Production Decisions

Tumbled and dyed SLS Datacatcher case, providing a paper-like material, with a grain

A fully diassembled datacatcher

After a number of enquiries and samples from European bureaus offering rapid prototyping services, we struggled to find a supplier who offered a variety of colours for SLS parts. At the time of this publication, it seemed early days for the dyeing of SLS parts; bureaus were either still in the stages of developing this process or only offered a limited selection of colours. Other bureaus only offered spray finishing, hiding the raw material.

As a research studio working on a large project, we were fortunate to be able to resource development of new making processes and technologies. Experimentation is core to our practice, so we took on the task of dyeing SLS parts ourselves. This also enabled us to introduce an element of craft in our objects, which has always been an important aspect of our practice and design-led research [1].

Having viewed a small number of dyed SLS samples at industry trade shows and exhibitions, we had a clear idea about the quality of finish we could achieve. We began to gather existing knowledge from a variety of sources, including conversations with rapid prototyping bureaus, manufacturers of SLS equipment and a nylon-dyeing specialist. We also followed discussions on 3D printing related forums. Whilst some bureaus were less comfortable with openly discussing the process, others were more open to sharing their experiences and the equipment used for initial experiments.

A manager at EOS, a manufacturer of SLS machines, provided recommendations for a colouring process based on commercially available nylon dyes and similar to the method used for dyeing synthetic fabrics. Another informative source was an online forum located on the US bureau, Shapeways. Here, conversations lasting many months detailed accounts of experiments using acid-based fabric dyes on SLS parts, with careful documentation of dyes, timings, temperatures and equipment. Challenges and successes were noted, including the difficulties in dyeing darker colours and post-processing treatments to reduce staining. Drawing knowledge from a variety of sources gave us the foundations to plan a basic process to begin testing.

A collection of materials from the development of our dyeing process

1

Initial dyeing experiments using permanent inks

2

Exploring the materials' ability to absorb dyes and inks

3

Experimenting with colour to try to conceal the seam between the two parts of the Datacatcher

4

Experimenting with iDye and basic kitchen apparatus

5

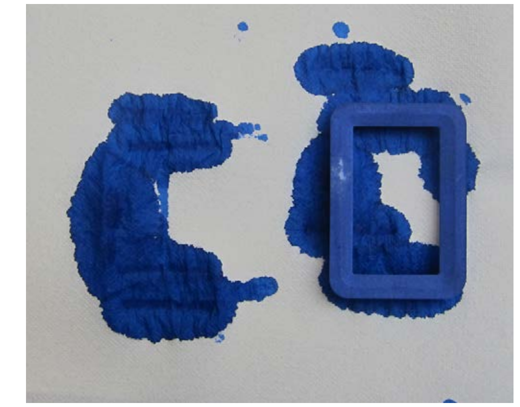
Dyeing development, ranging from initial results on the left, to more practiced dyeing techniques on the right

6

With a method in place, we experimented with mixing dyes to produce a whole spectrum of colours

Learning, Testing, Refining

1



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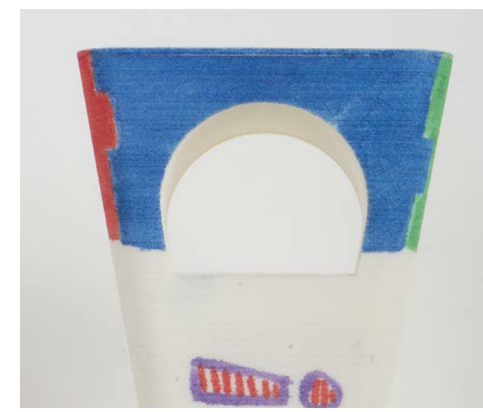

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5

6

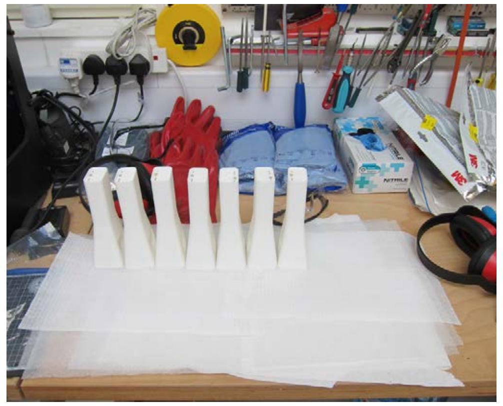
We began using some basic kitchen equipment to replicate the experiments we had been reading about. We started with a cheap slow cooker bought from a supermarket and packets of Jacquard iDye Poly fabric dye and began dyeing some SLS samples. The basic process was to dissolve the iDye in water and heat the solution to near boiling point; parts were then put into this solution and left to dye for anything between 10 to 30 minutes. We experimented with several colours and, although initial results were [quite literally] patchy, we saw the potential that the fabric dye had. There were two main issues; first, we found that, while some parts would be consistently dyed on one side, the other side could be badly stained with intense dye spots. Second, we realised that heat needed to be perfectly consistent. Parts would darken if they touched the slow cooker bowl [which is the heated part], whereas anything that floated on the surface would be lighter where it was not immersed. Intensity of the dyed colour was incredibly sensitive to temperature variation. Additionally, it was clear that, if we wanted to efficiently colour 400 parts in batches, we would need equipment that could hold a far greater volume of dye than the slow cooker.

The solution again came in the form of kitchen equipment, this time in an item of catering equipment in the form of a 28 litre Clifton sous vide water bath. The equipment heats water very precisely and this allowed us to dye very consistent colour across batches of parts. It also has a large capacity, allowing us to dye up to seven Datacatcher cases at a time. The only issue we had was that, if parts did float to the surface, they could still pick up the stained appearance we had with the slow cooker. This seemed to occur because of an oily slick that would collect at the surface of the dye liquid, which combined with a cooler surface temperature to spoil dyed parts. The solution would be to find a way of holding the parts just under the surface of the liquid. We tried several materials, from stainless steel mesh to a laser cut acrylic lattice; however, these all had heat-sink properties that would lighten the colour of parts they touched. The final solution was simple; a layer of large bubble-wrap was all that was needed to hold the parts under the surface without affecting the colour.

We found that the optimum dyeing time in the water bath was 20 minutes and we developed a practice of turning the parts over after 10 minutes to ensure colour consistency [although we do not think this is strictly necessary]. After removing parts from the bath, we found it useful to clean them in an ultrasonic tank to remove excess dye, after which the parts were allowed to air dry. Overall, we found this process produced good result with only a handful of the 400 parts rejected due to dyeing blemishes.

Mini and full-scale Datacatcher dye samples

Tools and Equipment

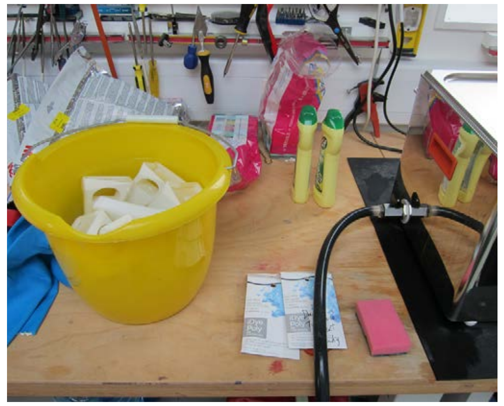


1

We used a single workbench in a clean workshop to set up our dyeing process, running from left to right.

Files, scalpels and compressed air were used to dislodge any loose powder from the parts, to ensure they were thoroughly cleaned before dyeing.

We found white J-cloths and kitchen towel useful when handling parts, as well as to maintain a clean and dry working area.



2

Buckets were useful for soaking the parts before and after the dyeing process, as well as to transfer water from a nearby tap to fill the bath.

Safety equipment and protective clothing were at hand during the process, including thick rubber gloves to handle heated materials, protective eye wear, ear defenders, lab coats and latex gloves to handle freshly dyed parts.

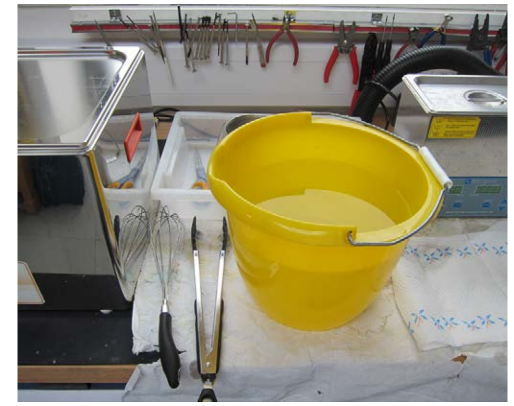
3

A 28 litre Clifton Sous Vide Water Bath was used to dye the parts. We believe a low cost slow cooker or the careful management of a thermometer and saucepan on a hob would also be sufficient for dyeing smaller batches.

We used Jacquard's iDye Poly. A 14g sachet [without the colour intensifier] was mixed with approximately 20 litres of water.

Oven-cleaning cream and green scourers worked well to remove any residue from the previous dyed water; the bath was then rinsed and dried using micro-fibre cloths.

Used water was drained through a thick rubber hose into a plastic canister located below the workbench.



4

After dyeing, the parts were soaked in a bucket of clean water. Green scourers were used to scrub any blemishes from the dyed parts.

Whisks and tongs were used to mix the dye and handle parts in the heated water.

Other useful tools included scissors to cut open the sachets of dye and a stainless steel container to transfer parts from the tank.

5

We used Allendale's 3-litre ultrasonic cleaner tank to rinse the parts after they had been soaked.

A teaspoon of BÜFA's Lavegel, a levelling after-treatment agent for dispersion dyeing processes, was added to the clean water in the ultrasonic cleaner.

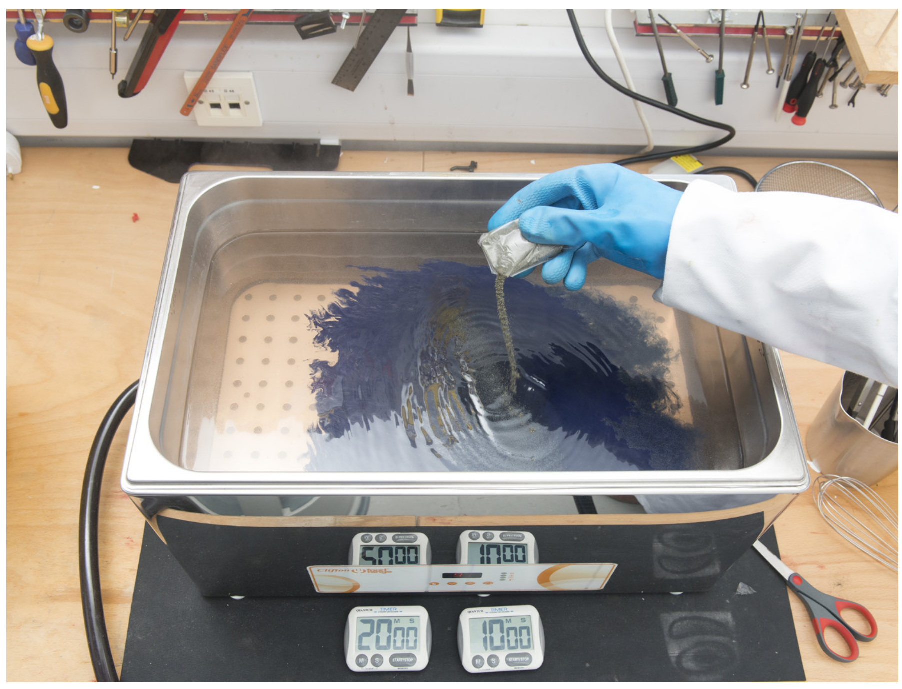
6

We made a bespoke drying rack to drip-dry the dyed parts, which was designed to suspend the parts in mid-air.

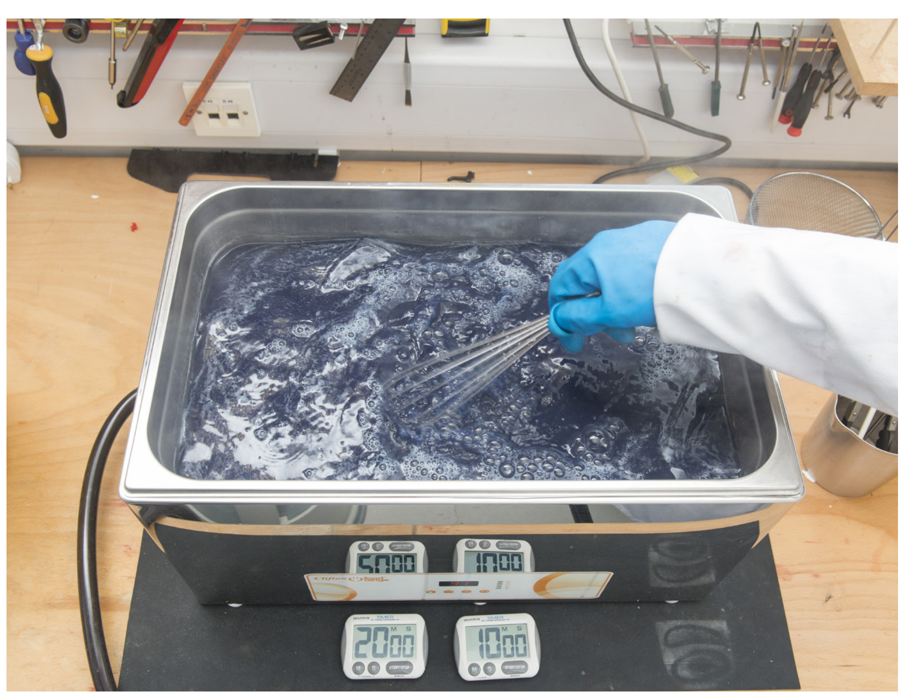
Pin here

1. Clean SLS parts were gathered in batches of seven, which comfortably fitted in the tank. The parts were soaked for 10 minutes in clean water before the dyeing process begun, which seemed to help with colour consistency. We filled the tank and heated the water to 95°C, which is the optimal temperature for the dye. It was important to thoroughly clean the tank before filling it with water - we found oven-cleaning cream and a green scourer worked well to clean the tank, which was then rinsed and dried using a micro-fibre cloth.

2. The iDye pack can be dispersed directly into the water [the transparent packs are soluble]. However, to eliminate any potential contamination, we emptied the powder out of the pack into a clean bath or fresh.

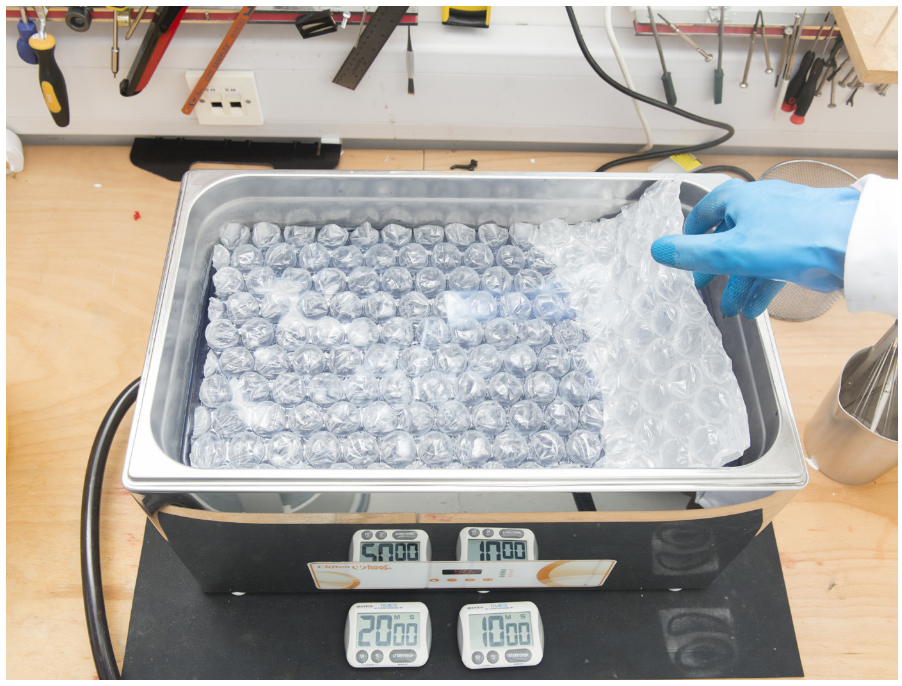


3. The dye was thoroughly mixed using a whisk. We then replaced the lid and allowed the water to return to 95°C before adding the parts.



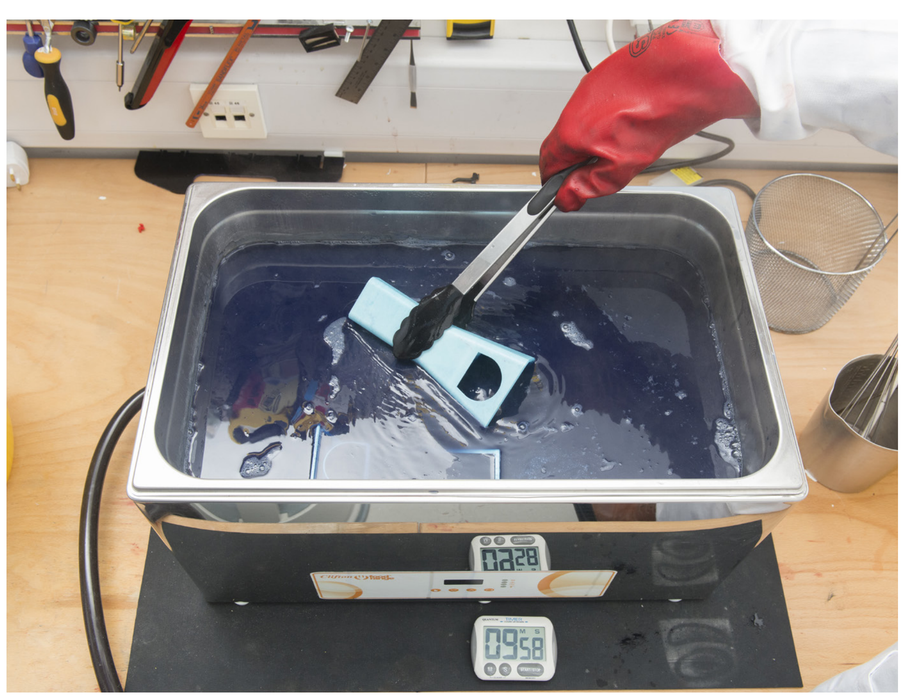
4. We prepared two timers, one for 10 minutes [to alert us midway through the process] and another for 20 minutes [to alert us at the end of the process]. The parts were fully submerged in the tank and allowed to settle back to the surface; we found all of the SLS parts we were dyeing floated.

5. We moved all of the parts away from the edges of the tank and carefully laid a sheet of bubble wrap on the surface of the water. A sheet of 3mm acrylic, laser cut to snugly fit the tank, was laid on top of the bubble wrap to weigh it down and ensure the parts were submerged just below the surface of the water. This stage of the process was crucial to ensuring an even, consistent finish.

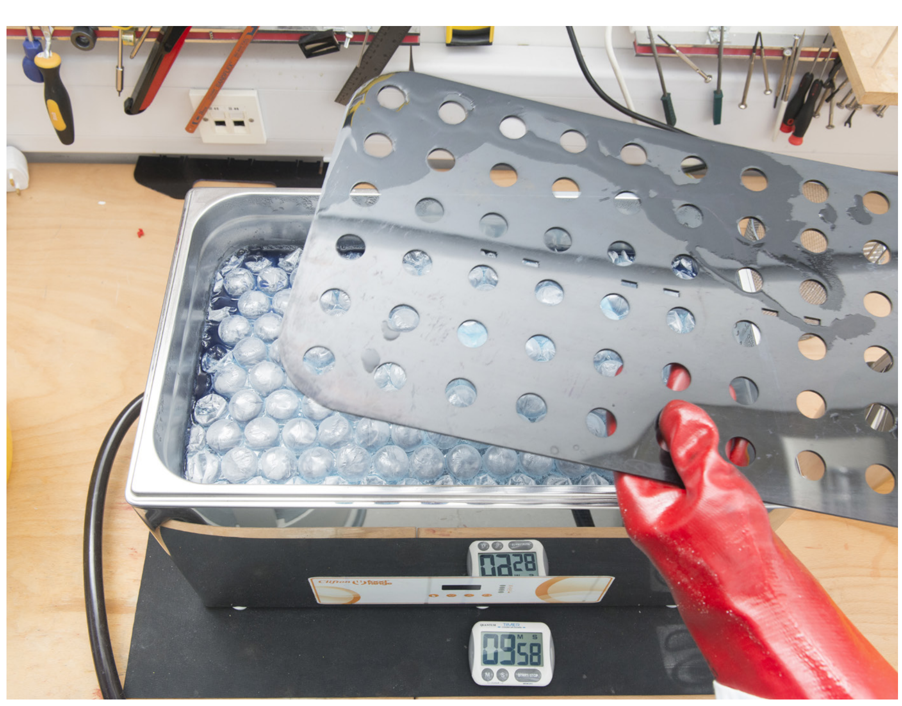


6. The lid was replaced and the two timers were started.

7. After 10 minutes, all of the parts were flipped 180°. This was to allow the dye to evenly access the material, to ensure the bubble wrap did not interfere with the part.



8. A fresh sheet of bubble wrap was laid on the surface of the water [as the first was distorted by the heat] and the same sheet of acrylic and the lid were replaced. The parts were submerged in the tank for another 10 minutes [a total of 20 minutes of dyeing].

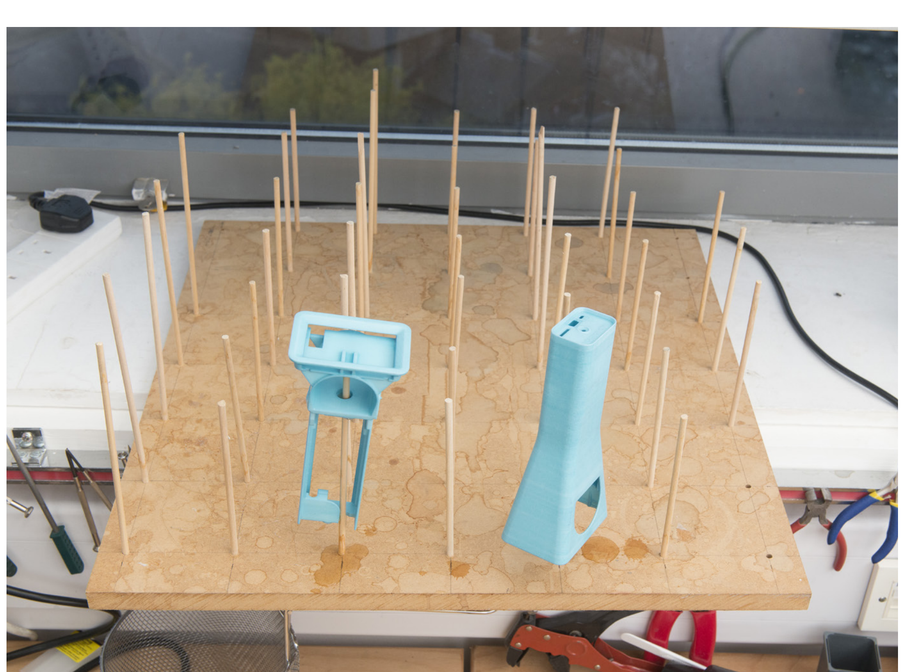


9. The parts were then removed from the tank into a clean bucket of water.

10. We rinsed the dyed parts in fresh water. Each part was inspected and lightly scrubbed to remove any obvious stains.

11. An ultrasonic tank was used during a final cleaning process. The tank was filled with water and a teaspoon of the levelling agent, Lavegal. This water was heated to 22°C and, wearing ear defenders, the ultrasonic tank was then switched on for 2 minutes.

12. Finally, the parts were left to drip dry on a bespoke drying rack.



This research was supported by the European Research Council's advanced investigator award no. 226528, 'Third Wave HCI'.

Written and edited by David Cameron and Andy Boucher
Foreword by Bill Gaver
Designed by Liberty Dent

We would like to thank those who openly shared their experiences and knowledge of dyeing SLS material, including Jonathan Rowley from Digits2Widgets, Stuart Jackson from EOS and the contributors to the Shapeways forum discussion on post production techniques entitled 'Black dye WSF & PWSF' [http://www.shapeways.com/forum].

We would also like to acknowledge Alex Wilkie and Matias Johan Vilhelm Bjoerndahl for their photography and our colleagues at the Interaction Research Studio, Robin Beitra, Kirsten Boehner, John Bowers, Richard Cook, Jen Estwick, Matthew Plummer-Fernandez, Bill Gaver, Mark Hauenstein, Robin Hunter, Nadine Jarvis, Tobie Kerridge, André Knörig, Lee Murray, Liliana Ovalle, Sarah Pennington, James Pike, Nicolas Villar, Alex Wilkie and Justin Wilson for their invaluable contributions to the project.

A digital copy of this publication is freely available at Goldsmiths Research Online [http://research.gold.ac.uk]

Reference:
1. Nadine Jarvis, David Cameron, and Andy Boucher. 2012. Attention to detail: annotations of a design process. In Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making Sense Through Design (NordiCHI '12). ACM, New York, NY, USA, 11-20. DOI110.1145/2399016.2399019

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