Interleaving Practices

and Critical Kits

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Abstract

This practice led PhD thesis proposes the method of *Interleaving Practices* as an approach to interdisciplinary work around art and science. In my art practice, artists work alongside science and other disciplines; they try to do what scientists do, copying their practice, re-empractising. Disciplines are not bridged seamlessly as if epistemologically flat, no impossible consensus is arrived at or antagonistic borders erased. Interleaving is supported by what I call 'Critical Kits' a term developed with art collective Re-Dock. Making these kits *fold-in* electronic components, documentation and raw materials, but also things normally unacknowledged, historical material traces, care, social relations, model organisms, supply chains, games and feelings. They also fold-in exclusions, externalities and political commitments. These kits are not art objects but by-products convivial to novel coalitions.

Making critical kits as participant observers reveals how diverse practices *stick together* but stay *separate*; that *interact*, but without *synthesis*; they *interleave* with each other without erasing difference. Like the multi-species collaborative labour of leavening bread *Interleaving Practices* is a generous strategic method for art and science work in precarious worlds.

Interleaving Practices responds to calls for slower methods of knowledge production that consider the politics of affect and care. It contributes to critique and praxis in technoscientific making in the fields of art, 'art-science', social science, and science and technology studies (STS). Making as *Interleaving Practitioners*, means research participants, artists, makers and scientists get their hands dirty, sticky and wet and reveal how their practices offer already existing critical spaces with rich opportunities for learning. Interleaving Practices not only contribute to interdisciplinary collaboration and inventive social science, but challenge practitioners in these fields to include and be transformed by an embodied politics of care, critique, intervention and struggle.

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Acknowledgements

Thanks to the seemingly endless capacities for care, support and solidarity at DoES-Liverpool and the Neuromuscular Centre in Winsford, Cheshire and the generosity of all my research participants without which the project would not have flourished and interleaved in the way that it did. Special thanks to Kay and Denise for being always open to new possibilities. As my neuromuscular condition advanced over the course of the research I have also benefited from that support and learnt what is the most important thing, the capacity to care.

Special thanks also to Dr Rod Dillon and Dr Jen Southern for their solidarity, support, care, critique and friendship. Academic flourishing would not have been possible without them and their unique interdisciplinary embodied knowledge. Thanks also to Prof. Paul Coulton who welcomed me into LICA's speculative design world and provided important design perspectives, Dr Mark Wright for early encouragement and introduction to Paul Dourish and Dr Ben Dalton fellow Barad traveller in carnivalesque network resistance.

Thanks and solidarity also go out to my colleagues and comrades at the Centre for Science Studies Lancaster, Domestic Science, the Endosymbiotic Calendar Coalition, Faculty of Health and Medicine at Lancaster University, the Foldscope team, Full of Noises festival and the people of Barrow park in Barrow-in-Furness, Dr Nathan Jones, Lancaster Institute of Contemporary Arts, Liverpool MakeFest, Re-Dock, the Science and Technology Studies community worldwide and South Walney Nature Reserve. I'd also like to acknowledge the passing of Bruno Latour and Richard Lewontin during the course of this research for their inspiration and scholarship.

I must thank my partner and children for their endless support for my slow emergent learning, physical and emotional needs. Dr Neil Dawson for sharing his neuro-scientific knowledge, professional networks and footage of his mouse collaborators and Dr David Clancy for his inspiring conversations and fly care tips. The most developed Critical Kit, the *LabFromAChip* requires special acknowledgments to Dr Alexandre Benedetto's generosity for introducing me to the vast microscopic scales of microfluidics and the Worm Breeders Gazette (Mendel, Wang and Harris, 1975), and Adrian McEwen for his indie manufacturing expertise and futuregazing toward the ultimate maker horizon. Thanks to my comrade Hwa Young Jung for many car rants and the troubling multitudes of non-humans and human that were contingent on the carbon released that got me where I needed to go. Finally thanks to the dialectical biologists Rod and Viv for their nurturing friendships, favourite microbes and homemade bread.

Declaration

I declare that this thesis is my own work and has not been submitted substantially in the same form for the award of a higher degree elsewhere. To the best of my knowledge it does not contain any materials previously published or written by another person except where due reference is made in the text.

The research is 50% practice and 50% written thesis. Approval for the submission of an Over-length Thesis has been granted.

Early reflections on my practice, relationality and Science and Technology Studies led to a short writing piece *Research In The Wild: An ever-changing map of connected relationships* commissioned by Contemporary Visual Arts Network North-by-NorthWest (CVAN NbyNW) and published online by The Double Negative (Dalziel, 2020a). Reflections on strategy and culture with participants at the research site DoESLiverpool in the section Organizing through Interleaving in the final chapter became part of a short framing piece for Andrew Wilson's Studio for Cooperation forthcoming publication *Making Space in Huddersfield* (Wilson, 2022) about the ending of a makerspace in Huddersfield.

I also participated in a 2 day workshop and publication organised by the Conscare group at the Lancaster Centre for Science Studies, for the European Association for the Study of Science and Technology (EASST) at their conference EASST2022, *Temporalities of Care in Conservation Environments*. In the workshop I worked with researchers Mariana Cruz and Edda Starck, and together developed the term 'lumpy coalitions', to refer to affective interdisciplinary alliances across our different research sites and discussed the 'Futuregazing' workshops I facilitated for DoESLiverpool as part of my research through practice (Boschen *et al.*, 2022).

I also delivered making and doing sessions with Critical Kits at the Society for Social Studies of Science (4S) Annual meeting 2020 (4S2020) in Prague and presented an unpublished paper based on case studies 1 and 2, at 4S2021 in Toronto on the panel *Art Science and Technology Studies - II Boundaries and Borders in Art and Science* organised Star Rogers and Halpern.

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Ross Dalziel

Chapter 1: Introduction and Context of Research

Research Questions

I explore three main questions in my research.

1. What do embedded and participatory art practices offer interdisciplinary work in art and biomedical collaboration?
2. What contributions do Interleaving Practices and Critical Kits make to theory and method in art, science and STS?
3. What are the implications and opportunities for knowledge production?

Introduction

This practice led art PhD thesis developed from 3 years of full time research through my art practice and its interactions with research participants embedded in 3 research sites, a co-working 'makerspace', a biomedical research and teaching institution and a charity for families living with neuromuscular conditions. These sites were the sources of data collected and then analysed and discussed as a series of case studies, which reflect on the interactions in each site. The thesis goes on to identify, discuss, explore and speculate on how this leads to the method of *Interleaving Practices*, an important new approach to interdisciplinary work around art and science and the supporting role of what I call, *Critical Kits*.

My research responds to calls for slower methods of knowledge production that consider the politics of affect and care such as the 2007 European Commission report *Taking European Knowledge Society Seriously* (European Commission Directorate General for Research, 2007). Similar, more specific calls come from the fields of art-science, for instance in *Tactical Biopolitics* by Da Costa and Kavita (Da Costa and Kavita, 2008), biomedical science, for example in Allotey et al's *Social Sciences Research in Neglected Tropical Diseases 1* (2010), maker culture, like *The Proper Care and Feeding of Hackerspaces* by Shaowen Bardzell (Bardzell, 2017), and in feminist Science and Technology Studies (STS), in the recent writings of lecturer and researcher Maria Puig de la Bellacasa (2011, 2017). It contributes to the milieu of artistic approaches to STS featured in the writing of foundational scholars such as Donna Haraway and Bruno Latour, in the wider STS canon, and more recently in the *Routledge Handbook of Art, Science, and Technology Studies* (Rogers *et al.*, 2021) edited by Hannah Star Rogers and Megan K Halpern, who hosted an open panel at the annual meeting of 4S2021 where I was invited to present an unpublished paper based on my research. Recently Michelle Kasprzak, in the review of The European Association for the Study of Science and Technology (EASST), reflected on the dominant content of the annual EASST conference of 2016, calling attention to a 'pervasive interest in repair, care, and maintenance' as part of what she called 'The Anti-Heroic turn' (Kasprzak, 2016). Such reflections complemented my own observations of an emergent shift toward maintenance and care in my art and maker peer groups and collaborating networks, in the proposal stage and throughout my research, including my own involvement as a volunteer in the development of the Festival of Maintenance (James and Turner, 2019), hosted at DoESLiverpool and initially a candidate for case study that was not pursued.

Science and Technology Studies (STS) became a core literature, reviewed as part of a series of sociology modules at Lancaster University. The work of the Centre for Science Studies (CSS) at Lancaster which I have since become a member of, and in particular, the work of their board and associates such as Joe Deville, John Law, Lucy Suchman and Claire Waterton, were significant in developing theoretical sensitivities to the complex configurations and relations of technoscientific objects and practices and how methods intervene in the world. Interleaving Practices and the supporting role of Critical Kits is put forward as a method for both discovering such relations and intervening productively. It commits to an 'inventive' approach to social research methods recently articulated by Professor Noortje Marres and her co-authors in *Inventing The Social*, who described a compelling intent to:

> ... articulate social phenomena not simply through describing them but by deliberately modifying settings and by inducing or provoking actors to behave and express themselves in ways they would probably not of their own accord. (Marres, Guggenheim and Wilkie, 2018, p. 27)

With this disciplinary mix in mind, my thesis is written so that it is both accessible and of interest to art, maker, science and social science readers. There is a wide range of literature to review from different disciplines so I have taken additional care to introduce it slowly, verbosely but clearly and methodically. This care is developed from the care at the heart of my practice, and part of an ethos of accessibility that permeates the whole PhD. I hope to show in the thesis how I developed a diverse interdisciplinary mix of theory, method and practice that make valuable and critical contributions to the fields of art, making, science, STS, inventive social science, political action, subjectivity and consciousness. I have also made a purposeful decision to use an unconventional format with regard to chapter length in order to interleave diverse yet appropriate interdisciplinary methodological and theoretical literature. The interdisciplinary practices that my own art practice draw out requires a large section devoted to case studies, with extensive analytic layers of discussion interleaved into them, and then elaborated on further in concluding discussions that answer my research questions.

The thesis introduces the art practice, key terminology, research topics and questions. As it's practice based, this is followed by a description of my research methodology and details of my ethics approval in chapter 2. I go on to review appropriate literature in The Practitioners in chapter 3. This explains my understanding and rationale for using theory to develop appropriate sensitivities for the study while situating, contextualising and developing the practice based methodology pursued in the study.

Arguments and discussion build on the analysis of the case studies in chapter 4, Doing What They Do There, leading to a set of key features introduced below. Each study contributed to these features and each other, but some specific features came from some specific cases.

Key Features

- *Strategic* - Looking for opportunities in the near and far future.
- *Cultural* - Maintaining a culture, allowing new capacities to emerge

- *Sensitive* - Sensitises practitioners to complex technoscientific objects and practices.
- *Affective* - Makes new shared affective and material interests.
- *Care-full* - Strategies and tactics for maintaining and generating capacities to care.
- *Inventive* - New playful capacities for social change, critique and care.
- *Fold-in* - Fold different knowledge, materials, historical traces and relations together
- *Un-fold* - Reveal invisible work, partly open black boxes, costing up care.
- *Collective* - New coalitions, new political subjectivities.
- *Multiple Temporalities* Interleaving not just spatially, but across different kinds of time, slow, with slow emergent working
- *Following Distractions* - Distractions can be valuable and strategic. They can also support an emerging culture's current and future capacity.
- *Productive failures* - Failure is key to making and knowledge production, making boundaries, finding out what works and what does not. Looked at from a historical perspective, failing is a dominant characteristic of all knowledge making, Interleaving lets practitioners learn to fail better.

Analysis

In analysis I've tried to follow Bruno Latour's critical and expansive approach to *description* and Gilles Deleuze's avoidance of metaphor, that is not always trying to find what something is *like*, but describe what it *is*. I take care to find what was already assembled together, without necessarily looking for some kind of explanation, or reveal something otherwise hidden. I've tried to describe and discuss critically what I saw and felt as a researcher through practice, together with my research participants.

As I described how things, practices, disciplines, objects, subject, were overlayed, interconnected, assembled and related to each other, *Interleaving* became the most convincing way to describe what was going on. As readers will follow in the discussions between each case study I began to see opportunities for an inventive, slow method for art, science and social science, full of care with affective political implications. Eventually I found that I could no longer describe the case studies or make anything in my practice, without interleaving.

Interleaving Practices is my concluding descriptive and theoretical idea that permeates the methodology, analysis, conclusion and organisation of the thesis. It means that a linear narrative of review, method, practice, analysis and conclusion is at times un-moored and *folds-in* on itself, it inevitably, interleaves. How this is manifested in the written thesis, is that Interleaving Practices, that I ultimately present as a research finding and method, makes its way, alongside other codes and concepts, into the analysis and telling of its beginnings. This is my writing method, a carefully interleaved assemblage of making, observations, research data, voices, perspectives and the building up of networks of connections for analysis by shifting temporality and scale in the discussion. At times I have used the capitalised word 'Interleaving' as a shorthand for this method.

At the same time, I take seriously Noam Chomsky's scepticism toward obfuscation in writing, critical theory and method, illustrated in an offhand remark to Marxist biologist Richard Levins on dialectics which he helpfully and not without characteristic irony 'translated' as 'thinking correctly' (Levins and Lewontin, 1985). My approach to what is 'thinking correctly' for this study also includes writing appropriate to specific disciplinary specialists so at times indulge in inventive writing that Chomsky would, if not object to, feel the urge to translate.

Overview

Interleaving Practices are supported by Critical Kits which act as formats and media for making artworks and technical objects in a critical way. My thesis argues for and exploits how method is not only performative; affecting what and how one can know things, and according to STS playing a role in reproducing the world, but a *strategy* for knowing and doing. Producing knowledge about the world and then, the point being, as Marx said, to change it (Marx and Engels, 1845). More specifically for science, according to Ian Hacking, the point is, to *intervene* (Hacking, 1983).

All methods, like all economies, are also part of an historical process, it is never 'just so'. In the first case study I begin *un-folding* the seemingly stable 'just so' story that we see with microscopes, making through Hacking's discussion of the history of microscopy. This is a core part of my research through practice, my critical making, exploring theory and practice through making with materials, to *fold-in* historical traces. Bruno Latour and other STS thinkers such as Susan Leigh Star, call these histories, 'invisible work', where the historical traces of what happened to make a science become a technology in the world are erased and it becomes a common tool. It becomes a 'black box'. For example we don't know how the technology of the newly domesticated, for the global north at least, lateral flow test (LFT) works in detail. We don't know how exactly it detects the Ribonucleic acid molecules on the surface of the virus. It just *works*. How it works may aswell be put in a black box. We put a swabbed sample on a tiny slot and a result emerges from the paper substrate. Something goes in one end of the box and a result, out the other. There are complex related histories folded into the LFT such as that of the Polymerase Chain Reaction (PCR) (Rabinow, 1996), the development of microfluidics and arguably years of neoliberal economics that led to the facts of the matter of an LFT test. Interleaving with Critical Kits help make practitioners become *sensitive* to this invisible work. Using the *LabFromAChip* Critical kit for example aims to let you see, feel and intervene at the non-human scale of microfluidics while offering opportunities to reflect on the labour required for that technique to become a technology.

I argue for the advantages of this kind of embodiment enabled by making in knowledge production. One advantage is to make new *capacities*. *Capacity* is an important concept particularly with respect to the political implications of my research. When we expect people to learn from and care for each other, it is not only based on immaterial human values, there is a cost to care and knowledge, a form of what social theorist Pierre Bourdieu (Bourdieu, 1986) would call social capital. From my experience in my research and beyond, there must be *material* capacities available for learning and care to be possible, they cannot only be understood as some innate

or moralistic human value. With this perspective, focussing on making and practices builds bodily capacity and not just speculative possibility. Capacity and consequently knowing and caring are not exempt from historical processes. In case study 2 I observe this process, how participants care for humans or non-humans when they work embodied alongside them. One can only understand the capacity of a 3D printer if you try to use one or even build one to use experimental biomaterials in case study 4. In case study 5 I explain how one can only know the limitations of DIY approaches to the diagnostics of disease if you attempt to make them, and fail doing so. Failure also builds capacity and knowledge and becomes a *feature* and *strategy* of the method.

A printed catalogue of the Critical Kits, the *Critical Kit Manual* (Dalziel, 2022a) is also the catalogue of artworks made as part of the research through practice. I have provided a summary and introduction to them and their relevance to case studies in the Artworks section below. These artworks are also prototypes that are only partly complete or working and remain problematic and embody limitations, and in this sense they are also a catalogue of failure. Failure is part of what all artistic and political projects share but rarely acknowledge: the importance and proliferation of defeat, which the biologist Stephen Jay Gould calls, in the terms of his understanding of the historical process of life itself, as 'decimation' (Gould, 1990). Gould and other thinkers from different disciplines contribute to how I understand the role of my critical kits as what I call *Assemblage Objects*.

Thinking of method in strategic terms generated all kinds of capacities for the practitioners interleaved in the studies. Interleaving Practices is not a metaphor for what was found out, it is a method that exploits what was already there, the complicated liveliness of different ways of doing and knowing things in art and science. Not necessarily hidden, just not always seen as an opportunity. I use the case studies and wider research to speculate on an Interleaving Practitioner in Chapter 5, who might use Interleaving Practices as a method convivial to the interdisciplinary strategic tensions of their respective fields.

Finally in my concluding chapter I summarise my answers to my research questions and discuss the real social impact, transformative change and increased capacity for care my research created directly at the Neuromuscular Centre, well beyond expectations. My research has led to new affective coalitions growing across the Neuromuscular centre's community and the transformation of an outdoor building into a new makerspace setup to support the community's making future. As I write this in 2022, Club members struggle to keep up with demand for new interesting making projects, in a garden and community that has flourished through the contradictory opportunities and tragedies of the COVID-19 pandemic.

Research Sites and Context

In my art practice I prioritise social activity over art objects and production to explore how knowledge is shared and made collectively. I do this through a form of playful interdisciplinary work often on the boundary of traditional art spaces and institutions with multiple authors and collaborators. The core of the practice is understood in my research as part of a genealogy of participatory and community art

and more specifically forms of 'embedded art practice' described by Marisa Jahn and her contributors in her book *Byproduct On The Excess of Embedded Art Practices* (Jahn, 2010a).

Most recently I have been embedded in 'maker' culture. 'Maker culture', populated by 'makers' and their 'makerspaces', refer to a social formation with origins in the now closed *Make* Magazine (Sivek, 2011), which has led to federated and independent iterations of makers as a community broadly committed to an open and creative approach to education in making technology, but also manifesting as a business model, educational and technical practice and identity that has spread around the world. The 'maker', as I write this in 2022, is a nebulous identity based on diverse craft and technical practices ranging from traditional woodworking and engineering, to software and hardware development, digital literacy, cutting edge materials research or radical experiments with internet connected and embedded autonomous systems and machine learning. The parallel development of a wide ranging Do-It-Yourself (DIY) culture and the partially democratising effect on knowledge production of the rapid global expansion of the Internet has helped spread the heterogeneous maker meme. This has lead to everything from individual hobbyist digital prototyping, school code clubs, numerous creative and commercial enterprises with a substantial globalised supply chain to small and medium scale manufacturing. Maker projects are often hybrids of digital and physical craft playfully connecting objects to the internet and incorporating electronics with diverse materials using a mix of open-source and proprietary software and hardware. 3D printing, lasercutting and other forms of Computer Numerical Control (CNC), the fine control of 'stepper' motors, motors that can be moved in predictable 'steps' of a standardised distance, means digital information and more traditional material craft practices can work together. Fundamentally it shares the most powerful and visible characteristic of DIY culture, a sense of communal support and democratic impulse toward learning and using science and technology, with makers convinced that 'anyone can do it'. Maker culture and its practices also has roots in internet driven 'hackerspaces', 'hackspaces' and wider technical cultures (Davies and John Wiley and Sons, 2017; Mazzilli-Daechsel, 2019; Marotta, 2021). Hackerspaces refer to independent community spaces for technically minded hobbyists and professionals to rent and share storage and social space to pursue software and hardware projects collectively or as individuals.

More specifically for this research through practice, I am embedded in the hybrid co-working independent makerspace DoESLiverpool (DoES) sharing many characteristics of both makerspaces and hackerspaces. I have worked from, advocated for and volunteered at DoES since 2013. This particular community and the practices peculiar to them has had a strong influence on my artistic practice independent of this research and has in some ways become an integral part of my work, in that I rarely work without depending on, learning from or engaging with that community. This is part of an approach to care in my artistic and research practice that requires long form political and practical commitments to build and maintain social relationships essential for the embedded art practitioner or a social science researcher. It is this relationship that made DoES an important research site and in many ways it framed the other sites and their case studies discussed in this thesis. I observed activity at DoES twice a month at the Wearable Technology interest group, an informal group I organised as part of my research with a research participant and co-director of the

organisation, who I refer to by the pseudonym Jackie.

The Division of Biomedical Life Sciences (BLS) in the Faculty of Health and Medicine at Lancaster University is a high ranking university life science department teaching all aspects of biomedicine including microbiology. At this research site as an artist-researcher I had access to student cohorts, module content and training and the teaching and research community. This complemented the study's supervisory team of Rod Dillon and Jen Southern, who are both advocates for, and practitioners of, a form of art-science practice, while also being leaders in their own respective fields of microbiology and social science. Dillon is interested in the resonance between art, maker culture and the craft practices of experimental microbiology and the study of insect vectors in the reproduction of disease. He actively supports the idea of opening microbiology labs to artists who can use it as an art studio. Southern, a collaborator of Dillon's also works across art, science and technology exploring hybrid methodologies for social science, in particular the field of mobilities. They also are senior lecturers, Dillon teaching microbiology at BLS and Southern Fine Art at LICA. Professor Paul Coulton whose research interests include the Internet of Things (IoT) and game culture, provided important supporting supervisory design perspectives. A final research site emerged as a consequence of the practice, over the course of the study at a 3D Print Club, a small maker community based at the Neuromuscular Centre a charity in Winsford, Cheshire again in the UK, supporting people living with neuromuscular conditions.

The First Person Voice

Ideally 'I' in this thesis should be 'we'; there is nothing in this thesis nor in the art practice that drives it, that is not 'social', that does not work with and depend on other humans, and non-humans.

I acknowledge a euro-American perspective on modernity from the global north which unavoidably shapes my position as researcher and necessarily limits the study. This thesis argues for strategies that include troubling decisions and tricky coalitions from problematic positions. This study has led me to consider the self to *not* be a singular entity. I follow leading biologist Scott Gilbert and his colleagues perspective that *We Have Never Been Individuals* (Gilbert, Sapp and Tauber, 2012). I take a reflexive stance toward knowledge making as not a progressive lineage of visionary individuals but a lumpy network of labour distributed across time, space, sedimented practice, power relations and difference.

> Foucault's ideas, like Trotsky's, are never treated as primarily the products of a certain intellectual milieu, as something that emerged from endless conversations and arguments involving hundreds of people, but always, as if they emerged from the genius of a single man (or, very occasionally, woman). (Graeber, 2004, p. 4)

The Art Practice

> We specialise in a kind of interdisciplinary art-science – a lesser known but established artistic genre where artists and scientists work together as equal collaborators. Our approach is to try and pick up on some of the things they do, like how to measure water pollution, as if it was a craft to learn. We don't make art with science as a subject or as a service to explain it, but to get close to scientists to do art alongside them. (Dalziel, 2020a, para. 4)

My more recent work is in the milieu of what Professors Andrew Barry and Georgina Born called, in their recent theorising of the modalities of interdisciplinary work, 'art-science' (Barry and Born, 2013). However it is more specifically grounded in an art practice where objects and production are deferred, de-prioritised or even absent; instead materials and systems facilitate social activity to foster what Michael Newman has called in his essay on conceptual art, 'political, social and cultural experimentation' (Newman, 1996, pp. 288–289) . Social labour is prioritised; the building and maintaining of relationships, sharing, giving, gifting, helping out, caring. There are no big spectacles, but instead intimate events for doing, making and talking often outside conventional art and academic spaces. Past example space include factories, cafes, canals, docks, markets, museums, boats, public parks, sports centres, shops. In some cases, social activity in unexpected places can act as a spectacle in order to attract participation, but its staging is only prioritised in terms of the quality of direct interactions it may afford. The practice is emergent, slow, contextual, mobilising and fostering formal and informal interest groups.

It has commonalities with the 'relational aesthetics' put forward by Nicolas Bourriaud (Bourriaud, 2002) and the participatory art practices Claire Bishop presents as an aesthetic problematic discussed later in the thesis (Bishop, 2010). Jahn's descriptions of 'embedded art practice' reviewed in this research, while part of the more radical approaches to traditional genealogies of artist in residence, also articulate how, in my practice '. . . context is half the work' (Jahn, 2010a, p. 41) . I align particularly with Jahn's description of 're-empractising', by which she means artists doing what people do in the places in which they are situated. This is something Jahn refers to alongside Barry and Born in their contributions to *Interdisciplinarity: Reconfigurations of the Social and Natural Sciences* (Barry and Born, 2013). Both these texts were indispensable in the early literature review, contextualising and articulating the art practice further. It is a practice informed by technology but committed to the social. The portable trestle table for temporary activities is the most common material platform and medium for this work. In terms of my art production, there are a few elaborate installations presented for exhibition but even these are incomplete without human participation and labour. Materials are presented convivial to participation incorporating low cost, familiar, 'domestic' components. Sophisticated technoscientific objects are often developed, using technologies popular in maker culture such as digital prototyping tools, 3D Printing and plotting and small scale manufacturing of electronic Printed Circuit Boards (PCBs). However these media are utilised under the terms of re-empractising, in order to embed further into the material and immaterial social practices concerned, most recently maker culture since 2008. It is a practice that intentionally foregrounds the collaborative, the collective

and interdisciplinary, often mobilising other practitioners to work alongside other domains of knowledge and practitioners, most recently the domains of maker culture, computer science and the life sciences.

A characteristic role of facilitator and curator are also significant. My background in youth work, community art and media and the idea of art as a social service, developed a sensitivity to positionality and power which has led to the privileging of collective practice. This informed my work as an independent self-employed professional artist and facilitator for clients and collaborators across art, culture, heritage, technology, science and education. This included organisations like Arts Council England, FACT (The Foundation For Art and Creative Technology) in Liverpool and The Whitworth gallery, Manchester.

Critical Kits

Figure 1: Image of slide of Critical Kits card game and book

'Critical kits' is a term that originated from a symposium I organised collaboratively with artist collective Re-Dock (Dalziel and Winterburn, 2016) in Liverpool in 2016 and a subsequent book, *Critical Kits And How We Use Them* (Jones *et al.*, 2016) (Figure 1) to explore the influence of maker culture on art practices in the North West of the UK. This emerged from observations of myself, peers and colleagues using 'kits' and 'kit-like' practices enthusiastically to distribute and mobilise complex participatory work with technology. Driven by my own and my peer group's perspectives on the importance of maker culture in the art and technology ecosystem of the UK, the symposium validated a need for critical reflection on this phenomenon. Building on the symposium, in my research I began to respond to this through forms of 'critical making'. Critical making in my research refers to the work of Matt Ratto, who coined the term, Garnet Hertz and others (Hertz, 2012; Ratto, 2017), in their approaches to criticality through making with materials. Critical kits are kits made through a

form of critical making informed by a diverse set of critical tools developed in the literature review, presented in the chapter The Practitioners and throughout my research. In particular I developed an understanding of kits as 'boundary objects', material objects that different practitioners from different disciplines can work with and also a category used to think about knowledge production, following and building on the ground breaking work of researchers Susan Leigh Star and James R Griesemer and others in the field of science and technology studies (Star and Griesemer, 1989).

Kits mobilise and reproduce knowledge, packaging up conversations, tools, methods and materials. They can be seen as useful supportive packages for both doing and knowing. Bicycle repair kits, sewing kits, software development kits, educational kits, biomedical diagnostics; any assemblage or configuration of tools, knowledge, practices or materials. This makes them significant assemblages for analysis to help understand technoscientific objects and practices.

Kits include but they also necessarily exclude. Not just components or materials but other ways of doing, feeling, knowing and relating. What ends up in a kit and what does not, has both practical, affective and politically meaningful implications. Capable of distributing knowledge and agency these helpful bundles of practices can also elide what cannot be included. Anthropology professor Sharon Mattern, in her online article responded to the symposium with Re-Dock, commenting how 'local and indigenous knowledges, lessons ingrained in the landscape itself – simply don't lend themselves to standardization, measurement, and "kittification."'. (Mattern, 2021, sec. 4)

Kits like artworks, could be seen as embodiments of sedimentary social process or of a social order but in my practice they also have a relational affective aesthetic, that they are always about to be used for something. In exhibition settings I have often presented kits as artworks or parts of installations but only present them in this way in order to set the stage for their social use rather than privilege their status as autonomous objects.

Artworks

The printed *Critical Kits Manual* is the equivalent of an exhibition catalogue and partly an artwork itself. In this art practice embedded in maker culture, art objects are not the priority. Instead materials and systems for activity take the form of kits and projects that are prototyped, developed and documented on the code sharing platform GitHub which provides a data 'repository' at a specific web address, detailed in the manual. This is part of a tactic for embedding, where GitHub is a popular platform for the maker practice of fine grained documentation, sharing and development of software and hardware. The use of GitHub in DoESLiverpool is discused in detail in case study 4. The artworks and prototypes, published on GitHub and presented in the manual are equivalents to art objects for exhibition that embody and enable the research through practice. The manual introduces the artworks in such a way that refers to the design format and writing styles of GitHub.

These artworks respond to my research into maker and kit-like approaches to biomedical technology. This research is featured with summaries and commentary in an

online Critical Kit Library (Dalziel, 2019b). Selected projects from this library are then playfully analysed using categories from science studies literature in a printed card game, *BioTrumps* (Dalziel and Jung, 2019). The game is based on the popular 'Top trump' style of card game, where different categories are scored against each other competitively. It is based on a similar game about art and maker kits *Critical Kit Trumps* (Dalziel, Jung and Winterburn, 2017) made for the original Critical Kits symposium. Using simple game formats is another feature of my art practice particularly in my work with Domestic Science, the art collective I founded with artists Hwa Young Jung and Glenn Boulter. This research prioritised low cost maker approaches to life science lab infrastructures and excludes the wider fields of digital biological science like bioinformatics. These include 3D printed microscopes, laser cut electrophoresis chambers, microfluidic printers and other lab equipment that attempt to democratise or contribute to more cost efficient approaches biomedical lab practices. This decision is grounded in my practice and the context of my research sites.

The written style and shifting tone of these introductions in the Manual are designed to be accessible to an audience of GitHub users while also including writing that might appeal to biomedical life scientists, artists and social scientists. Each artwork's source and development files are provided online, at locations detailed in the manual. Below is a summary of each project and a description of their role in my research. The manual is a format found in many technical cultures. The cover refers to the house style of the publisher O'Reilly, well known for publishing canonical guides to software programming languages used by makers and scientists like Python. Some project repositories like *LabFromAChip* feature tutorial videos and serve the source files for related project websites often guiding and documenting activity for others to follow in workshop settings. Readers may care to follow the rabbit hole of some of these projects or even get a sense of their development by browsing the publication history of GitHub 'commits', when documentation, code and objects are published to these publicly accessible websites on the GitHub platform.

Below I introduce the contents, context and significance of each project repository in the Manual with respect to the research through practice.

BlackBoxGolf

The artwork is a playful pop up golf hole exploring the idea of the black box and a space to do a kind of what one participant at a Science and Technology Studies (STS) conference called 'folk STS'. Example of early making using the maker vernaculars of 3D printing and lasercut acrylic, in response to STS literature.

BREADBOARD-LAMP

Breadboard version of a design for a low cost Loop Mediated Isothermal Amplification (LAMP) DNA Amplification System (Velders, Schoen and Saggiomo, 2018). Breadboarding is the maker practice of prototyping electronic circuits on 'breadboards', plastic flat interconnected perforated boards that allow standard electronic components such as electronic resistors, Light Emitting Diodes (LEDs) and other

electronic components to be assembled and tested. *BREADBOARD-LAMP* is part of case study 5 and part of the prototyping and review of scientific and maker literature in the field of low cost molecular diagnostics completed with a research participant and is part of the *WaxPlotters* project.

EthicalMicroscope

DIY microscope stage that can be built with common makerspace tools. The *EthicalMicroscope* is a remix of Public Lab's version (Mach, 2017) of the Hackteria maker microscope (Dussellier, 2013). It's part of my research into microscopy practices in biomedical science and DIY-Bio, a maker approach to microbiology and an experiment in building a boundary object interesting to artists, makers and scientists.

FlyFarms

Kit for imaging and streaming environments of *Drosophila melanogaster* a form of *Interspecies Gaming* a term developed with artists and designers Jasper Meiners and Isabel Paehr at the *DisruptEncodeConsolidate* (Dalziel, Dawson and Dillon, 2018) symposium event organised at the start of my research. The kit was developed with participants at the NMC and BLS and allowed beginners to observe 'model organisms' and stream them on a Critical Kits Live Stream on the streaming platform Twitch. A model organism is a non-human organism studied to understand specific biological systems and phenomena of relevance to the understanding of other organisms, including humans. This is discussed in Case Study 2: The 3D Print Club. It features components from existing ant Formicariums, educational kits available on eBay for observing ants. EBay provides many of the components for these kits and a common source of 'stock' for maker culture. The availability of something as a commodity on eBay indicates a certain level of development for a technology or scientific practice that it can support complex local supply chains.

LabFromAChip

LabFromAChip is a kit that uses 'Lab On A Chip' technology (Wheeler, 2001), the use of micro-engineering in biomedicine and biochemistry to interact with model organisms. It became the most developed kit in the research and was part of numerous interactions with participants and features the existing *Foldscope* kit made by Prakash Labs (Prakash, 2014). The *Foldscope* is a key component of many of the other kits such as the *BlackBoxGolf* and *SourdoughBreadBoy*. The ongoing use and development of a particular technological 'platform' is a characteristic of maker culture, art and biomedical practice that my research through practice articulates. I use the *Foldscope* as a platform to support moulding bespoke microfluidic environments for observing the model organism *Euglena gracilis*, a practice used by researcher Alexandre Benedetto and observed at BLS in the research which I develop as a research through practice activity. Later on the *my-first-pcb* project supports the development of a manufactured *LabFromAChip* printed circuit board (PCB), a

handheld programmable electronic lighting stage for Foldscope and microfluidics. The system is compatible with the Raspberry Pi, a Linux computer popular in maker and hacker culture and more recently used by experimental biologists for the cost effective observation of large numbers of model organisms that also use computer vision and machine learning libraries popular with makers and scientists such as *IdTracker* (Romero Ferrero *et al.*, 2019). For example, Dr Neil Dawson used Pi based systems for recording the behaviour of mice used in his research on ageing. Combined with a Foldscope lens, the PCB acts as a lighting stage for prepared microfluidic slides and with a Raspberry Pi Zero, can support the streaming of images using an HD camera and a cheap 128x64 pixel OLED screen to enable interactions with Algae and other microorganisms. It's discussed in detail in Case studies 1 and 3 yet and is significant for the way it includes many of the practices observed in DoES, BLS and my research into kit culture including biotic gaming, the gamification of interactions with microorganisms like algae and slime mould, and electronic PCB badge making used at maker and hacker culture annual conferences.

Latourscope

The Latourscope is a folding origami map kit based on the work of Bruno Latour from his performative *Inside* Lectures (Latour, 2017b). It also complements the paper based folding technology of the Foldscope. It is only discussed as an example of how my practice will often take conceptual ideas or practices and represent them in a playful way using practices from maker culture. The Latourscope was used in a workshop with Lancaster Arts exploring the importance of soil.

MicroMart

Documentation of the BioArt activity used as a teaching component at BLS developed by Dr Rod Dillon and his colleague Dr Jackie Parry as part of the Microbiological Technique module for undergraduates. I observed this event for my research having been an invited artist guest in the past. Originally there was an attempt to turn this activity into something that could be run with the general public at an art event. Research into this and the health and safety implications prevented this from happening. It is significant as an example of the limitations of some practices and the complex infrastructures required for biomedical learning that must be secluded from the public and cannot be simply or carelessly democratised through maker approaches to DIY Bio. It is discussed at length in The Interleaving Practitioner Chapter in the section Lost in the MicroMart.

my-first-PCB

Introduction to designing printed circuit boards for small to large scale manufacturing. Maker culture often attempts to democratise technoscientific making processes like this, something I follow, re-empractising. It is an example of the extra care required of my embedded art practice which otherwise might be considered as distractions from developing finished autonomous artworks for exhibition. Instead of simply

making the LabFromAChip PCB as an artwork, a series of collaborative learning materials are developed in collaboration with Internet of Things consultant, maker and co-founder of DoESLiverpool, research participant Adrian McEwen. I helped run 2 training courses for his company in exchange for his expertise making the PCB. It is discussed in case study 4 and referred to in discussing maker practices. For those readers interested, like many of the works in the manual, the GitHub repositories feature fine grained information and design files that enable others to reproduce the works or learn from them as resources. It is a unique guide and educational resource for introducing the design process of PCBs for both beginner and intermediately skilled makers.

NMC3DPrintClub

Source files for the 3D Print Club project and website that developed from an initial introductory workshop into an ongoing interest group and one of the main research sites and is key to understanding the importance of transformative communal affective care in both maker culture and scientific practice informing the Interleaving approach. It is discussed at length in Case study 2 and was significant in understanding how 'newcomers' to a practice became 'oldtimer' experts. The collaborative development and fostering of informal interest groups and clubs is a feature of my art practice.

SourdoughBreadBoy

A 'Fork', that is, a different version of a piece of software, of the Arduino based *BreadBoy* (Blinky, 2018). The *Breadboy* is a non-soldering DIY breadboard based arduino gameboy based on the Arduboy. (Bates, 2015; Harbaum, 2020). This prototype is my artistic response to the Mikroskopisk PacMan project (Bartley, 2016) at the Institutt for mikro-og nanosystemteknologi (IMST) ved HSN Universitetet i Sørøst-Norge, Kunnskap for fremtiden, a re-creation of a maze from the game PacMan using microfluidic technology explored through the research. The *SourdoughBreadboy* is a speculative handheld gaming platform that refers to this microfluidic experiment, the genre of 'biotic games' and historical materialism of the Marxist critical tradition. This does not feature in case studies but is an example of a project that fails to complete or fully develop while informing and evolving into other projects and research through a form of critical making. The concept of a handheld biotic gaming device using the *Foldscope* was developed further in the LabFromAChip Printed Circuit Board.

ProtestsForProtists

Early experiment using the *Foldscope*, *EthicalMicroscope* and *SourdoughBreadBoy* prototypes to engage visitors to *Liverpool MakeFest* a regular maker event the DoES community contribute and support at Liverpool Central Library. Passers by can learn to count algae using hemocytometers and then count them in DIY microfluidic spaces generated with a desktop digitally controlled vinyl cutter, that echo local street maps. Participants are invited to take part in an anthropomorphic thought

experiment to imagine how the microbial world might protest against biodiversity collapse and antibiotic resistance and the success of a protest's impact based on quantitative or qualitative change.

WaxPlotters

My research through practice methodology means a project like *WaxPlotters* brings together many practices I observed and explored in art, maker culture and biomedical science. Like much of my work it remains unfinished and ongoing, with the working group of research participants still developing it sporadically and since evolving into a similar project aiming to standardise a set of interoperable machine tools for the CNC control of extruded biomaterials. This research through practice project is discussed in the case study 5 section of the *Doing What They Do There* chapter, Printing and Plotting Diagnostics.

WearableTechBadgeWorkshop

This part of my research through practice explores the limits of my critical making approach in formalised workshops and features in the discussions around case study 4, in the Wearable Tech Badge Workshop section of the Doing What They Do There chapter.

Games

Early on in the research I also made playful lo-fidelity games and social media that were displayed in a bespoke full size lasercut arcade cabinet (Figure 16) made with artist, maker and collaborator James Medd, called the *Arcade De Bruno* (Dalziel, 2019a) referring to the cabinets of early computer game arcades of the 1980s and made in response to science studies literature. The cabinet is a cost effective platform for independent games and allows audiences to play a game to understand why neuroscientists kill mice *C-2-DG Sugar Mice in The Wind* (Dalziel, 2019e). This is discussed further in the section Follow the Things: Actor Network Theory in the chapter The Practitioners.

Chapter 2: Methodology

Method, ... will often be slow and uncertain. A risky and troubling process, it will take time and effort to make realities and hold them steady for a moment against a background of flux and indeterminacy. (Law, 2004, p. 10)

Ethics

Ethics approval (reference FL18152) was granted by the The Faculty of Arts and Social Sciences and Lancaster University Management School joint Research Ethics Committee (FASS-LUMS REC) that oversees ethical review of proposed research in all Departments of both Faculties on 7th June 2019.

I applied for ethics approval based on observing human participants producing 'kits' with me that engage critically with the life sciences. I informed them that I used established forms of interdisciplinary 'research through design' and participant interviews to explore how kits help artists and scientists work together and contextualised it with respect to scientific literacy and agency. I secured informed consent with all research participants before observing or recording specific activity or interviews or making sessions. Each participant received a participant information sheet (PIS) which they would confirm they read and understood, and returned a signed informed consent form indicating their understanding of the project and their participation in it. They would also indicate whether they wished to be fully anonymised or attributed and identified directly or under a pseudonym. In a few cases participants are identified by their real names but again only with their informed consent.

The blank PIS and consent form is available in Appendix 1.

Critical Kit Making As Method

Re-empractising is where I began, doing what people do in the situations I am in. I have adopted craft practices used in 'maker' culture in my art practice since 2008 that continue to feature in my research. Making using Computer Numerical Control (CNC) implemented in laser cutting, 3D printing and 2D plotting in a range of materials. Open source software and hardware were used throughout and were shared through tools like GitHub already mentioned and more maker specific platforms such as Thingiverse.

In my research diverse yet relevant sets of kits at the intersections of art, design, maker culture and biomedicine were explored. Grounded in the situations of the study and informed by the reviews of literature in The Practitioners chapter, existing kits were introduced to research participants and re-mixed and re-made in response to their interactions. Observation of these interactions and the reflexive process of making and re-making made up the data of my research. Participants made and used kits provoking their limits, unravelling their little inclusions and exclusions. *Critical* kits are in a sense, little 'détournements' - in translation from the french, they 'un-tie' components and relations to help understand them. They don't just deconstruct however, they also *fold-in* material critique and participant responses. This underpins my approach to critical making (Figure 2).

Prototypes are made, often responding directly to literature and published as repositories on GitHub. For example Latour's performative lecture *Inside* (Latour, 2017a) became a printable origami map used at campus events at Lancaster University (Dalziel @cheapjack, 2020) (Figure 3) interleaving the data from a maker culture research project, Indie Manufacturing by McEwen and his colleague Andy Goodwin

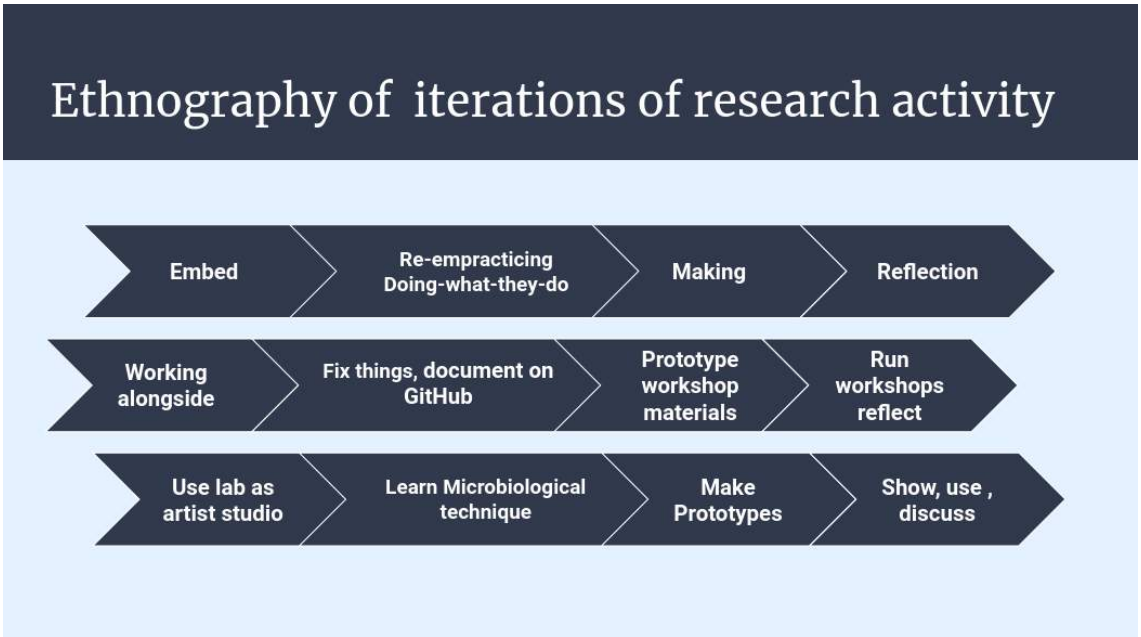

Figure 2: Diagram of iterations of research activity

for the Royal College of Art's Future Makerspaces in Redistributed Manufacturing project (Stewart *et al.*, 2018) (Figure 4).

I also re-made, re-mixed or consolidated existing maker projects like a simple maker microscope (Figure 5) (Dalziel, 2021a) which fold-in a range of open-sourced microscope designs into the simplest newcomers to microscopy a key feature of the democratising impulse of makers whose practices I follow in my own. I made 'bread-boarded' versions of other projects, a low cost technique for prototyping electronic circuits for beginners, of an Arduino based gameboy platform SourdoughBreadBoy (Dalziel, 2020b) (Figure 11). Each kit in the *Critical Kit Manual*, include elements of different practices folded together. For *SourdoughBreadBoy* (Dalziel, 2020b), I fold-in gameboy culture, game hacking, open-source Arduino development, microscopy and the concept of Interspecies gaming.

Critical Kit making and embedding, following the practices of others, were at the core of the method and the kits embodied my research through practice in the research sites. Chapter 4: Doing What They Do There features discussions of key case studies where kits act not only as embodiements of my research but as objects convivial to exploring the interdisciplinary situations of the study. For example, the *LabFromAChip* (Dalziel, 2019c) kit helps artists and microbiologist work alongside each other and provokes interactions we observe and reflect on. Patterns emerge and develop in iterations of my research and making, informing the emerging analysis which are then folded in to further iterations of kits in subsequent interactions of my research. This generated a rich ethnography, close to an auto-ethnography embodied in the kits and journaled in text, images and code alongside documentation of diverse materials from research in the field of practice relevant to the study.

I worked regularly at DoESLiverpool as any member of the makerspace and ran a bi-weekly evening event, the Wearable Technology Interest Group (Dalziel and Pease, 2020) with two of the organisations co-directors throughout the study. A range of

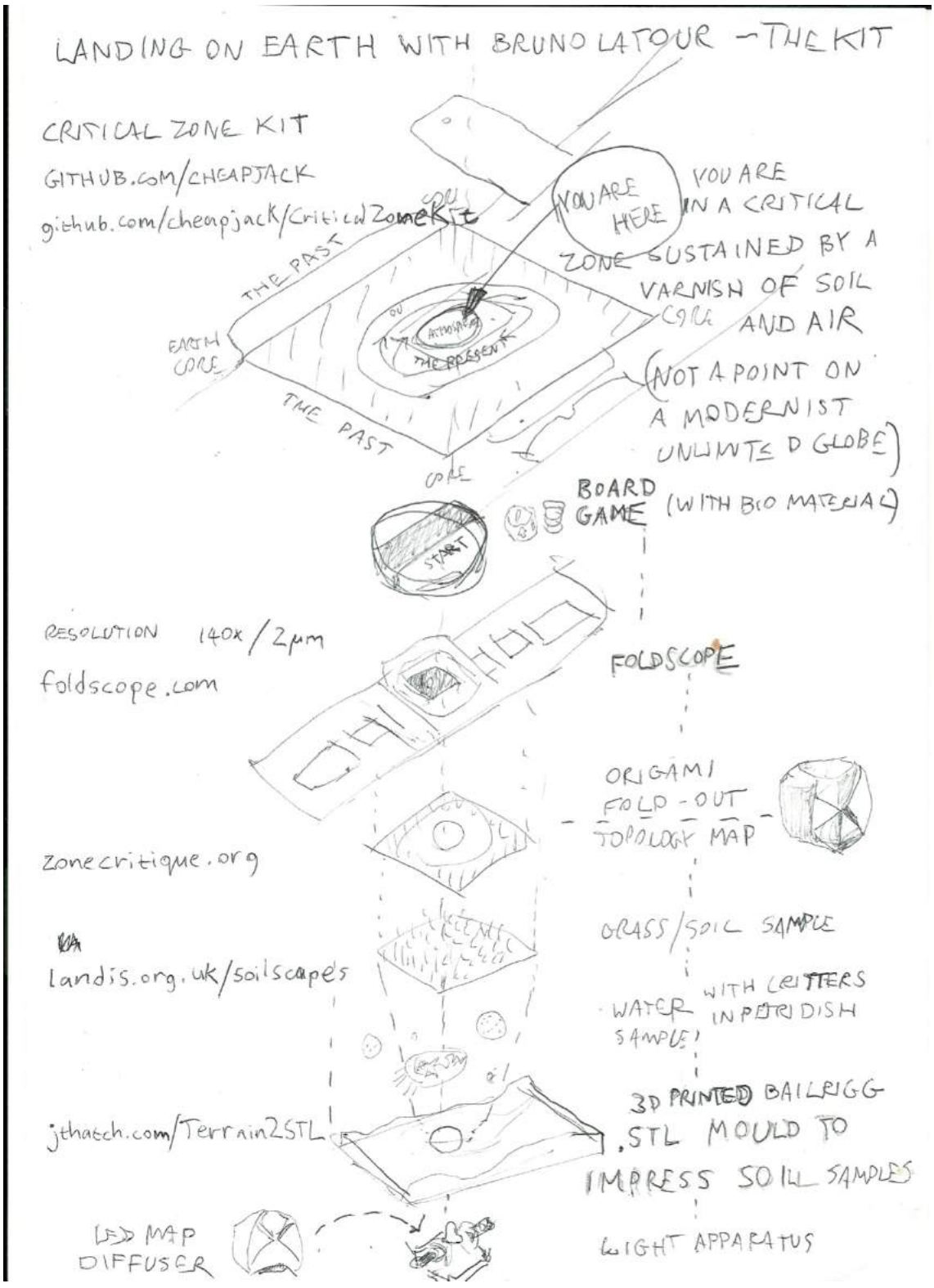

Figure 3: Latourscope design sketch, (Dalziel, 2019)

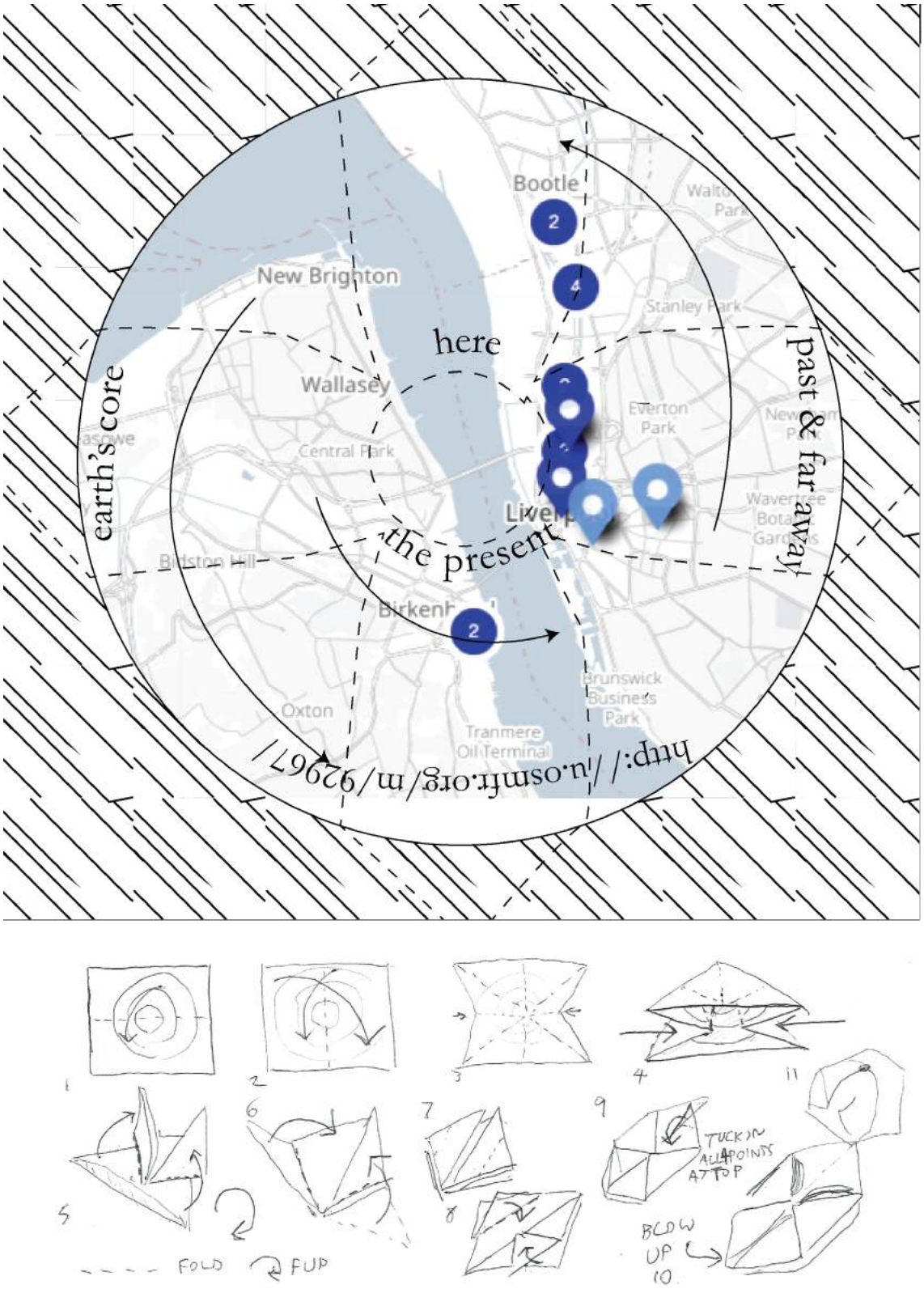

Figure 4: Latourscope document for printing and folding with data from a trade counter dataset made by the *Indie Manufacturing* project (Goodwin and McEwen, 2015)

Figure 5: Image of the *Ethical Microscope* a remix of popular simple microscopes made by makers

activity took place there, with myself as a collaborator and participant, making and sharing work using Biomaterials, DIY textile dyeing and making practices and developing workshops with fabric and textile based sensors. At the same time I shared laboratory space in BLS, with supervisor Rod Dillon in his laboratory facilities for the study of Leishmaniasis, a potentially fatal disease that features debilitating skin lesions and ulcers that affect millions of people. Leishmaniasis is caused by the single celled parasite *Leishmania*, spread through the gut of numerous sandfly species throughout the world, and means the lab facilities include the maintenance of important sandfly colonies. Here I experimented with approaches to microscopy, microfluidics and the observation of a range of *model organisms* such as *Euglena gracilis* and *Drosophila melanogaster*. Non-human model organisms are used extensively by biologists to understand specific biological systems and phenomena, relevant to the understanding of other organisms, including humans. I also had the opportunity to interact alongside undergraduate, graduates, research and teaching staff and their projects in the lab and the BLS teaching modules. Crucially I participated in microbiological technique training to inform this research as a participant observer and contributed to lectures, modules and work with selected undergraduate and Masters students.

Interactions with the 3D Print Club which I setup with the NMC came later but then ran in parallel and emerged as a consequence of my research in BLS and DoES. It is a feature of my practice, to not only find and work with existing interest groups, clubs and other social formations but to create, facilitate and develop them.

Grounding In Theory and Practice

This method evolved from early reviews of grounded theory and related qualitative research methods (Bryant, 2011; Charmaz, 2006; Reichertz, 2009). For example I analysed my study participant interviews with qualitative coding, grounded in my research data (Bowen, 2009) and wrote codified 'memos' to myself in journals for use in analysis. I made diagrams based on these codings, observations and ethnographic interactions, influenced by Actor Network Theory (ANT) (Latour, 2005). Diagrams were developed further with Mermaid, a 'markup language' for flow charts and gantt diagrams that feature throughout. A markup language allows users to use text and notation that a machine or computer can then parse and interpret into a useful format like a webpage. My method of writing is grounded in practices from technical culture. For example I wrote in the markup language Markdown, using text editors popular with software developers like Atom and Vim and generated the thesis pdf with Pandoc and LaTeX.

I followed up observations with semi-structured interviews around a topic or during a making or design activity. The experience of my art practice and its interactions with materials and participants in the study sites is the source of my research data, and the subsequent analysis and writing. The interviews pursued emergent analysis of observations of kit making and group interaction, and in some cases became a form of co-analysis. In the 3D Print club, for example, there are periodic reflections with my research participants on how the club 'works' which informs this.

The critical making method which I describe is grounded in emergent data and

theory, critically making in response to the intersections of my situated practice and the perspectives and practices of theory-method described The Practitioners. For example a book by Michel Callon, *Acting in an uncertain world: an essay on technical democracy* (Callon and Rabeharisoa, 2003), leads to 3D Print Club experiments with *Drosophila melanogaster* and then presented to a genetic researcher from BLS. An open-source paper microfluidic CNC plotter kit emerges based on data from interactions with textile makers in the DoESLiverpool Wearables group, and a participant writing a dissertation on Open Source approaches to the diagnosis of neglected tropical disease (NTDs).

Limitations - What and who gets cut

This study is limited by specificity. It makes specific observations and interventions in specific spaces with specific bodies. Nevertheless they partially represent and are in relations with wider structural practice - they are part of a wider *assemblage* an important concept from social science discussed later in the conclusions. In a sense, I use DoES, BLS and NMC as model organisms, scaled down, relatively easy to manage models of practice analogous to wider technoscientific practice. This convenience presents opportunities to see interventions and interactions in detail yet sets a limit to the study in terms of what can be speculated on. The use of model organisms as I observed in the study requires care and difficult ethical responsibilities.

Taking feminist and post-colonial theory seriously, prompted by STS literature means acknowledging the limitations of the demographic of this study. Predominantly many of my research participants benefit from being racialised as white and cis-gendered europeans from the higher income nation states of the global north. It is beyond the scope of the study to address structural disparities but I must specify the position of my research. I offer due diligence for ethical practice in the subsequent ethnographies and later aspects of co-analysis that I produce with my research participants in interview and while observing making together. I take seriously the epistemological limitations of this research and any conclusions must be considered in the context of how my research sites excludes many human and non-human bodies.

Although influenced by feminist and indigenous standpoint theory, acknowledging multiple voices and ways of knowing, I also take the position to not assume that there is necessarily any special objectivity endowed to specific bodies or histories. I understand all bodies, that are classed, gendered and racialised in various ways as being in constant interaction with other bodies, and so always have the potential for radical solidarity, understanding and empathy across categories.

Where possible research participants are given maximum agency and transparency in their role; as a researcher I commit to supporting their social worlds and stand in solidarity with all actors struggling to live in the trouble of ongoing land, data and resource extraction and enclosure.

Chapter 3: The Practitioners

. . . not just to show that my history is better than yours, or my history is worse than yours. I'm a victim and you're somebody who's oppressed people or so on, but rather, to understand my history in terms of other people's history, in other words to try to understand, to move beyond, to generalize one's own individual experience to the experience of others. And I think the great goal is in fact to become someone else. To transform itself from a unitary identity to an identity that includes the other without suppressing the difference. (Said, 1998, from 33:18)

I present the literature review in this chapter, 'The Practitioners', which I have divided and subdivided using the conceit of what I call 'Practitioner Identities'. These 'identities' are based on widely recognised practitioners related to the study; artist, curator, natural and social scientist, maker, teacher, amateur, the subdivisions and section headings at times playful references to the field. Each set of identities explain my understanding of the literature and its relevance to the genealogies and situations of the study. At times I use short biographical vignettes of my past practice to explain how the theory and literature is relevant to my research through practice.

The rationale for the study's literature review was to develop a set of critical tools that could be applied to the particular situations of my research. I used literatures to understand how kits and kit culture in biology and maker culture, are contingent on complex material histories of the mass reproduction, manufacture, mobility, political economy and expansion of scientific method and technoscientific objects and systems such as computers and microscopes. It developed an understanding of practices in maker culture and biomedical science I observed in the study and my research into their mobilisation as kits, particularly how they politicize knowledge production and learning intimate to the human body.

The literature developed a critical perspective using relevant critical thought. Raymond Williams' understanding of *the critical* was a useful starting point. In his landmark dictionary of 20th century cultural analysis *Keywords*, 'Criticism' is described as 'a definite practice, in active and complex relations with its whole situation and context.' (Williams, 1988, pp. 24–25). Theory and method from Science and Technology studies and the wider social sciences, learning and interdisciplinary theory, cultural studies and political theory all contributed to understanding the subjects, objects and situations of the study in their 'active and complex relations' and supported the development of this research's methods, analysis and findings.

My approach is to *fold-in* theoretical and analytical work into the practice of making with materials embedded in the situations of the study, the core methodology of my research. *Folding-in* is a way to focus on practice; my own practice, and the practices of the participants and my research sites. I respond to theory at times by immediately imagining playful maker prototypes to explore it. This originates from a tactic as a self-employed artist to use each paid workshop as an opportunity to develop an idea or technique in practice. In the beginning of my research I responded with a playful tone, a characteristic of the projects that makers collectively present at maker culture social events. For example, I made a kit based around a full size laser-cut 1980s arcade computer game cabinet and a 3D printed crazy golf hole design is inspired by Bruno Latour, *The Arcade De Bruno* (Figure 16) and *BlackBoxGolf* (Dalziel, 2019).

The conceit of The Practitioners is to review literature and acknowledge how it is situated in practice and how identity plays a role in learning. My understanding of identity, based on social science literature is that it is performative, emergent, multiple and also sedimentary, made up of complex histories and relationships with others. This understanding resonates with the so called 'natural' sciences and the material complexity of the biological world, even within a single human body which can be understood through the idea of the 'holobiont'. The holobiont is the idea that any biological individual is also a symbiotic community of millions or billions of

smaller organisms in relations with each other. This idea was developed in the life sciences and explored by innovative scientists like Lynne Margulis and Scott Gilbert (Gilbert, Sapp and Tauber, 2012) and many others. It is useful for understanding the relationships between microbes, microorganisms and the larger scale of complex invertebrates and humans in the research I carried out at BLS.

A key concept of science and technology studies (STS) literature that I draw heavily on and consider this research a contribution to, is that theory and method are something that is 'enacted'; it is *done* in a particular place, at a particular time, by particular people. Pierre Bourdieu provided a useful reminder that 'theories, like all symbolic goods, owe many of their key properties to their social conditions of production and circulation.' (Bourdieu, 1996, p. 201).

The Practitioners: The Structure Of The Review

Below I briefly describe the structure and content of the sections where literature is discussed:

The Embedded Practitioners explores my art practice and its relationship to genealogies of embedded art practice, participatory art, design, interdisciplinary art-science and the categories of 'Bio Art' and 'DIY Bio'.

The Amateurs of Reality section title plays on Anne Marie Mol's description of Latour's Actor Network Theory (ANT) (Mol, 2010). It reviews Science and Technology Studies (STS) and describes how it has re-configured and re-articulated my practice and the scope of this study in unexpected and exciting ways.

The Radical Pedagogists This section explores learning theory which allows me to critically reflect on teaching and learning practices in the intersections of the study. My analysis makes claims for the learning potential of these practices.

The Organic Intellectuals I use a range of political theory and practice to contextualise my political claims and speculations. Broadly I review a background of left leaning thought downstream from Marxism, from the work of Raymond Williams to the post-colonial conjunctural analysis of Stuart Hall and Gramscian understandings of strategy through the work of Chantal Mouffe and Jeremy Gilbert and their perspectives on artistic practice.

The Assemblagists Here I review different implementations of 'Assemblage theory' in STS and the philosophers and activists Gilles Deleuze and Felix Guattari.

The Embedded Practitioners

The Glue

Passing Through (Dalziel, 2001) was my earliest substantial professional funded work as an artist, funded by Arts Council England, a residency based at a protein processing factory Croda Colloids, in my home town of Widnes. Known locally as 'The Glue' or 'The Glue Factory', it gives a certain part of the River Mersey

estuary and occasional powerful unpleasant smell of rendered animal hide. This artist residency was an extension of my foundational practices of drawing, found sound, photography and ethnographic video, where long duration observations and collection of site-specific materials evolves into media and artefacts collected and presented on and off site. Works include video displayed in the factory reception, readings from a workers memoir and a historical re-enactment on a weigh-bridge at the factory gates (Dalziel, 2000; Allen, 2000). Off site was an exhibition, not in a contemporary art gallery, but at Catalyst, Museum of the Chemical Industry in a soap factory building. In 1999 I arrive, the middle class grandson of a local corrugated iron worker, at the head office of Croda Colloids, a large chemical manufacturer, approaching the chief executive with a proposal inspired by the work of the Artist Placement Group (APG). Founded by John Latham and Barbara Stevani in 1966, the group organised industrial work placements at organisations like the British Steel Corporation, British Rail and the coal board. Explaining APG's approach and that the residency is funded by an Arts Council England programme to embed art in the non-art world, the 'Year of the Artist', gets me in to the factory and permission to wander around a relatively dangerous protein processing plant for 6 months leading to over 3 years of work.

Marisa Jahn's book reflects on some of APG's problematics that resonate productively with my work. In Peter Eley's contribution, he describes APG's 'delicately utopian co-existence of antagonism and service' (Jahn, 2010a, p. 41). This resonates with a bemused comment from a social science student I met while reviewing an STS Methods Module at Lancaster University. Having listened patiently and politely to some of the features of my artistic practice they asked 'But where's the art?' (Conversation with STS Methods student, 2019). Eley echoes this in his observation of how '. . . context could become the entire work. . . sometimes at significant cost, vanishing into its rhetoric and practice, lost in what looked to anyone else as straightforward social service activities' (Jahn, 2010a, p. 41).

Jahn's texts contextualise the importance of de-prioritizing art objects into what she calls 'by-products' (Ibid.). It articulates how this kind of practice instead prioritises the traces and embodiments of located, social relations. It is worth noting here that for some art critics, like Alfred Gell, in his anthropological approach to conceptual art (Gell, 1998), understood art objects as already entangled with social process that do not require extra contextualisation. While that may be true, explicitly centring social relations and practices as method and material for art making makes a difference in that it opens up more possibilities for engaging with the social and the political. Assuming an artistic method will have its contextual meaning produced elsewhere with no internal, reflexive relationship with the political and the social seems limited. Jahn's perspective allowed me to reflect on my own embedding in makerspace and technical cultures and afforded a transformative account of my practice. My artistic medium and materials are entirely dependent on where I am embedded, not by my own concern for form, content or material exploration in and of themselves. More important than spatial embedding, is Jahn's concept of 're-empractising' (2010a; 2010b), doing what 'they' do in the situations of the art practice. Re-empractising is essential to my practice and my method in my research. It frames my adoption of craft practices used in 'maker' culture; digital prototyping and fabrication through Computer Numerical Control (CNC) a method for the computer control of cutters,

pens, robotic arms or extruders, implemented in laser cutting, 3D printing and 2D plotting. The logic behind re-empractising is to get entangled deeper in social relations. In maker and wider technical culture, open-source software and hardware is used to develop and share technology, systems and artefacts through popular online platforms and tools like GitHub, which became the characteristic format for documenting the critical making with research participants in my study.

My residency at the Glue factory was the first articulation of embedding; and included a video work made by processing animated microscopic images of bacteria samples made with the protein processing test team at the factory; a key shift to seek out, participate in and include relevant site specific practices not just using found materials or re-presented artefacts or aesthetics. Looked at through the lens of my review of STS in the section The Amateurs of Reality, this past work can be understood as an industrial ethnography of a protein processing plant, a kinship described later with Bruno Latour's observations of soil scientists, biochemists and his commitment to following 'Science in Action' (Latour, 1999, 2003).

Despite the deprioritisation of art objects, kits in this study could be seen as my artworks. Artefacts like this can be the only 'proof' that an artist has done something in an embedded practice. My attraction to kits is how they appear in diverse fields of practice and are common to both art, science and maker culture. In art history they are part of a genealogy of art instructionals, the traditions of DaDa and the readymades of Marcel Duchamp. In science, all kinds of scientific instruments and experiments are packaged into modular 'kit like' forms, such as a kit for performing electrophoresis, the process for separating macromolecules used in the analysis of protein and genetic material. Makers approach to kits that initiated this research package up materials for learning and doing, primarily to understand concepts in computing and electronics in a friendly way, reducing barriers to participating in maker culture and apparently democratising technoscientific knowledge

Looking back, the *Passing Through* exhibition at the glue factory is my first project that starts to prioritise relations over art objects. It's a approach that denies its own autonomy and turns its main commodity, the artwork, into by-products and its agency, into a dependence on understanding others. It is a desire to centre 'the Other', without artistic vision getting in the way. Critical social science teaches us that 'not getting in the way' is impossible however. It leads to an honest critique that the real desire driving any practice is to affect an intervention, to participate and ultimately, intervene productively.

Critical kits are kits that are intentional, socially engaged, utilitarian and convivial to the people and contextual situations worked with, so that they both reveal and *intervene* in social relations.

The Facilitators

Residencies like this are scarce. Facilitation and informal art as education roles otherwise dominated my art practice; technician, facilitator, workshop leader, teacher, youth and community arts worker, artist assistant. This helped economically sustain my practice and fed into the commitment to a social led practice.

Early workshop and technician work with FACT's Tenantspin (Superflex, 1999) a groundbreaking programme of socially engaged art and critical media practice, a partnership between FACT, Superflex and Liverpool housing associations developed my role of facilitator led by Alan Dunn and Patrick Fox. It included supporting artists like Chris Watson, Felix Kubin and Greyworld, deferring my own artistic vision and placing me in a field of practice where embedding interdisciplinary practices outside of art galleries and exhibition spaces, in secondary schools, social housing or playgrounds in the North West, was normalised.

This informed my early relationships with the technical media culture of sound based art practice, co-evolving with the emergent UK maker culture of the early 2000s. I co-founded and worked for SoundNetwork (Dalziel and Lambert, 2007) an artist led organisation supporting sound based art practice in the North West region which revealed in practice, sound art's close relations between art, science and technology. I worked, through SoundNetwork, with the Owl Project (Blackmore, Hall and Symons, 2003) who developed and shared their own software and hardware platforms Muio, based on emerging accessible programmable integrated circuits that led to the emergence of the Wiring and Arduino projects (Barragán, 2003), now well established ubiquitous maker culture tools. Their multi disciplinary participation in communal software, hardware and older craft practices of woodturning was more than just an interesting subject for an artist to make work around. They critically participated in the practices of software, hardware development and woodturning. They became part of the culture. This was the starting point for my embedding and facilitation in the then emergent UK maker 'scene'. I organised one of Liverpool's earliest Arduino event for artists, *Howduino* in 2010 with McEwen, and organised the city's first open-source software festival with northern digital organisation Folly called Open Source City ('Open Source City | SoundNetwork', 2008). More recently, I organised collaborative international exchanges across hackerspaces (Brinkmann *et al.*, 2014) and contributed to the Royal College of Art's studies of UK based makerspaces (Stewart *et al.*, 2018). These practices formed the background to the symposium on Critical Kits (Dalziel and Winterburn, 2016), the origin of this study.

The Community Artist

I have often identified as a community artist and described my work as socially engaged and participatory. This originates in past experience as a youth worker in the 1990's and ongoing practices that are valued primarily through their vocational and educational qualities, facilitating other's creativity and learning. The Embedded Practitioner re-articulates these identities to some extent, but they still inform my practice, particularly the aspects of communal organising required by community film making and work with local councils and community groups. The community artist imaginary with its clear solidarity with non-artists and others remains an important part of my practice.

> two approaches continue to be seen throughout the multiple instances of participatory art that develop in their wake: an authored tradition that seeks to provoke participants, and a de-authored lineage that aims to embrace collective creativity; one is disruptive and interventionist, the other constructive and ameliorative. In both instances, the issue

> of participation becomes increasingly inextricable from the question of political commitment. (Bishop, 2010, p. 11)

Art theorist Claire Bishop's mapping out of participation and aesthetics prompts me to acknowledge a range of positions I may have taken along the continuum she describes here. I would say in response, that I embrace collectivity but not purely in ameliorative terms and would disagree with any over simplification that all collective organised endeavours must be consensual and constructive. There is no inevitable 'either-or' between these aesthetic positions and their political commitments. Collective work can be disruptive and still involve authorship or leadership. I return to Bishop's critique later through the work of political theorist Jeremy Gilbert.

The Designers

Initial reading in the proposal stage of the project began with designer Paul Dourish. In his book *Where the Action Is* (Dourish, 2001) his embodied approach to design and technology provoked further investigation of social science literature. This also provoked the contextualising of my work with respect to art and design more broadly, specifically with the tradition of Christopher Frayling's idea of research through design (Frayling, 1993).

Although I am not a designer, design discourse and a design sensitivity proves useful for embedding in specific social worlds that have their own design language, and provides the ability to play with site specific formats and contexts. For example I have worked with design, designers and makers most relevant to a site and situation; for a Library installation of a pervasive RFID game, traditional typesetters and book binders; for the Endosymbiotic Love Calendar project, one of this research's 'by-products' (Kumordzi *et al.*, 2020), a designer experienced in commercial lithographic print outside the field of performance art and microbiological content of the work, but an expert in the language of commercial calendar design, the format for the work.

Maker culture, and its kit culture is a rich but incoherent design language, visible even on a single shelf of the makerspace DoESLiverpool (Figure 6). Eccentric, non-ergonomic lasercut plywood features a disconcerting mix of 'steampunk' and CNC-efficient-typefaces. Maker objects resemble a kind of post-internet folk art, featuring breadboards hot-glued together and veroboard based hand soldered electronics. Messy 3D printed prototypes sit awkwardly alongside high quality product design, bespoke Printed Circuit Boards (PCBs), DIY carpentry and hacked IP-65 rated waterproof enclosures. In DoES many of these objects are speculative designs for innovative Internet of Things (IoT) prototypes; devices that use the internet to connect everyday objects into networks of data, like my own RF-Craft project (Dalziel @cheapjack, McEwen and Fenner, 2017). These prototypes, sometimes no more than a bag of components and desktop printed folded A4 instruction sheet, sit alongside fully realised IoT products for sale.

This study and the wider institutional frameworks of this art practice based PhD at Lancaster Institute of Contemporary Art (LICA), is situated in the historical formation of art practice and design *as research*, as a way of knowing. This is

Figure 6: DoESLiverpool showcase at entrance of space

reinforced later in the study by a participant at an STS conference using one of the critical kits, seeing them as 'formats of research' (Conversation with Dalziel at 4SPrague, 2020).

Design's significance is not only in its utility for the art practice, but its contribution to thinking through interdisciplinarity and art practice as research. I carefully considered designer Christopher Frayling's vital contributions to articulating 'research through design', his foundational provocation to art and design schools (Frayling, 1993). Over time both Frayling and his peers in the design community responded and developed this idea, thinking around 'research *into* design', 'research *through* design' and 'design *as* research' (my emphasis). Frayling took part in a series of revealing conversations with the Research Through Design Conference series organised by the Delft University of Technology (Durran, 2015, 2015a). In these online conversations to camera, Frayling discussed how, in his early provocations, he was thinking of both visual art *and* design. Frayling cites Herbert Read's early text at the end of the 1960's, Education Through Art (Keel, 1969) as an influence, adapting Read's approach to 'teaching through art', to design, which was then adapted by Frayling and others, in the new art schools through the idea of *art practice as research.*

He goes on to anecdotally summarise the subsequent moves in UK design toward ethnography, and the possibilities for design driven, commensal partnerships across art, design and social sciences with the shift from art schools to universities, as centres for design research. He shares a critique of the limitations of an approach to research through design when it is used as a 'bolt on'; where research is carried out 'as usual' and well designed artefacts and publications are added on after the fact rather than embedded in a research methodology. Researchers into interdisciplinarity, Andrew Barry and Georgina Born, critique what they identify as a '*subordination-service* mode' for some art-science relationships which could also apply to bolt-on design (Barry and Born, 2013, p. 11, their emphasis). This elaborating interview with Frayling, discovered via collaborator, and fellow STS traveller and designer Ben Dalton in his PhD research, *Taking on the Network* (Dalton, 2018) was crucial for my early position with respect to art as research method. Frayling would be aware, if not responding directly, to the interdisciplinary discourse resonating around C P Snow's (1959) curiously persistent account of 'two cultures' - that of 'Science' and 'Arts and Culture' - a debate that Barry and Born use to frame a historical commentary and summary on the political imaginary, shape and economy of Art, design, science and innovation in the 50 years since Snow's lecture, providing a vital historical context for art-science practice.

In Barry and Born's study of the Masters program in Arts, Computation and Engineering (ACE) at the University of California at Irvine (UCI), Frayling's later appending of art and design *driven* research became more compelling (Durran and Price, 2015a, 2015b). They describe an interdisciplinary constructivist approach to art and design, summarised as a 'radical pedagogy', which 'places the radical ontological shift proffered by conceptual art smack in the middle of its interrogation of the categories not only of art, but science, technology, agency, life and the human.' (Barry and Born, 2013, pp. 260, chap.11). This contextualises supervisor Rod Dillon, Jen Southern and their colleagues art-science practice and Dillon's own radical pedagogical experiments within the modules of the life sciences at BLS.

Cultural Probes Research driven design includes a range of approaches relevant to the idea of Critical kits. Designer Bill Gaver's approach to design, and used widely in design practice, involves what he calls 'cultural probes' (Gaver, Dunne and Pacenti, 1999). Cultural probes are kit-like sets of materials designed to be sent to specific communities or groups to prompt or prime subsequent responses that will help designers fully understand the context, 'texture' and situation in which they work. Interestingly, Gaver situates his probes, resonating with Frayling's art and design thinking, not only in design practice, but in the practices of the mid 20th century Situationists. This group of artists primarily critiqued, especially in the work of theorist Guy Debord, 'the spectacle'. They made interventions in the 'spectacles' of mass culture in response to how advanced capitalism can lead to alienation and loss of agency, sublimated into homogeneous experience. These probes contain the researcher's interests and preconceptions, but are also intimate and made specifically for the users. In common with my own approach, these kits could be considered as anti-spectacles, that encourage engagement not alienation, and intentionally provoke affective responses, while intimating their agency in the design process.

My Critical Kits share these intentional, intimate, affective aspects, packaging up agency but in a specific shape. However in addition to Gaver's approach to prompting, critical kits in use are observed, the probes picking up the texture of socially engaged relations and then are re-made with participants. Their affect in context was part of a set of careful design iterations which made them reveal much in the study. These iterations reveal care and social interactions that are more important than where they get to in terms of the utility of a designed object. However like cultural probes, the kits are not only the by-products of the social relations and care revealed, but part of the process of how these relations are produced and provoked.

Gaver clearly cares and is careful when sending out his probes; but for me, intimately concerned with revealing and provoking a critical sense of care where I practice, often prioritising their interests over my own, the choice of word is unfortunate. Probing seems invasive and uncharacteristic of the careful intentions of Gaver's paper working with older, potentially vulnerable people. The word seems to undo the sensitivity of his generous materials for fostering playful openings. Probing feels like a relic from early life science's invasive and male dominating urge to open up, reveal, dissect, exploit 'mother' nature's secrets. Without obsessing over the wording of the typology, what cultural probing lacks is a sense of care and *accountability* that is clearly both in Gaver's original intent and practice, and is also the source for the agency his design method employs. The idea of accountability was useful in considering the ethics of kit making particularly in the wet messy and controversial worlds of bio technology looked at throughout the study informed by STS scholar Lucy Suchman.

Speculative Design Speculative design projects possible futures by thinking critically about the present through design prototypes, and can range from complete fantasy to the perfectly possible. It is related to forms of design fiction, and indeed science fiction, where designed products and objects are prototyped or imagined. It is also related to the idea of critical design that, like critical making, is an attempt to bring in elements of critical theory, the theoretical developments of post-marxist critique in the 19th and 20th century, but with a focus on design and materiality. Artist and designer Thomas Thwaites who I met at the digital art festival in Linsz,

ArsElectronica and his *Toaster Project* (Thwaites, 2010) is an example of critical design relevant to maker culture and this research's attempts at historical tracing. Thwaites spent years attempting to make a toaster 'from scratch', a generic example of Western domestic technology, including refining his own raw materials in his mother's back garden using domestic appliances.

Figure 7: BioTrumps Card Game individual cards

Returning to speculation, artist and scientist Raphael Kim speculates on a technology that exists but is yet to be implemented, the *Microbial Breathalyser* (Kim, 2015) where specially cultured microbes 'respond' to alcohol through microbial communication processes explored in the *MicroMart* (Dillon and Jackie Parry, 2014) project in my research. Similarly another ArsElectronica prize nominee, *Microbial Design Studio* (Telhan, Hogan and Hogan, 2017) prototype a workable remote internet accessible lab system for democratising the 'design' of microbial communities that might be employed in Kim's fiction. These are part of the speculative and critical design tradition, but with the added specialism of being life science focussed. Many of the life science kits studied in my research and presented in the online *Critical Kit Library* (Dalziel, 2019b) a catalogue of life science kits that express or deny criticality, and a card game, *Bio Trumps* (Dalziel, 2019) (Figure 7), follow this speculative approach. One problematic symptom of this kind of work and my own, is that the critical speculation is restricted to discourse, missing out on the texture and knowledge of making and using prototypes in the material world. Critical kits and critical making attempt to address this restriction.

A compelling approach for this research was a hybrid mix of speculative and critical design, science fiction, social science and participatory co-design described in *Co-designing prototypes with vulnerable communities* (Southern *et al.*, 2014) a paper based on the *#Patchworks* project that both Jen Southern, Rod Dillon and my own long time maker colleagues, MadLab UK, co-founded by my collaborator Hwa Young Jung, contributed to in 2014. Here speculative prototyping with vulnerable people is conceived as a carefully constructed ethical social process following methodologies

from both Design, maker Culture and STS. This kind of work is one response to calls for 'slow innovation' (European Commission Directorate General for Research, 2007) that this research responds to. This approach slows down the potentially damaging 'disruption' of innovation rhetoric and pays attention to accountability, a responsibility for the position and location in which knowledge is produced.

The project cares for the contradictions in academic and maker prototyping and slow innovation. The authors conclude by emphasising how designing and speculating the future although exciting, radical and innovative reveals some tensions:

> a constant tension between the potential 'opening' of possibility inherent in imagining the future and the anchoring of design decisions that draw us back to the everyday when working with diverse participants on a co-design project. (Southern *et al.*, 2014, p. 141)

They centre the vulnerable communities not as exotic others but as essential collaborators that leads to a complex form of what the authors call 'distributed agency' in order to deal with complex problems of the future and present. This is a kind of de-authored collective agency that is neither ameliorative or provocative but depends on a complex assembly of relations, care and accountability with the prototypes of the future less important than a long tail of ethical reflections on design method.

Co-Design Co-design aspires to democratise the design process by engaging and including a range of actors in an object or system's development. A range of participatory strategies can make this possible. Designer Tad Hirsch explores the political aspect of co-design further with the idea of *contestational* design. This takes seriously the political theorist, Chantal Mouffe's insistence on the impossibility of an ultimate consensus or final ground where all disputes and antagonisms can be resolved. For Mouffe, Antonio Gramsci's concept of hegemony is essential to her understanding of the political role for art and design practice which I discuss in more detail in the Organic Intellectuals section. From Hirsch and Mouffe's perspective, the design process is not neutral and made up of harmonious rational decisions, instead some needs and approaches must dominate while others are discarded or excluded. Hirsch sees all design and making as political and potentially in conflict, which is the source of design's possibility for changing the world.

An antagonistic understanding of the political and Hirsch's contestation is important in being critical of how co-design plays out. Co-design takes place on a continuum that ranges from carefully managed democratic procedures contributing to every design iteration, to what could be considered lip service where a prototype is presented as something to be 'tested' only to reinforce its preconceived intent and use value. But even with a carefully managed democratic and deliberative project, like the aforementioned *#Patchworks*, at some point there has to be some kind of closure. Difficult design decisions must be made, some participants input must be considered, but eventually discarded in favour of another. What eventually is designed forms the shape of particular social arrangements and power relations and socio-political intentions.

My making practice share the democratic aspiration of co-design as part of an approach to collaboration. I work on specific projects that require collaboration

with practitioners with the knowledge and skills I do not have, and in that sense they must be co-designed. However again, my core concern is not to realise novel exotic transdisciplinary objects but to understand and reveal social relations and possibilities in the technoscientific world. I often set the frame and brief for these collaborations responding to work opportunities and carefully select and curate my collaborators.

At the same time I became sensitive to the approaches of practitioners and often design projects around their sensibilities. Although I will always pay collaborators either financially or through an exchange of labour, there is never a completely transactional artist-technician for hire relationship. I will embed in situations like maker culture and carefully build relationships with other practitioners. For example, I made extensive use of technologist Cefn Hoile's *Shrimping.it* (Hoile, 2010) kits and would often advocate for his project to other makers. Eventually I collaborated with Hoile on a project for *Domestic Science*, designing and building a multi site text game *Class Aves* (Dalziel *et al.*, 2018) (Figure 8) using RFID (Radio Frequency Identification) technology that required the development of complex hardware and software. Again RFID, a now ubiquitous technology where tiny electronic tags act as radio transponders that can be identified by a unique identification code used in retail inventory or travel cards, reveals the rich networks of practice in maker culture and game design.

I do not wish to develop a strong pre-conceived artistic vision or body of work instead I desire the transformative experience of getting to know the already existing territory of others while challenging how an interdisciplinary practice can be accountable.

Figure 8: RFID driven distributed text game at Liverpool Library, *Class Aves* (Dalziel *et al.*, 2018)

Found Formats My long time collaborator, designer and artist Hwa Young Jung, co-founder of Domestic Science, and fellow lead artist for the *Endosymbiotic Love Calendar* (Kumordzi *et al.*, 2020) (Figure 9) takes conceptual arts use of objects 'found' and applies it to the domains and formats of design, what she calls 'found formats' (Jung, 2021). Found formats are a critique of design's aforementioned probing disruptions, paying attention to reconfiguring the existing world. Rather than simply appropriating design artefacts, however, Jung participates in that design language, embedded in their design worlds and spends time with makers, printers, hackers, gamers, carers and users.

The apparent playfulness of the appropriation of 'everyday' existing design objects and genres obscures the care taken, not only in reproducing them but in engaging project participants and context carefully through them. Jokes for those literate in the formats found, are secret messages of solidarity rather than cynical elitist puns, while playfulness allows careful unpicking of design's contributions to the construction of public imaginaries and the material discursive knowledge that is part of its reproduction. She uses a tacit literacy of every day domestic formats like an annual wall hanging calendar (Kumordzi *et al.*, 2020) to negotiate agency in complicated, difficult social and interdisciplinary problems working closely with both print designers and a network of biologists put together with Rod Dillon. Together we used the format of 'Top Trumps' card games for the *Bio-Trumps* card game (Figure 7) in this research, an update of the game made for the Critical Kits Symposium. In her own work, the experience and reproduction of living in the probation system through a board game (Jung, 2018) and the hidden locations of care and mutual aid in the town St Helens in a tea-towel (Jung, 2019). Found Formats, similar to Critical Kits act foster and support interdisciplinary work.

Human and Non Human Design Maker culture often features the development of playful hybrid digital and physical games, often at the intersection of Internet Of Things (IoT), citizen science, Science Technology Engineering Mathematics (STEM) and game design approaches to learning. I have made numerous projects that explore this area for the *CloudMaker* research programme (Dalziel @cheapjack, 2016) with FACT in Liverpool, using the game Minecraft as a learning ecosystem. I worked with a mix of makers and researchers such as Radamés Ajna, Patrick Fenner, Paul Harter, McEwen and Dr Mark Wright which resulted in numerous related projects, such as *RF-Craft* and *ShrimpCraft* (Dalziel @cheapjack, McEwen and Fenner, 2017); (Dalziel and Hoile, 2016).

This makes Human and Computer Interaction (HCI) literature relevant, again initially through the lens of the work of Paul Dourish (Dourish, 2001), with his essentially relational approaches to computers, equally at home in the ontologies of computer science, phenomenology and the philosophy of science. HCI is a space many of the artists, scientists and makers reviewed in my research work in, like Raphael Kim mentioned earlier. Kim's work is speculative design, but essentially a critique of human centred game design within the sub field of HCI, 'biotic gaming'. Biotic gaming explores HCI through the filter of indie game development, and the traditions of game development in maker culture where makers develop novel and strange devices, interfaces and systems for fostering playful material engagements that help people learn.

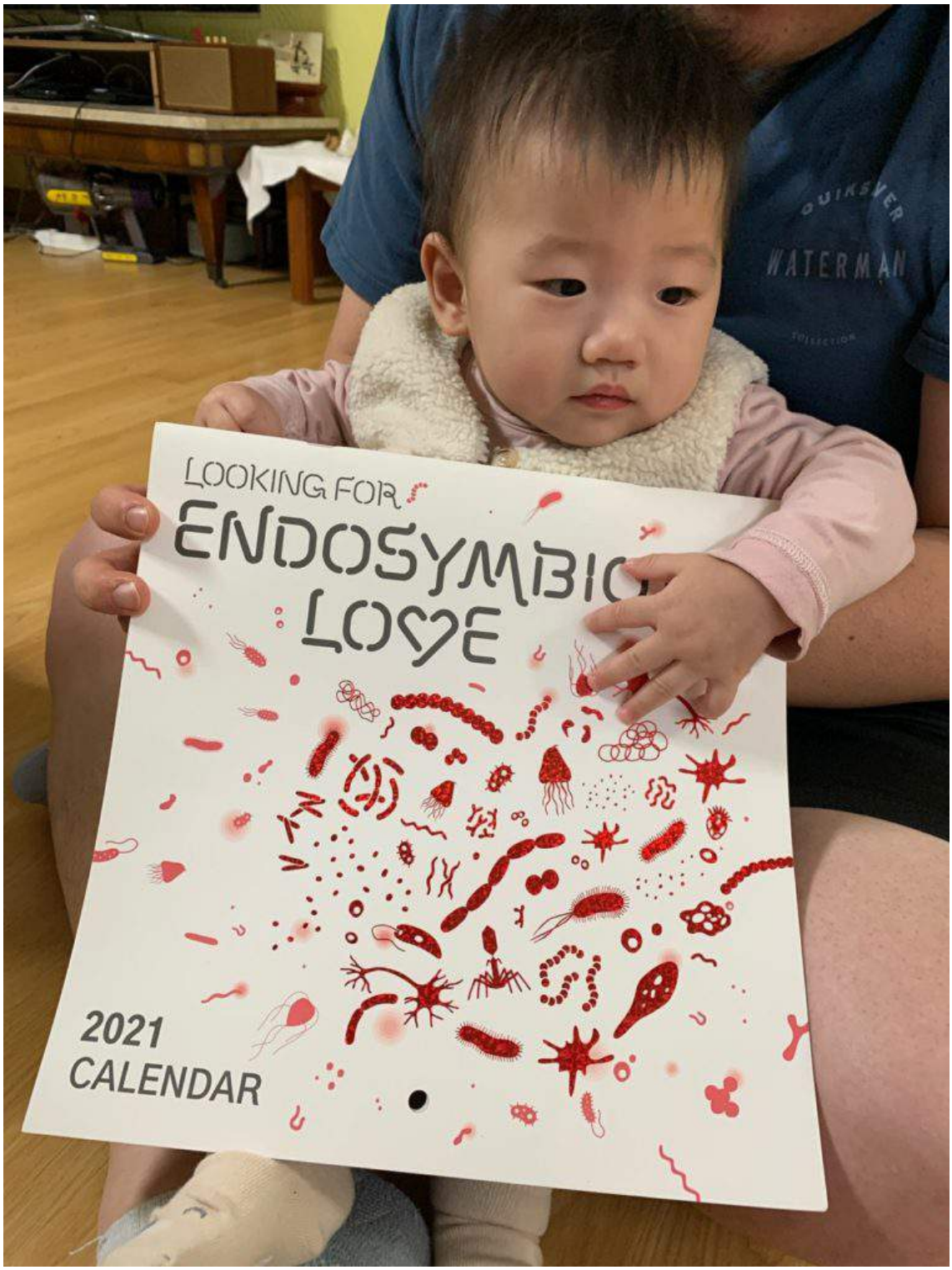

Figure 9: Promotional image For the online shop selling the *Endosymbiotic Love Calendar* (Kumordzi *et al.*, 2020). Image credit Hwa Young Jung

Figure 10: *Critical Kits Trumps* card game

Many of the early prototypes in my research critically participates in maker related game cultures such as Interactive Fiction, board games and retro 8-bit and 16-bit games using community software languages, platforms and tools like *Inform*, *Bitsy*, *Twine* (Klimas, 2009; Short, 2010; Le Doux, 2015) and also Arduino based gaming platforms designed to interact with the photosensitive *Euglena gracilis* algae.

The field of Biotic games is explored further through a significant database compiled by researchers Wim Van Eck and Maarten Lamers from the field of HCI (van Eck and Lamers, 2013) that resonated with prototype kits in my research and the review of Bio-Art practitioners such as Roland Van Dierendonck (van Dierendonck, 2018) in the *Bio-Trumps* card game. Of particular relevance to maker culture are the engineering labs related to HCI where game-like approaches are common features of their research methodologies often seen as valuable methods for developing scientific literacy (Riedel Kruse *et al.*, 2011; Harvey *et al.*, 2014; Cira *et al.*, 2015; Kim *et al.*, 2019). This research led to the first case study, featuring the use of the *Foldscope* made by Prakash Lab (Prakash, 2010; Cybulski, Clements and Prakash, 2014), a key component in the *LabFromAChip* kit and *SourdoughBreadBoy* (Dalziel, 2020b) (Figure 11) that explores both biotic gaming and the microfluidics observed in BLS.

The Art-Science Practitioners

In this section I consider my position in what Barry and Born call the 'plural genealogies of art-science' (2013). I outline an area of this field relevant to this study by discussing practitioners who have a relationship with the biological life sciences. The art-science practitioners I consider here are of particular significance to this research and my practice. Some are internationally known and some geographically local and part of an art ecosystem in the North West of England that I am part of, having met or worked alongside some of them. This contextualises my art-science work, while differentiating my approach from others.

An art-science symposium (Dalziel, Dawson and Dillon, 2018) organised with senior research staff member at BLS, Dr Neil Dawson, at the outset of my research made another local sample of contemporary art science practices. This event (Figure 12) featured BLS researchers and a group of European undergraduates studying neuroscience to share practice with artists selected through an open call locally to the

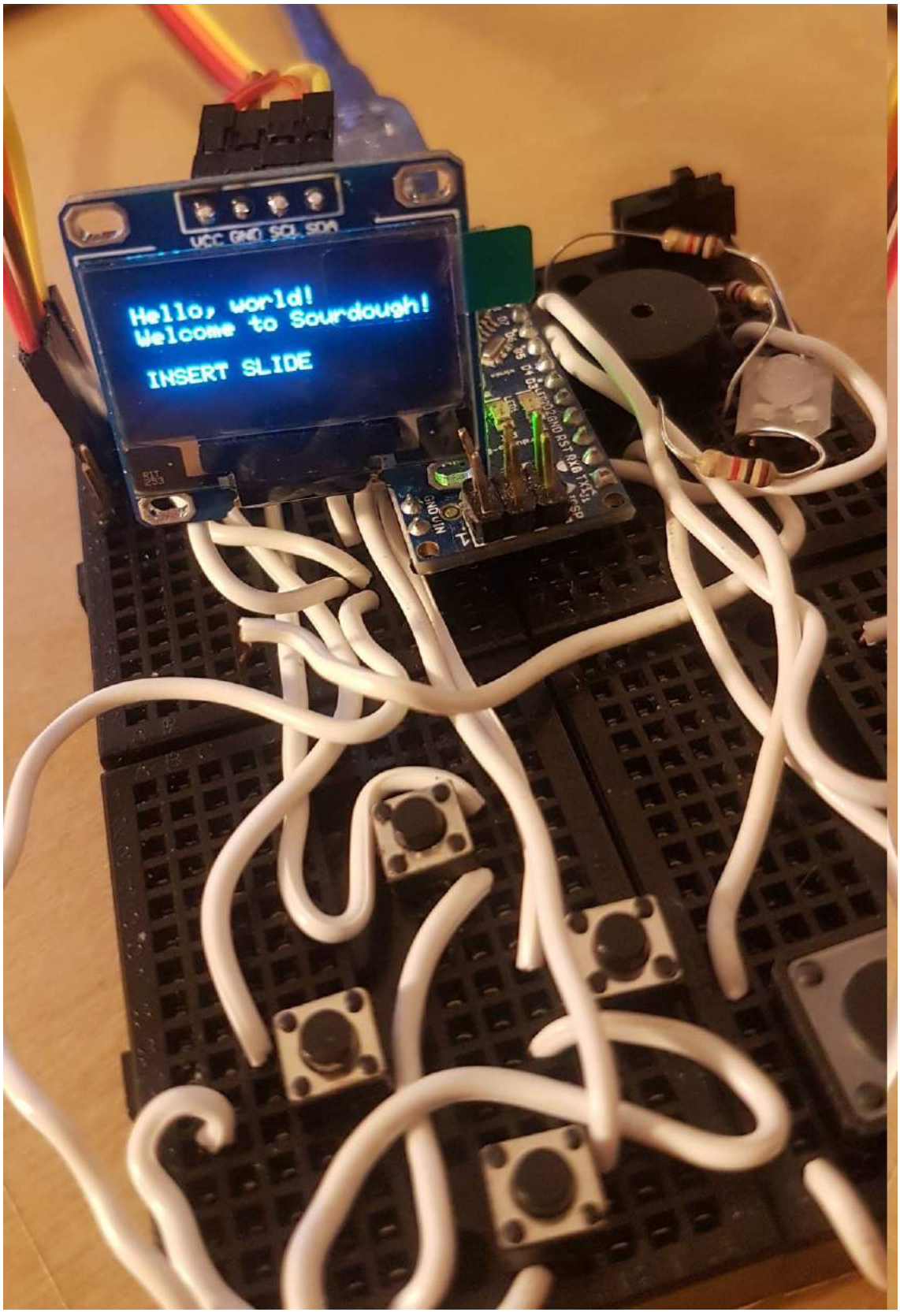

Figure 11: *SourdoughBreadBoy* a biotic gaming prototype (Dalziel, 2020b)

Figure 12: Image of participants at the *Disrupt Encode Consolidate Symposium* (Dalzie, Dawson and Dillon, 2018)

UK and Europe. The call out was structured by my historical professional networks of my art-science work, situating it, and the study, in a wider yet still specific artistic ecosystem. It also was strategic; it aimed to foster institutional cross departmental work between LICA and BLS, and generate interdisciplinary opportunities for the future of the study. The call out was sent through my own social media networks and distributed through Manchester based festival Abandon Normal Devices (AND), who I have collaborated in the past, who shared it further. The sample was not representative of art-science as a whole, but formed a local and temporal snapshot for framing and positioning the study.

At a similar time, in late 2018 to mid 2019, I worked with FACT and the *Arts at CERN* programme, a program of the European Organization for Nuclear Research, Geneva, who together organised the art and physics exhibition, *Broken Symmetries* (Aranda *et al.*, 2018). Here the curatorial and education team at FACT, who I have a long collaborative history with, attempted to integrate the work of artists like Yunchul Kim, Juan Cortés, Semiconductor and James Bridle into an innovative art and science learning space for young people in formal and informal education. My role was as a critical friend, to help develop what Barry and Born would call a 'radical pedagogy' modality, where the radical critiques of conceptual art, the humanities and social science are brought alongside the natural and engineering sciences for mutual benefit and learning. Although it did not develop into a case study or was part of my research's observations, it nevertheless made me reflect on my practice's close relationship with education, which was in turn, the basis of my long term relationship with FACT who without doubt have been my most consistent employer in a 20 year career. This included work with the aforementioned *Tenantspin*, supporting artist led participatory work, contributing to training programmes for artists and teachers in a professional development programme, *M.I.T.E.S.*, curating a major experimental music, sound art and technology exhibition *DING»DONG* (Dalziel *et al.*, 2008).

My work with FACT from 2009 onwards, particularly with the *CloudMaker* project was situated in the now established approach to 'creative' technology and learning science, technology and engineering known through the acronym STEM (Science, Technology, Engineering, Mathematics) and the more recent shift to 'STEAM' (Science, Technology, Engineering, Art and Mathematics), which attempts to integrate art and creativity into the teaching of science and technology. My art practice aligned with STEM primarily due to how closely the approach aligns with maker culture, but also as a pragmatic response to capitalise on its popularity. Many makerspaces are seen as ideal sites for this approach particularly with respect to encouraging people to learn the principles of computer science and digital literacy.

Figure 13: STEM ambassador card

Part of the starting point for this study and the eponymous symposium I organised with Re-Dock in 2016, was to explore the implications of STEM and STEAM critically. STEM from my standpoint in 2016, seemed to be a particular approach to developing the technoscientific economic base at a governmental national and regional level, but also part of wider developments in interdisciplinarity, art-science practice and maker culture. STEM and STEAM although frequently framed and positioned in radical pedagogy, from the perspective at the end of my research is that it is representative of what Barry and Born call the 'logic of innovation', where art can be seen as an important service generating novel approaches to science. I have experience as a card carrying 'STEM ambassador' (Figure 13), a programme developed by *STEM Learning*, a non departmental Government organisation, and have delivered numerous creative workshops in formal and informal education, which have often been framed as related to STEM and STEAM approaches to learning science and technology. However I have explicitly framed my study outside of this, in the wider genealogies of art practice, interdisciplinarity and technical culture and in the biological sciences, which are comparatively under-represented in STEM. None of my research sites were engaged in any significant way with the teaching of young people in primary or secondary teaching and so I have not included STEM in the literature I review.

STEM is however significant in terms of the popularity and proliferation of maker culture, itself a consequence of the rise of importance of interdisciplinary technoscience in advanced capitalist democracies developing their forces of production. Although this study develops a method outside of that educational framework, there is scope for integrating critical making, Specific features of my Interleaving Practices method, such as *affect*, *care*, and *productive failure* could enrich STEM approaches and would need further study.

Bio Art and The Birth of Biopolitics

> The twenty-first century has been dubbed the Biological Century because the advances in the biosciences have begun to change our understanding of life itself, in ways that recall, and go beyond, the ways in which the atom bomb, physics, and engineering defined the twentieth century. (Da Costa and Kavita, 2008, p. xix)

Beatriz da Costa and Philip Kavita's book, *Tactical Biopolitics: Art, Activism, and Technoscience* (Da Costa and Kavita, 2008) illuminates the political aspects of the art-science genre and helps place this research in a political space. They introduce a diverse and compelling ecosystem of art and activist approaches to the life sciences, the contributors describing not only radical implications of biotechnology for art production but the possibilities for power and social control. These range from surveys of the instrumentalization of art, what might be called a form of bio-art-washing, a covert and at times unintentional practice which suppress critique of the pharmaceutical and genetic engineering industry in cases explored by Jackie Stevens in her chapter 'Biotech Patronage and the Making of Homo DNA', (pp. 43-61), to discussions of mid 20th century Californian laboratory politics and scientific labour organising in an interview with Marxist biologist Richard Lewontin (pp. 3-23). The book gathers together material that argues and calls for a range of artistic interventions in a new technological paradigm. One of the moves the book makes is to use the slippery term 'biopolitics'. On the one hand, it is a phrase to describe a radical re-framing of the importance of the biological to politics, and on the other, a quiet reference to the posthumous work of Michel Foucault, in the translation of the transcription of a lecture series he made at the Collège de France between 1978 and 1979, *The Birth of Biopolitics* (Foucault, 2008).

Foucault's work can be understood as an important historical archaeology of power relations, that is how power is distributed and relates to different bodies and how they are governed. Biopolitics for Foucault, refers to what he argues, is a profound shift in modernity, how different groups of humans and human systems distribute different kinds of power and different kinds of 'governmentality'; how society is governed. Foucault could be seen to be initially contributing to Marx's radical analyses of power in his critiques of capitalism, the foundation of almost all critical theory, although by the time of the Collège lectures he was virulently opposing Marxist thought, convinced that it contained the kernal of an inescapable authoritarianism (Zamora and Dean, 2021). Despite his reactionary relationship with Marxism, and indeed other theorists, Foucault's key and arguably, complementary innovation to Marxism, was to consider the historical shifts in European secularised modernity and the social contract in terms of power. He described the shift from 'sovereign'

power; essentially the power and reign of kings and their monopoly on disciplinary violence and punishment, to what he calls 'biopower'; a new logic of power where the individual biological bodies of citizens are governed not just by a monolithic conception of a modern nation state, but by power distributed at a 'microscopic' scale acting on populations through aggregated logics and practices of institutions such as hospitals, prisons and schools. Put very simply, Biopolitics is the political interactions that lead to the control of biological bodies at scale through the hospitalisation and treatment of bodies that carry and host disease, the policing of racialised and classed bodies, or the disciplining of bodies in the classroom.

This framing of new distributions of power is analogous to the developments and shifts of human biological technology explored in Da Costa and Philip's book. The biopolitical shift is not simply due to the advanced developments of the mechanical understanding of the human body, its cells, reproductive and developmental systems, but the ability to treat the human and all life itself as *information* through the innovation of the discovery of the structures of DNA, Deoxyribonucleic acid. Such information can then be distributed, controlled and commodified, in a form radically abstracted far beyond Marx's material abstractions of political economy, or Foucault's microscopic governance of individuals and the body politic. Da Costa and Philip's collection situate critical art practice and activism in the messy entanglements of political economy and the biological, technological, control society of the 21st century.

This move relates to moves in social science and STS, which I return to in The Amateurs of Reality section, where art practice can be seen as an important tactical method for revealing and intervening in the sciences. The book offers rich and wild possibilities for art-science practice that can be described by the equally slippery categories of 'Bio-Art' and 'DIY-Bio'. I use these two categories in the next section to position my practice, reflect on and differentiate it from a selection of other practitioners. They are not necessarily mutually exclusive categories but partially related fields of practice and familial kinds of practitioners.

Bio Art I became familiar with Bio-Art in my work producing fringe activity for FACT's *SK-Interfaces* exhibition (2008) curated by my colleague Marta Ruperez and curator Jens Hauser a contributor to Da Costa and Philip's book. *SK-Interfaces* featured some of the work of the most famous performative forms of Bio-Art, Stelarc, the artist who has grown prosthetics made from his own living tissue, notably an ear on his arm, and ORLAN the artist who performs radical prosthetic surgery on her body as part of a critique of gendered norms of sexuality and aesthetic beauty. Bio-art is a slippery term that encompasses a range of artists who use living and non-living human and non-human organisms in their work directly and materially, not just discursively. The Bio-art I consider for understanding my art-science practice is far removed from these spectacular performers taking a more de-authored and distributive approach. Eduardo Kac, another influential Bio-Art artist in *SK-Interfaces* is more significant, his artwork for experimenting with the genetic engineering of fluorescing *Escherichia coli* a coliform bacterium common to mammalian gut microbiota, *Cypher* is presented as a DIY genetic kit (Kac, 2009).

I supported the exhibition with a series of fringe events in the 'unconference' tradition of critical media festivals like TransMediale and ArsElectronica, facilitating

experimental participatory workshops by local and international artists alongside the exhibition led work at FACT, using a local alternative art space which occupied a disused building. This kind of positioning of practice often on the periphery of major art exhibitions and festivals is a significant characteristic of both maker culture and bio-art. Maker culture, Bio Art and DIY Bio must not only be understood as exotic lone wolves and trans-humanist trans-discipline pioneers, which capture the popular imagination, but as practitioners working on the boundaries of art and life science institutions in a dynamic, often dialectical relationship. BioMakeSpace Cambridge ('Biomakespace Cambridge', 2016) for example, is a makerspace supporting DIY-Bio and Bio Art, and part of Cambridge University's existing biomedical campus and facilities. This relationship is partly to support access to advanced equipment and facilities but also to cope with the complex health and safety issues that come with experimentation with microorganisms and living tissue.

Mark Dion is a high profile international contemporary installation artist with quite a different approach and relationship to Bio-art than the SK-Interfaces artists such as Kac, Stelarc, ORLAN and Critical Art Ensemble, many of whom come from the critical media tradition. His relationship to bio-art is through a concern with the biopolitics of climate crises and an interest in art-science interdisciplinarity. Although he operates in the upper echelons of big budget contemporary art often realised as large ambitious spectacular installations he nevertheless appears to work in a way that is grounded in an embedded ethnographic approach, and an interest in the idea of the 'amateur' which aligns closely with my work. I reflected on Dion's work through a video interview with him by contemporary art organisation *Art21* to illustrate my understanding of art-science with social science undergraduates in a STS Methods social science module I contributed to at Lancaster.

> I tend to adhere to a particular methodology... I'm not really a studio orientated person I like to make stuff on site... And I begin poking around, into the history of that place and I begin reading, I begin writing, I begin drawing, I begin looking at things like vernacular architecture, looking at the way people dress, visiting museums, Seeing... trying to insert myself into the kind of specific social history of the place... I know I can never be from there, but at the same time I'm not, that's not my job you know, I'm sort of an, er, I'm hired as a, 'foreign troubleshooter', who comes in to look with a new set of eyes, and a new set of categories, and I bring with me, my sort of, 'suitcase of ideas', and the history of my work and concerns and I begin to sort of come up with ideas. I work as an archaeologist or as a biologist - I'm not really claiming to be that person - nevertheless I'm taking on, I'm shadowing, their methodology. (Dion, 2008, from 0:20)

Dion is an important example for me, of an artist with a practice related to both STS methods and embedded art practice. Like my Critical Kits, his work offers possibilities for exploring STS related subjects in formats beyond academic papers, in experimental and experiential institutional spaces. One work especially, *Neukom Vivarium* at the Olympic Sculpture Park in Seattle, seems to powerfully articulate the constructed fragile nature of technoscience through the preservation of a rotting fallen tree installed in an elaborate gallery greenhouse setting. (Dion, 2000). This ambitious work, although grounded in embedded practice, depends on spectacle in

its effect, and is in complete contrast to my work which explicitly avoids that kind of scale. A further political contradiction is its entanglement in big liberal capital philanthropy, the title a knowing nod to the absurdity of an artwork commenting on the anthropocene partly funded by William Neukom a silicon valley lawyer made powerful by Californian post war technoscience. My work is not without such contradictions, as it is also dependent on the contingencies of silicon valley hegemony and power through the computers and electronics that feature in my practice. The difference is essentially one of scale, as my work capitalises on the affect of 'the spectacle', but on the intimate scale of people working together. Maker events such as Liverpool MakeFest clearly use communal spectacle similarly, to draw in participants, network and reinforce their identities as makers.

Dion's work, shifting notions of expertise, subjective and objective knowledge resonate with Barry and Born's 'ontological logic' of art-science that radically shifts the meanings of both objects and subjects of scientific and artistic practice. Barry and Born use the artwork of the aforementioned author and artist Beatriz Da Costa as a key example of this logic of interdisciplinary work. In *PigeonBlog* (Da Costa, 2006), da Costa worked with pigeons, their human pigeon fanciers and air quality scientists in LA. Together they developed a distributed system that collects air quality data from sensors worn by pigeons, whose flightpaths include working class communities often missed from urban air quality studies, despite being most affected by pollution. She embeds her practice in the air quality technical community and local pigeon enthusiasts. Embedding in an already existing human and non-human relations, using the existing network of humans and animals means not only that previously inaccessible data can be collected, but a new relationship can be developed between all the actors in the situation, without imposing alienating weather stations that extract data. For Barry and Born, da Costa and her collaborators make a radical contribution to science, not just collecting data in an innovative and ethical way but in a way that:

> points to a recognition that air quality should not be considered a property of air, but understood as a relation between air and those who breathe and are affected by it, who are in turn differentiated by class, location and other variables (Barry and Born, 2013, p. 263).

This ontological logic can be understood simply as a logical chain of reasoning, where what a project 'does' has changed the way things 'are'. The object of study, 'air quality', is not only explored in a more innovative way, but the idea of air quality and what it means subjectively, scientifically and socially must now be reconsidered. The project reconfigures 'air quality not as a property of air, but as a relation between pollution and those who are affected by it.' (Ibid.)

Artist John O'Shea's *Pigs Bladder Football* (Brunsden, 2011a) project, like Da Costa's work is similarly embedded in a technical community to explore scientific practice, in O'Shea's case, bioengineers at a local university and local makers at DoESLiverpool who help realise his project when access to the laboratory became difficult. O'Shea used the bioengineering practice of growing monocultured living cells, that is identical living cell types, around a 3D printed scaffold in a reservoir of sterile growth medium. The scaffold material gradually dissolves once the cells have reproduced and grown around the structure. O'Shea does not make a new organ but

instead grows a version of an existing social object, a traditional football made from a sewn up pigs bladder, a by product of commercial meat production. Such footballs were made this way before the game fully developed in England in the way we know it today. Although O'Shea makes a novel art object, a bio-engineered football, like da Costa's living Pigeon Air Quality sensor, what is crucial is how he entangles this object with a traditional ballgame in the working class communities of the North of England called 'Uppies and Downies'. The most significant aspect of both these projects is how art-science novelties are explicitly entangled with social practices and structures, in both these cases particular class and technical social formations. The art object is utilised in a social practice, it is a social object potentially fostering agency and material engagement. For da Costa, the pigeon fancying and collecting air quality relations, and with O'Shea interactions with makers and workshops sewing footballs and playing the game of *'Uppies and Downies'* in the working communities of Florence mine (Brunsden, 2011b). Both these approaches reconfigure novel art objects as new social objects that embody experimental social relations. Science does not simply support innovative 'science-y' art objects, and Art does not just re-present science in an 'arty' way, instead art is a mutually transformative encounter that my work attempts to foster and is of particular relevance to my analysis of my later case studies.

Anna Dumitriu's work also features rich materials, explorations and long term collaborations with scientists like da Costa and O'Shea. In her approach art objects remain central, but less as social objects and more as embodiments of her deep engagement with scientific concepts and craft practices. In *Plague Dress* she combines the technical practices and labour of microbiology with historical textile making cultures (Dumitriu, 2018). From Peter Obourne's perspective, a contributor to Barry and Born's book, her abilities in the discipline of textile making in this project is what helps her to 'qualify as a player' (Osbourne, 2013, p. 82). My work with makers is also dependent on becoming a player in this way. In recent projects, I learnt the craft practices of embedded computing and the Internet of Things in order to work alongside makers and not just use them as technicians. However like my own approach, none of these artists work in a simply transactional way with the non-artists they work with. For me this is not just a way of ethical working but part of the transformative aspect of interdisciplinary collaboration, becoming not just an amateur or dilettante, but part of a community, shifting my own subjectivity and understanding.

Gina Czarnecki's art-science work is similar to Dumitriu, in her approach to maker and scientific craft while still retaining rich and novel art objects for exhibition. She uses 3D scanning, printing and bio-engineering to realise her art work while exploring a range of interdisciplinary modes of working. In *Heirloom* (Czarnecki and Hunt, 2014) she collaborates with scientist John Hunt, growing skin cells from samples of her daughters skin, to enable delicate portraits using traditional casting made from their own biological material. As art objects in a gallery space without context they often elide her concerns with the material and relational conditions of producing such work. Another project investigated the Human Tissue Act and procuring donated hip bones from volunteers undergoing hip replacement, referring to the use of salt and sugar for meat preservation and the Liverpool slave trade (Czarnecki, 2012). Czarnecki is a part of a tradition of conceptual media work and

video installation horizontal to Dion and Dumitriu but operating in the same North Western art economy as myself and working closely with my supervisor Rod Dillon. In one account by Dillon, her research to realise her artworks led to a more cost effective cell culturing process, the process of reproducing modified cells, potentially beneficial to biomedicine and microbiological technique, an example of what Marisa Jahn called a 'double ontology' where value is generated for art and science.

Although elaborate and rich art objects are prioritised and conform to gallery conventions by both Czarnecki and Dumitriu, both artists commit to the relationships and labour of the multidisciplinary practices necessary to realise their art objects. The social histories of learning that take place in the production of their work are not necessarily only by-products of art production. Czarnecki's installation for Heirloom staged the growing process in the gallery and organised complex debates over the implications of a citizen's access to their own biological materials. However despite this the artworks primacy is always privileged and this history of social learning can be difficult to see. My embedded approach is similar to the depth of engagement with science that Czarnecki and Dumitriu pursue, but often limits activity almost entirely within the enclaves of the community of practice I am embedded in and are manifested in conventional art spaces as artworks rarely. This approach does not reject art institutions or exhibition formats, but works along its boundaries to experiment with other modes of production that embedding in technical cultures can afford. There are contradictory drawbacks that limit the impact of this approach however which I discuss in my conclusions.

Yasaman Sheri is an artist and designer who made a set of objects in a residency situation with the commercial bio-engineering company Ginggobioworks, whose promotional website presents a working environment that seems almost utopian and speculative. Sheri's residency there (Sheri, 2019) featured prototype biological sensors that implement the microfluidic technology I explore in my research at BLS, the engineering of tiny spaces to manipulate and control microscopic scales of fluid and biological material.

More specifically she shares my DIY approach to paperfluidics (Figure 14-15) I learnt in my research (Tsai, 2006; van Schaik, 2015) an implementation of microfluidics widely used in biomedical testing, recently entering the public imagination in the mass distribution of COVID-19 lateral flow tests. Her work is similar to the unfinished wearable prototypes in my research (Figure 15) but highly developed, through carefully curated public workshops, carefully designed and finished using commercial lab facilities. Her approach confirms a problematic of focussing on embedding, the endless deferral of completed objects or projects, missing out on opportunities for wider communities to engage with fascinating robust artwoks.

DIY-Bio

> There is quite simply no space outside the laboratory, no space that isn't in a lab, no part of the lab that isn't a site of social, political and artistic regulation and invention (Da Costa and Kavita, 2008, p. xiv)

'DIY-Bio' is essentially a maker culture for the life sciences. I consider a selection of individual practitioners but it is impossible to consider that practice without the

Figure 14: Image of my experiments at DoES making microfluidic wearables

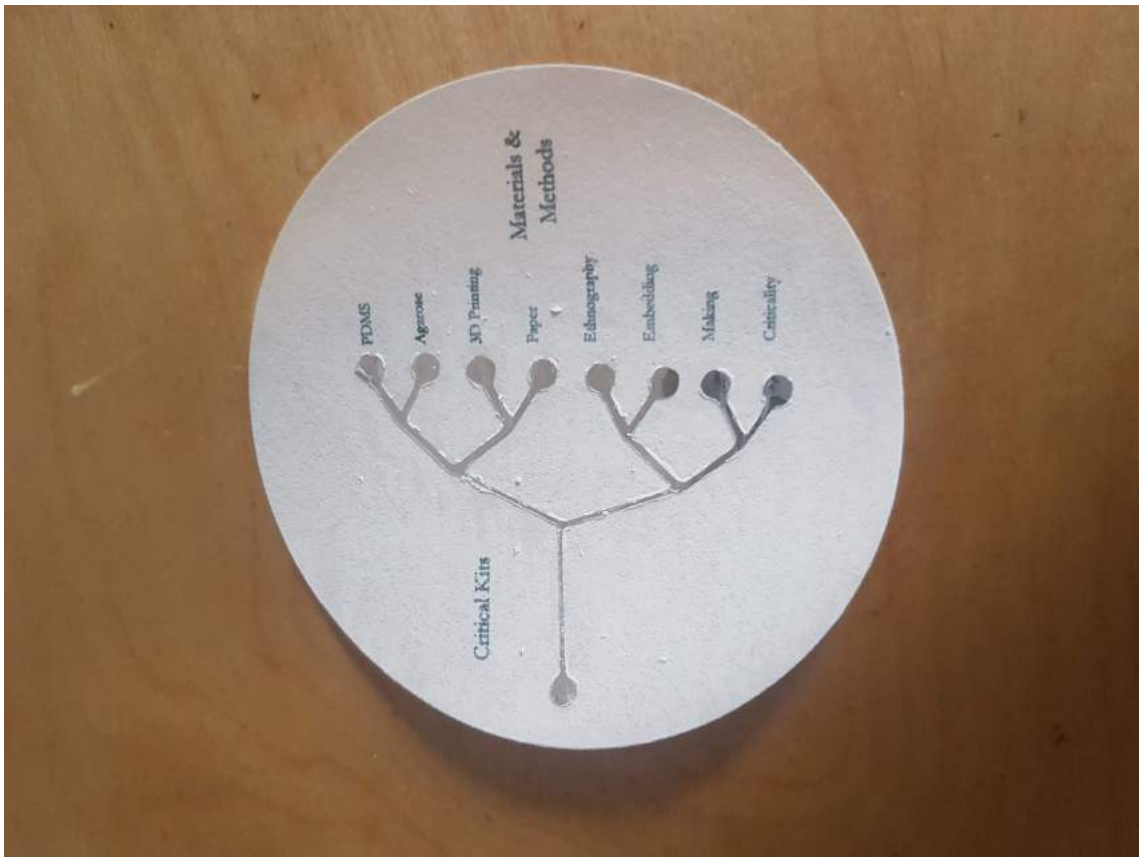

Figure 15: Image of paperfluidic prototype to move liquid to different test 'zones' labelled using categories from analysis of my research data

complex ecosystem of collective spaces and communal networks which distribute and support them. These DIY-Bio labs are often outside or on the periphery of conventional research and commercial labs. DIY Bio can be seen as a social formation, related to Bio Art, a technical milieu connected to the democratic shifts in technology characteristic of maker culture often supporting art-science biological experiment and kit making. Temporary and permanent spaces, virtual and actual communities and institutions with diverse backgrounds/ and funding models are explored in my research as a database published in the *Critical Kit Library* (Dalziel, 2019b). DIY Bio practitioners are often part of or depend on these diverse spaces. Some are actual biology focussed makerspaces that are part of biomedical academia like *Cambridge Biomakespace* ('Biomakespace Cambridge', 2016), individual and small collective DIY spaces like *Little Pink Maker* ('Littlepinkmaker', 2018) in Copenhagen, programmes of DIY Bio activity in makerspaces or technology institutes like MadLab UK and Waag society (Waag Society, 1998) and in online aggregating forums tracking activity internationally like DIY-Biosphere ('DIYbiosphere', 2019) or sets of instructional resources such as Hackteria ('Hackteria', 2009). Other organisations explore low cost lab technology like *Lab on the Cheap!* or are entrepreneurial maker projects and start-ups like *Bixels*, *IoRodeo* and *miniPCR Bio* (Lemma *et al.*, 2021; Cell Free, 2017; Long and Dickson, 2009; miniPCR, 2013). The collectivity resonated with my social perspective and the social contexts of my research sites.

Cathal Garvey is an early British pioneer and participant in the DIY Biology phenomenon. Trained as a biology PhD researcher he based his research in his homemade lab, exploring the possibilities of what DIY can mean in biological technical practice (Fagan, 2020). Like Garvey, Roland van Dierendonck is a biologist disciplined in microbiology but exploring art, maker culture, education and biopolitics and closely associated with Waag society. His art practice develops from his grounding in biology but evolves along very similar lines to my own by using maker technologies and exploring spec1ulative and critical design approaches but through the form of participatory art. He independently makes playful works with *Euglena gracilis* a key non human participant in my study and in the field of biotic gaming.

Andy Gracie is both a Bio-art artist and DIY-Bio and maker culture advocate. He co-founded the *Hackteria* organisation ('Hackteria', 2009) following an event at Medialab Prado in 2009, taking the logic of Garvey's home DIY lab closer to traditional hackerspace culture. For a while Gracie was connected to the same art ecosystem as myself, Czarnecki, Dillon and O'Shea. He developed the complex interdisciplinary work *Drosophila titanus* (2009) which is a biological experiment, artwork, maker project and form of speculative design, attempting to breed a variant *Drosophila melanogaster* resilient to atmospheric conditions on Saturn's moon, Titan in collaboration with Dillon. The atmospheric conditions where setup with a pragmatic maker approach of re-using readily available and cheap domestic equipment such as a bike pump, smoke alarm and vodka. I used hackteria resources for my ShrimpCraft project as part of my work embedded in the Minecraft community and in the Ethical Microscope prototype developed for this research. (Dalziel, 2021a). Although he was active in the DIY-Bio Hackteria hackerspace at the beginning, he seems to make little of the connection on his most recent website instead focussing on the development of his art-science practice which he now situates in the field of astro-biology.

In contrast Slime Mould Collective (Barnett, 2009) is an art-science collective exploring the world of slime moulds and similar organisms, setup by artist Heather Barnett around the time of the emergence of maker culture in Britain in 2008. Although similar to Hackteria in the sense that it is a resource of information, communal communication is the focus. It is fitting that they use a sprawling online forum prioritising communal communication over a Wiki format (Cunningham, 1995), considering how they experiment with the non-human organism that perhaps most embodies commensal communication. Although not strongly identifying necessarily as DIY-Bio or makers or hackers they nevertheless share a generous communal approach to the craft and care required for doing biological science outside the more secluded research of institutional of commercial laboratories. They specifically focus on microbiology, and during lockdown I attended some meetings to get a sense of them. Here art practice is common but not the only creative practice, the ever changing group seem to focus on communal support and sharing of a hobbyist culture and the site is a rich resource considering it is based around a single group of organisms.

DIY-Bio at Manchester's MadLab (Calow, 2012) followed Hackteria as one of the earliest UK makerspace based projects engaging with the DIY-Bio phenomenon in Britain, funded by a Wellcome Trust grant and facilitated by collaborator Hwa Young Jung and Rod Dillon. Jung, Dillon and Calow developed a series of public workshops often on the street that explored micro biological practices that could be practised outside of the lab. One of the biggest challenges for all these labs are the formidable issues of health and safety and the scale of infrastructure required to make many biological practices and technologies possible. This is discussed in my attempts to incorporate DIY-Bio practices into DoESLiverpool. Whereas in DoES, I limited practices so they would work within the makerspace safely and in agreement with the wider community another group of makers involved with Cambridge Hackspace in developing BioMakeSpace Cambridge incorporated their space into the Cambridge Biomedical Campus. ('Biomakespace Cambridge', 2016)

Labs DIY Bio is also part of an interesting lineage of artistic and educational appropriations of the lab imaginary, by which I mean how the idea and pre-conceptions of 'the laboratory' exist in the popular imagination. These lab traditions can be seen especially in critical media, digital art and creative technology institutions (Medialab Prado, 2000; MIT Media Lab, 1985) but like DIY Bio, these labs vary wildly in scope and duration and can often simply refer to something entirely discursive, without any of the features of the laboratory as a site for experimentation with materials. Labs act as powerful metaphors for setting up the *radical pedagogy* of Barry and Born and in my practice I developed a sound based Medialab for a primary school and collaborated with Full Of Noises on Digital Medial Labs for over four years alongside many of my artistic and maker peers such as Czarnecki and O'Shea but also Jung, Dave Lynch, Gemma May Potter, McEwen, James Medd, Neil Winterburn and maker supplier Aaron Nielson of no longer trading maker supply company Oomlout.

Rod Dillon as a senior member of staff at BLS explicitly brings in artists to his lab facilities to advocate for the benefits of creative interdisciplinarity and has a wealth of expertise and experience in building commensal relationships between the life sciences and other disciplines. This is quite a different model for what social

scientist Michel Callon's calls 'research in the wild' and challenges the model of the institutional lab that is the basis for much anthropological work in science and technology studies. In my research the lab is revealed as an important site for the possibilities of human and non-human collaboration and biomedical life science and radical pedagogy uniquely able to be open to the social sciences.

Bio-art and DIY Bio can also be understood as both a symptom and consequence of what Carlos Andrés Barragán called 'the de-territorialization of knowledge and expertise' in his review of Da Costa and Philip (2009, p. 329). De-territorialization refers to the shifts in global capitalism, primarily through the development of the internet, that leads to the possibility of an ostensibly democratic access to knowledge, at least for some people. Do It Yourself (DIY) culture is dependent on this more democratic force of production emerging alongside and often supporting the art practitioners discussed here, like Kac. These categories are also dependent on world historical events such as the development of advanced industrial capitalism and a highly developed bourgeois culture. More specifically, they depend on the infrastructure of technoscience and atomised working practices characteristic of 'post-fordist' capitalism. Post-fordism is the highly distributed division of labour that evolved after the Ford car factory model for manufacturing, where a completed product and diverse specialised labour force are arranged on a production line in a single factory. Now multiple specialist factories and workshops are distributed across global supply chains to provide relatively friction-less access, again to certain people of certain incomes in certain nation states, to products like 'cheap' electronic components. The proliferation of electronic components means small collectives and individual hobbyists and practitioners in maker culture and art can participate and intervene in the technoscientific practices of the life sciences without the support of institutions or the state.

The Parasites

> interdisciplinarity assumes a certain consciousness of disciplinarity as a condition for its accomplishment (Osbourne, 2013, p. 82)

In this section I discuss the work of Barry and Born in greater detail. In this research I reflected on the development of my 'art-science' practice and my understanding of it as interdisciplinary work, full of boundary work between art, science and the humanities. I realised I was not doing some kind of radical hybrid trans-disciplinary or even anti-disciplinary practice. Thinking through Barry and Born's work, I found that in my research, there were no significant breaches or breaks of disciplinary boundaries that the portmanteau term art-science might imply. Instead, different disciplinary practices are bundled together alongside each other. I gathered together and participated in different disciplines in a particular way, responding to interactions of participants and context. Through the thesis and my research through practice, I developed the term *Interleaving Practices* into a method, and make an argument for its importance in describing and shaping the care and politics involved in art-science collaborations.

Barry and Born provided conceptual tools and typologies for the understanding and analysis of the interdisciplinary work in the study and were indispensable in

developing the Interleaving Practices idea. Thomas Osbourne in his contributing chapter to *Interdisciplinarity: Reconfigurations of the Social and Natural Sciences*, 'Inter that Discipline!' (Osbourne, 2013), describes how in order to be interdisciplinary you have to be partly transactional and parasitic upon actual disciplines. We need 'disciplines' to 'inter'. Particular disciplines authority is often hard won, which I have observed in attending BLS teaching modules and in particular participating in microbiological training programme. Barry describes how 'disciplines discipline disciples' (Barry, Born and Weszkalnys, 2008, p. 20). This can make one feel a sense of freedom as an interdisciplinary interloper, yet at the same time a sense of frustration when attempting to embed yourself in a discipline you know you will never experience as the specialists you try to work alongside, collaborate and learn from. At times as an interloper jumping across disciplines one can feel like a parasite, depending on others expertise and knowledge that you demand simple explanations of for your own ends, with little equitable benefit to your disciplinary host.

At the same time interdisciplinary workers can be exploited. They can be lauded as hybrid innovators yet overlooked when investing. I concur with Barry and Born in some of their dispiriting conclusions of their study when interdisciplinary work is 'apparently highly valued, recognised as a site of invention and a source of fascination, and yet starved of security and adequate funding.' (Barry and Born, 2013, p. 268). I have observed in my experience that only a fraction of art and innovation infrastructure and production budgets trickle down to participatory workshops, engagement teams and their projects, yet they remain primary sources for validating an institution.

Marisa Jahn talks of the limits for attempting to embed in a discipline. 'the question of when an embedded practice stops being 'embedded' and just becomes, well, life?' (Jahn, 2010b, secs 2, para.14). When trying to embed somewhere, is there ever really somewhere not-embedded? Is embedding, that is, doing what 'they' do, to 'qualify as a player' (Osbourne, 2013, p. 82) as Osbourne notes, always parasitic in some way? Jahn insists that there must be a 'host-upon which embedded art practices are predicated.' (Jahn, 2010b, secs 2, para.4).

Complex and contradictory relationships of power however could be the source of interdisciplinary work's enduring power and desire to innovate, combine and reconfigure things. Jahn presents Michel Serres writing on 'the parasite', chiming with interdisciplinary biological research where some parasitic protists enact important creative relationships with a 'queer performativity' (Barad, 2011; Werren, 2008) that resonate with understandings of the organisms researchers in BLS work with:

> The Parasite has placed itself in the most profitable positions, at the intersection of relations. (Serres, 1982, p. 43)

Jahn pursues an argument for what she calls 'double ontology' where embedded practices both create and enact something inside and outside of disciplines or contexts. A material outcome or meaning in the art world and another for the 'real world'. In my Public Engineering (Brinkmann *et al.*, 2014) work I attempted a mutualistic exchange of utility, practice and labour across two sets of makers in the UK and Germany. The project was part of a festival in Bochum Germany that hoped to respond to recent developments where the region lost their car industry to competitors in Liverpool. My response was a project that worked as a family-friendly participatory

installation where people could build large structures from cardboard blocks made on an assembly line with a specially made robotic pick and place machine, as a space and informal forum to discuss this loss of a local industry. The project worked as an art installation responding to the festival concept, yet at the same time acted as a platform for the hackerspace the festival new nothing about, an under-represented non-profit technical community. Outside the concerns of the festival I developed something that would also be an opportunity for younger makerspace members in Germany and Liverpool to work together. I built into the project money and space for an exchange between the two makerspaces. It attempted to offer something for myself as an artist and something for the community I depended on, the hackerspace and makerspace. However a side discussion following the project, revealed how the community felt they might be being exploited by the cultural organisations who commissioned me.

Becoming a parasite is always a danger for ethnographers or artists. Sensitivity and reflexive critique are essential parts of complex interdisciplinary work. However to pursue a purely equitable interdisciplinary relationship with no differing power relations in not only impossible, but something that denies how 'boundaries' between one discipline or community and another is productive. Antagonisms must be negotiated in order to allow change and meaningful interventions to happen.

Rod Dillon comments on the importance of understanding the range of social relations between organisms in biology. The most popular relationships in the public imaginary with biological origins is *symbiosis* a form of mutualism where organisms are in a mutually beneficial relation, or the parasitism, where one organism is harmed and another benefits. Dillon points out that there are other relationships that are less well known including *amensalism*, where one organism is harmed or exploited but the other is not affected and *Commensalism*, a long term form of mutualism where one organism benefits, but the host species are not exploited or harmed. Commensalism, introduced by Belgian zoologist Pierre Joseph van Beneden in the late 19th Century, resonates strongly with my approach to work in BLS, DoES and the NMC. Manoli Moriaty, a participant at the DisruptEncodeConsolidate symposium, usefully mapped out these biological approaches and their outcomes in his presentation on the interdisciplinary relationships he developed with dancers in his research, summarised below.

Table 1: Comparing different types of biological relations with their affect on host and symbiont in response to Moriaty's presentation and Dillon's approach to art-science

Typology	Symbiont	Host
Amensalism	Neutral	Negative
Commensalism	Positive	Neutral
Mutualism	Positive	Positive
Parasitism	Negative	Negative

Interdisciplinarity This mapping is useful when considering how Barry and Born and their contributors challenge additive, synthesis and other 'best of both worlds'

models for understanding interdisciplinarity. They avoid characterising interdisciplinary work as simple transactional mutualism however. For them, contemporary accounts of interdisciplinary work, in art-science particularly, are often 'conceived as rendering science more accountable and communicable to the public' (Barry and Born, 2013, chaps 11, p.254). They see this as reducing any meaningful multiplicity:

> We propose that art-science should be understood as a multiplicity, and that part of its interest lies in not being reducible to the imperative to render scientific knowledge more accessible or accountable (chap. 11, p. 248)

They critique a range of assumptions and describe a spectrum of interdisciplinary arrangements and relationships.

- Multidisciplinary, where multiple disciplines cooperate and collaborate but keep their boundaries,
- Interdisciplinary, attempts to synthesise and integrate disciplines.
- Transdisciplinary, 'the transcendence of disciplinary norms'.

In response, they make a nuanced outline for three modalities of working in that spectrum; *service-subordination*, *integrative-synthesis* and perhaps more significantly for this study, the *agonistic-antagonistic* mode that resonates later on in the review of the work of political theorist Chantal Mouffe. This leads them to three 'logics' and guiding rationales.

- Accountability - Art subordinated as a service to make science understandable or accessible, or science appealed to as an authority
- Innovation - Art and creativity innovates, supporting science economic and technological growth.
- Ontology - Reflexive, dialogic, multiple accountabilities. Novel publics and meanings and hybrid forums; 'transforming the relations between artists and scientists and their objects and publics.' (chap. 11, p. 249)

There are times when all three logics take place in my practice. Accountability and innovation logics are often selling points for beginning and certainly funding art-science collaborations they can be the first step on making a case for your approach in my experience. This is not always a sinister phenomenon of judgement it just acknowledges the different logics as analytical tools. Barry and Born insist these logics are not exhaustive, rather they move through each other and can only really be understood when things are 'in play'. 'While the three logics are interdependent, then, they are not reducible to each other.' (Barry, Born and Weszkalnys, 2008, p. 20).

Most significantly for this thesis and understandings of Interleaving and Critical Kits, is a 'logic of ontology'. This logic which I described earlier in the artworks of da Costa and O'Shea is 'an orientation apparent in diverse interdisciplinary practices... towards effecting ontological transformation in the objects and relations of research.' (p. 21). They also offer a warning to not get lost in enthusiasm for inventive interdisciplinarity that art-science practitioners can be prone to, disavowing a 'necessary or privileged affinity between interdisciplinary research and invention' (p. 42). I have observed this privileging in the hyperbole for STEM and STEAM approaches to learning in maker culture and participatory digital art practice where

the disciplinary rigour of a discipline or the complexity of a subject is over simplified: 'interdisciplinarity must attend to the specificity of interdisciplinary fields, their genealogies and multiplicity' (Ibid.). I use this advice in discussing the role of Critical kits in BLS and consider the extent that they, and the Interleaving method can:

> lead to the production of new objects and practices of knowledge, practices that are irreducible both to previous disciplinary knowledge formations and to accountability and innovation. (Ibid.).

In following variances in the approaches of art and science between professed Non Governmental Organisational (NGO) strategies and practitioner insights, Barry and Born neatly describe both the features of my practice and the pluralities of art science. They help discriminate between the multidisciplinary aspects of engineering and biology in the practices and interactions with kits in the BLS case study; following ostensibly *accountability* and *innovation* logics and the critical kits which follow more *agonistic* and *ontological logics*. Embedding and re-empractising in the mess of social relations; doing what people do in the situations of the practice; means the artist does not only observe and address actors, but becomes meaningfully entangled and implicated in relations.

Like da Costa I take extra care toward what can be made absent in the day to day practices of entrepreneurial makers and science teachers, the shape of the locally embedded relations where social meaning happens. In this sense the deprioritisation of the art object is not primarily some disavowal of art as commodity, and replaced by the kit form but more a symptom of a commitment to social relations. In conversations with colleagues Hwa Young Jung and Rod and Viv Dillon, I discussed the artist-maker and the awareness of the complexity of scientific knowledge. Every discipline and sub discipline and sub category has its own 'silo'. As disciplines and practitioners dive deep into a subject they are disciplined in order to become sensitive to the fine grained difficulties of understanding the world within specific frames and context. An artist 'using' science, in the logics of accountability and innovation, skitters across the openings of the silos and makes inventive connections. In my practice embedding allows you to descend a few feet down each disciplinary silo. Just enough to be able to get a 'feel' for the silo while still being aware of all the other openings - and a sense of just how far down the rabbit hole goes. This builds up *capacity*, a concept I lean on heavily later. Unlike the idea of possibility, capacity is not just something immaterial or virtual, waiting for something to happen, but a more concrete ontological opportunity, a set of resources to help understand a scientific method or interleave it with other disciplines.

The Amateurs of Reality

> we need to ask about the issues and the tools in the social study of technology. But we also need to think about identities: about who we are when we study the technical, where if anywhere we belong, and whether indeed we have or need stable identities. A post-disciplinary answer beckons: it is that we might make ourselves mobile; make heterogeneous alliances; and patch together friendships, projects, and insights, tools for thinking from a variety of changing sources. (Law, 2000, p. 1)

In this section I explore Science and Technology Studies and explain its relevance to the study and begin to introduce how this thesis might contribute to it.

John Law's Sandwiches

Social scientist John Law of Lancaster University's Centre for Science Studies is eating his sandwiches in the car park of Daresbury Labs, not 8 miles away from the Glue factory and 8 years prior to my Year Of The Artist residency, concerned over the overload of data in his ethnography of the management of a complex laboratory renovation.

> There was too much going on. Meetings, activities, experiments, disasters, triumphs, comings, goings, arguments, friendships, documents, policies, programmes, aspirations, promotions, conferences, memos, cups of coffee... Sometimes, especially in the early days of the ethnography, I found that I needed to retire to my car to eat my sandwich by myself at lunch time, or to use the library to make some peace... what I needed was a better tuned and more discriminating method assemblage... (Law, 2004, p. 108).

Law's struggles with overwhelming cascades of information embedded in the messy situations of his study resonate with my own and for me, Law is key in opening up art practice as STS method. Law draws attention to how in research, artistic or otherwise there will always be, more or less; routine and necessary 'cuts' that must be made in the 'noise' of the world. What is *excluded* and what is *included* what is *Othered*, or *made absent*. For kit makers deciding what goes 'in the kit/in the bag', Law sensitises us to these cuts. What is contingent on cutting? What and who gets to cut? When does it matter? When does it not? Perhaps choosing to eat his sandwiches in the car park is another assemblage, a pragmatic break to shift his signal to noise ratio. The embedded artist practitioner can attest to both the difficulty of finding methods for dealing with significant data in the noise of the field, and getting a half decent sandwich befitting a high profile scientist in Runcorn. Law's concepts of 'mess', 'generous method' and 'allegory' were powerfully resonant.

> ***10 years of neo-liberal de-regulation later and 7.5 miles away at the factory in Widnes, the supermarket sandwiches in the local Asda are now pretty good. The Arts Council are funding work outside art venues in a millenial programme called 'Year Of The Artist'. Nervously I wandered the site in ill fitting steel toed boots, keeping note of the location of emergency showers to wash away potentially fatal hydrofluoric acid spills. I'm almost paralysed not by health and safety concerns, but more by extreme self-consciousness, aware of the gulfs of experience and class my friendly hosts and myself, the pretentious artist in residence at a glue factory. At times this paralysis and hesitation limit what 'data' I feel able to collect. From Law's perspective I need another method assemblage. More cuts need making. Do I visit Paul in the nice dry protein analysis lab again or persevere with High-***

Viz-Brian shovelling part dissolved animal hide into hoppers? Is this a sensitivity that Others? I visit Brian with his shovel and take a picture.

"Lets see your hands..." I look at them automatically "You've never worked a day in your life" he said.

Science and Technology Studies

Understanding the scientific objects and practices of maker culture and biomedical science in their full complexity called for literature from the field of Science and Technology studies (STS). STS in its first generation, was attuned to the social structures of scientific knowledge and a fundamentally historical approach to how science is socially constructed. It asks how knowledge and technology is produced, how it is contested, verified and becomes credibly accepted as reality as a sedimentary social process. Thomas Kuhn (Kuhn, 1970) explores historical accounts of this; how science is made up of people and practices and that they must work in particular ways to make scientific knowledge, before scientific objects like 'the gene', 'DNA' or a sub-atomic particle like a neutrino can be said to exist. Kuhn's innovation was to understand that this gradual social process can quite suddenly qualitatively shift at critical moments, when something in the 'chain' is broken or must be reconsidered. He describes these as 'paradigm' shifts and in the terms of revolutionary discourse, leaving facts on either side of the rupture incommensurable.

Ian Hacking asks similar questions of scientific objects, practices and discourses that are often naturalised and de-historicised, becoming intuitive common sense to scientists and non-scientists alike. Asking questions of already settled scientific controversies can seem ridiculous when I incorporate it into a workshop activity. Hacking asks 'Do we see with microscopes?'(Hacking, 1983) resonating with another question 'Why are LEDs so cheap?' I put to makers on the silk screened surface of a printed circuit board. Hacking provides fascinating historical accounts of the history of microscopes resonating with the main component of my *LabFromAChip* kit, the *Foldscope*.

Second generation STS explores the social and political implications of the historical construction of science and technology and critiques canonical social science; that the world is 'out there' simply waiting to be discovered. STS challenges the separation of the way we think about the world and the world itself; our theories and methods not only shape what it is possible to know and theorise about, but partly produce their objects of study performatively. This resonated with my tacit sensitivity to art-science and the boundaries of different ways of knowing developed over years of working along the boundaries of art and other practices.

Kuhn and Hacking lead me to the work of Donna Haraway and Bruno Latour. Haraway's notion of 'situated knowledge' (Haraway, 2016), that scientific and other knowledges can never be from nowhere, but always embodied, and 'nature-culture', that there is no clear distinctions between human, the non-human and technology became essential in broadening and critiquing what is at work in technology and science. Latour's ethnographies of hormonal bio-chemistry and soil science (Latour, 1999, 2003), gave some interesting interpretative lessons to observing science and

industry. I felt a close kinship to Latour's early ethnographic work, recognising my relationship to ethnography in the methods of my practice. From here, many STS trajectories were followed (de Laet, 2000; Callon, 2009; Law, 2004; Suchman 2012).

Law explores how theory and method are intertwined and like Hacking, Kuhn and Latour he is not only concerned with the construction of scientific facts as an accomplishment, but how such accomplishments might fail to acknowledge different ways of knowing, while Callon maps out new models for scientific and public research. Lucy Suchman explores the idea of 'located accountability' (Suchman, 2000) in technological production building on Haraway's situated knowledge and Mol's paper *The Zimbabwe Bush Pump: Mechanics of a Fluid Technology* which introduces the idea of fluidity and love and what makes normative public goods in technical objects. Mol, in her description of Latour's Actor Network Theory (ANT), articulates, re-contextualises and develops understanding of STS and aspects of my practice and this research.

> ANT is not a theory. It offers no causal explanations and no consistent method. It rather takes the form of a repertoire... The point is not to fight until a single pattern holds, but to add on ever more layers, and enrich the repertoire. One might say that... researchers involved in ANT are amateurs of reality. Their theoretical repertoires allow them to attune themselves to the world, to learn to be affected by it (Mol, 2010, p. 261)

STS practitioners as 'Amateurs of Reality' are sensitive to both the creativity and dangers of the parasite and the dilettante. Eugene Richardson a critical clinician playfully called STS practitioners, in his presentation at the international STS conference 4S2021, 'curators of facts' (Richardson in a comment during his presentation *The Coloniality of Global Public Health* (Richardson, 2021) at 4S2021) making a distinction between academic practitioners that critique facts, and practitioners that construct them, scientists. However many of these researchers take their curating of their interdisciplinary research subjects and their own subjectivity seriously, in many cases trained in the natural sciences and develop a strong intimacy with their fields of study.

STS theory-methods at the beginning of this research became 'handy' relational 'kits' for developing a repertoire for my own reporting of 'science in action' that Latour explores (Latour, 2003). Many of these 'kits' are important terms or conceptual tools. *Technoscience*, a concept originally developed by philosopher Gaston Bachelard used ubiquitously in STS is useful for understanding the interleaving of technology, technical objects and scientific practices. Technoscientific objects in STS contain and reproduces both material power and ideology and can be challenged by the most basic of commensal questions, *Who benefits? Cui Bono?*. Haraway and others take technoscience further with the non-binary fusion of *nature-culture* exploring human and non-human hybrids and cyborgs. Importantly for the study of my critical kits, is that STS methods have a dominant concern for *accountability* in technoscientific objects, methods and practices. STS does not just study how and what technoscientific objects do, what they measure, allow us to analyse or effect, but help understand how they partly produce and enact their objects and subjects of study and what kind of worlds this can produce. Technoscience is also made up of the idea of the social or public *imaginary* referring to a hegemonic set of discourses, signs,

norms and laws that make up a social group or their understanding of something. For this research the imaginaries of 'genetic scientist' and 'kits' became important.

The origin of this project, the Critical Kits Symposium I organised in 2016 (Dalziel and Winterburn, 2016), came from an intuitive concern that art-science practitioners and makers making kits had few tools for acknowledging how their methods, ways of knowing and political commitments produce and reproduce the world in a specific way and not in other ways. STS help articulate not only what kits *include* for their intentions and interventions but what they *exclude*, what those inclusions and exclusions mean and what realities they enact.

Ethnography

> Parts of the world are caught in our ethnographies, our histories and our statistics. But other parts are not, or if they are then this is because they have been distorted into clarity... Perhaps we will need to know them through the hungers, tastes, discomforts or pains of our bodies. These would be forms of knowing as embodiment. (Law, 2004, p. 2)
>
> When one carries out an ethnography, one observes what people do, and then tries to tease out the hidden symbolic, moral, or pragmatic logics that underlie their actions; one tries to get at the way people's habits and actions makes sense in ways that they are not themselves completely aware of. One obvious role for a radical intellectual is to do precisely that: to look at those who are creating viable alternatives, try to figure out what might be the larger implications of what they are (already) doing, and then offer those ideas back, not as prescriptions, but as contributions, possibilities — as gifts. (Graeber, 2004, p. 7)

The lab culture which I described as part of the DIY-Bio phenomenon although rich and diverse is nevertheless peripheral to the formal research laboratories in universities and the commercial pharmaceutical biomedical industry. These laboratories are the basis of many key social science ethnographies in science studies that lead to STS theory by academics such as Bruno Latour and Paul Rabinow (Latour, 1999; Rabinow, 1996) and related science biographies by Evelyn Fox Keller (Keller, 1983, 2002). This literature informs the method and the analysis of the study. It considers the concept of positionality and the need for a reflexive awareness of how the ethnographer is implicated in the things observed. This is significant in developing the embedded art practice and the method of Interleaving Practices it leads to.

Lancaster University's FASS Qualitative Research Methods modules (Hess, 2001; Mack et al., 2005) also supplement this understanding. The observational data in the study generated by the practice, is considered as a form of auto-ethnography. Sebastian Dahm in his relevant studies of hackspaces calls this an Ethnomethodology (Dahm, 2017). Underpinning my ethnography of my 'own' practice is its dependence on collectivity in the making of kits together with the others of my research participants (Ingold, 2013; Niewöhner, 2016).

A research participant at 4S2021 suggested that the kits produced together as part of a making and doing session with the *LabFromAChip* kits were suggestive of the traditions of the 'second books' in early French anthropology that accompanied

dense structuralist ethnographic studies. These seconds were a more affective, loose and creative literature meant to evoke the 'feelings' and 'atmospheres' of the ethnographic encounter (Debaene and Izzo, 2014). In this sense kits are a kind of affective ethnographic data for the study to help researcher and research participant to get a 'feeling for the micro organisms' as a recent bio-engineering paper explored (Calvert and Szymanski, 2020). These 'second' analytic literatures are more open to the transformative affective nature of the ethnographic encounter which I discovered in my research.

Follow the Things: Actor Network Theory

> We have taken science for realist painting, imagining that it made an exact copy of the world. The sciences do something else entirely - paintings too, for that matter. Through successive stages they link us to an aligned, transformed, constructed world (Latour, 1999, p. 78)

Bruno Latour's work is grounded in a rich scholarly knowledge of the history of natural philosophy, humanities and social science, perhaps just as comprehensive and idiosyncratically polemic as Foucault's knowledge of power. Unlike Foucault, Latour also uses more worldly ethnographic approaches to science comparable to the work of Paul Rabinow in his fascinating explorations of the development of Polymerase Chain Reaction (PCR), the now essential component of DNA based molecular analysis. Latour, and to an extent his predecessors Kuhn and colleagues John Law and Steven Woolgar, are partly responsible for the key social science 'controversy'. This is the scandalous idea that rational science, facts perhaps even reality itself is at least partly socially and historically constructed.

Latour maps out the practical 'doing' of science, where years of measurements by thousands of creative scientific workers and experimenters are inscribed as texts, maps, assays and linked together like a network, a network of human and non-human actors, his *Actor Network Theory* (Latour, 2005). He is interested in what he calls the 'chains of transformation' and 'circulations of reference' where data from the world is assembled by the careful labour of scientists and their equipment, from pedometers to PCR tests and transformed into credible facts. He extends this network to a model of the social that includes both human and non-human 'actors', like road and rail networks, coffee cups, the local restaurant, oil infrastructures, eye wash stations or printed circuit boards.

This has been dramatically presented as a 'crisis of rationality' in the so-called 'science wars' of the 1990's (Law, 2004) where some 'natural' scientists objected to critical theory and the critical social analysis of science. This seems less controversial from the perspective of my artistic practice. The Embedded Practitioner, who has been in residence in science labs, factories and the offices of engineers, intuitively knows it is people with situated bodies and histories, intimate with their novel technical apparatus that do the work of science: the 'science in action' Latour explores (Latour, 2003). From the perspective of working in BLS and at previous artist residencies, scientists are always doing stuff together with each other and with, what Latour calls, their 'inscription devices' (Ibid.). In this study API 20e testing kits, balances, centrifuges, hemocytometers and fume cupboards. Latour, like many artists, also takes up residencies in the field, observing, for example, soil samples

slowly interlinked and transported into a soil pedo-comparator, log books, tables of data, vertical sections and reports in the Amazon jungle.

In his 1999 essay, 'Circulating Reference Sampling Soil in the Amazon Forest', like the colonial anthropological traditions of the white european in the big American Other, Latour carefully maps the perilous journey across the unknowable semiotic ocean between ***things*** in the world and representational ***signs***. A critique of science, might be that it is overconfident, jumping from object to word, world to sign, assuming too much about access to reality. Latour shows that scientists are not jumping around carelessly; or making representations, they are always testing their assumptions of reality, always disciplining themselves. Latour carefully articulates the practical details of the travels of soil and plant samples from the forest/savanna boundary to the field lab, local restaurant and the map, to the research paper, but crucially he notes how these are not representations or resemblances that 'jump' from word to world but instead, carefully transported and transformed *circulating* references, reversible chains and networks that can be traced back to the world for proof of work, reminiscent of the cultures of issue and version tracking in the use of project management software Github that I observe in DoESLiverpool and then re-empractice in my own work. He does not talk of overconfident scientific abstractions, but reveals necessary *reductions* that nevertheless gain a foothold on reality, to be able to point and then *'intervene'* with some confidence. For him, and myself as a layperson participating and trying to learn, scientists *necessarily* 'construct' facts in a vast network of knowledge, apparatus and social activity. Despite the persistent myth of the singular scientific genius this is deeply socialised knowledge made by constant contestation. The term 'scientific consensus' trips off our tongues, hiding laborious and dramatic antagonisms amongst thousands of dedicated labouring human beings.

Latour and others in STS observe how these intermediate links between things and words, observations and data tables, all the relational messy 'invisible work' (Law, 2004) of practice gets deleted and forgotten, and we are left with stable facts and 'just so' stories, that appear to have been waiting for us to discover all along. Latour describes these deletions as part of the 'black boxes' of science and established knowledge. These deletions obscure and elide how this knowledge is 'situated' in historical, material social, political, economic and ideological worlds, a key theme in the work of Latour's colleague and adversary Haraway.

This could sound like, and has been characterised as, an attack on science. In the 90s, this evolved into some kind of culture war, perhaps pathologically shoring up scientific certainty at the peak of US covert imperialism and hybrid proxy war. However for me in my field work, it is this socialised constructed network of historical labour that stabilises scientific facts, what makes them important, viable and above all meaningful. The socially constructed nature of science that includes non-human objects, habits, craft practices, and materials does not cast doubt on science where facts are weird 'inventions' 'made up' by scientists; instead, scientists labour to produce a set of circulating references from the world to signs, from soil to scientific paper (Latour, 1999). Latour helps one see the value of this labour in my intuitive attempts to embed in BLS. Contrary to the image of Latour as the postmodern academic debunking reality and inventing non-human collaborators, Latour's critiques of post-modernist philosophy explore diligently the importance of aggregations of sceptical testing, in the tradition of the falsifying scientist.

> Our philosophical tradition has been mistaken in wanting to make phenomena the meeting point between things in themselves and categories of human understanding. Phenomena, however, are not found at the meeting point between things and the forms of the human mind; phenomena are what circulates all along the reversible chain of transformations, at each step losing some properties, to gain others that render them compatible with already established centers of calculation (Ibid., p. 71)

This suggests slow aggregated layering and interlinking over time resonating with physicist and historian Thomas Kuhn's work. However time for Kuhn is far from simple linear progression. Scientific theory and methods can disrupt links and transformations in catastrophic 'paradigm' shifts rather than a mythical linear progression toward truth (Kuhn, 1970). These are like mass extinction events for scientific methodology. This is echoed in my research of biologist Stephen Jay Gould's analysis of mass extinctions in the early fossil record (Gould, 1990). Gould suggests sudden mass extinctions can be seen as not just a tragic loss but part of an essential process, unravelling the idea of evolutionary progress from lower forms to the dizzy heights of human endeavour.

The carefully crafted chains of reference of scientific knowledge can be vulnerable to sudden material, epistemological, social and political change. This perspective suggests that kit making and messy DIY re-empractising of scientific technique through sewing, making electronics and 3D printing could be an opportunity to partly recover this invisible work to better understand, learn and engage with science. Here, there is a tension between how educational kits use 'ready made science' (Callon, 2009), effectively re-enacting it, and a DIY open constructivist approach (Papert and Soloman, 1972) that is more like 'science in the making' (Callon, 2009).

> Finished or 'ready-made' technoscience consists of Black Boxes: taken-for-granted elements (well-established facts, unproblematic objects) that can be employed, risk free, for a variety of purposes (including making more boxes, accumulating capital, bending others to your will). (Shrum, 1988, p. 398)

My work in maker culture with computers reveals many 'black boxes'; in computer science a kind of invisible work is the 'stack' of computing infrastructure. This is the aggregated work that allows the hardware base of a matrix of logical circuits linked to machine code and stacked 'up' layer by layer to the abstractions of object orientated programming languages like Python or maker culture platforms like Arduino (Barragán, 2003). It is why many programmers talk about standing on the shoulders of giants; like some kind of digital version of Thomas Hobbe's conception of the political leviathan, a metaphor for political representation and pre-modern sovereign governance. Few users of Arduino know or use machine code, or remember the work mapping machine code to logic gate of the ATMEGA328 control chip, the platform is a black box. You learn the higher level instructions and get the expected (or unexpected) results. Working alongside computer scientists in maker culture, reveals the value of sometimes opening up black boxes, if only briefly and partially. Cefn Hoile colleague and founder of the *Shrimping.It* project in Morcambe (Hoile, 2010) made an interesting intervention in the black box of the Arduino platform by providing a DIY Arduino as a kit of components accompanied by detailed walk

throughs for assembly. Each step explains how the components are related to the abstractions of the Arduino programming language. In my experience this means people of all ages and backgrounds can say they not only programmed an Arduino, but *built one* from components and grasped some basics of electronic logic. Hoiles intervention radically opens up agency by partly opening the black box, just enough to generate a sense of the material reality of machine code computation and electronics. The other benefit is that it slashes the cost of building an Arduino and is the difference for myself and my maker colleagues being able to run an Arduino course with a select few in a code club or a whole school class.

At a point in my research the characteristic of maker kits in a bag resonate not only with De Laet and Mol's fluid technology of the Zimbabwe bushpump (de Laet and Mol, 2000) but with a reading of Ursula K Le Guin's *Carrier Bag Theory of Fiction* (Le Guin, 1986). Maker kits like *Shrimping.It* are not so much *black boxes*, but *black bin bags*, generic, ubiquitous, perhaps bad for the environment in the generation of waste, but easy to seal or re-open.

Following actors is Latour's advice for understanding the black boxes of science an technology. In my research through practice, this can mean making 8-bit computer games using the *Bitsy* development platform (Le Doux, 2015) itself a black box for making simple computer games in an internet browser. My artwork, *Arcade De Bruno* (Dalziel, 2019a), is a black retro arcade cabinet painted black (Figure 16) adapted from the designs of maker and artist colleague James Medd, who's *Awkward Arcade* project allowed independent video games normally only playable by solitary gamers on laptops or desktop computers to be played in a friendly social spaces like pubs and bars (Medd, 2016). Together with Medd I used his designs as a platform to host my early making experiments like my game *Sugar Mice in the Wind* (Figure 17), based on the mouse brain slicing practices I observed of researcher participant Dr Neil Dawson (Figure 18). I used images from Dawson's innovative mappings of glucose in the brains of laboratory mice (Dawson, 2018).

Just as black boxes hide the real nature of the actors in a network that make them function, maker platforms hide the networks of collaborative relations of labour and care that make maker cultures valuable and innovative. The Actor Network point of view makes deep networks of relations accessible, and is what John Law called 'radical relationality' (Law, 2000). Things, actors, people, instruments are not 'situated' in structures, they *are* networks. Taking ANT seriously however could lead to a problematic almost fundamentalist commitment to flatness. For Latour real things are not situated in some kind of social aether or base and superstructural dialectic, but instead their ontology *is* the network. Relevant to the study, is the implication from this network point of view, with respect to Latour's work about Louis Pasteur (Latour, 1988), for even the humble microbe to not only have agency, but could be thought of as a collaborator. This idea resonates with Dillon and Southern's *Parasite-seeing* project (Dillon and Southern, 2019), where they use a range of playful anthropomorphic tactics to understand the complex networks of human and non-human social relations and mobilities that are part of tropical disease vectors.

This radical relationality, what has been called his 'critique of critique' (Latour, 2004) potentially undermines ANT's ability to describe patterns of power or act

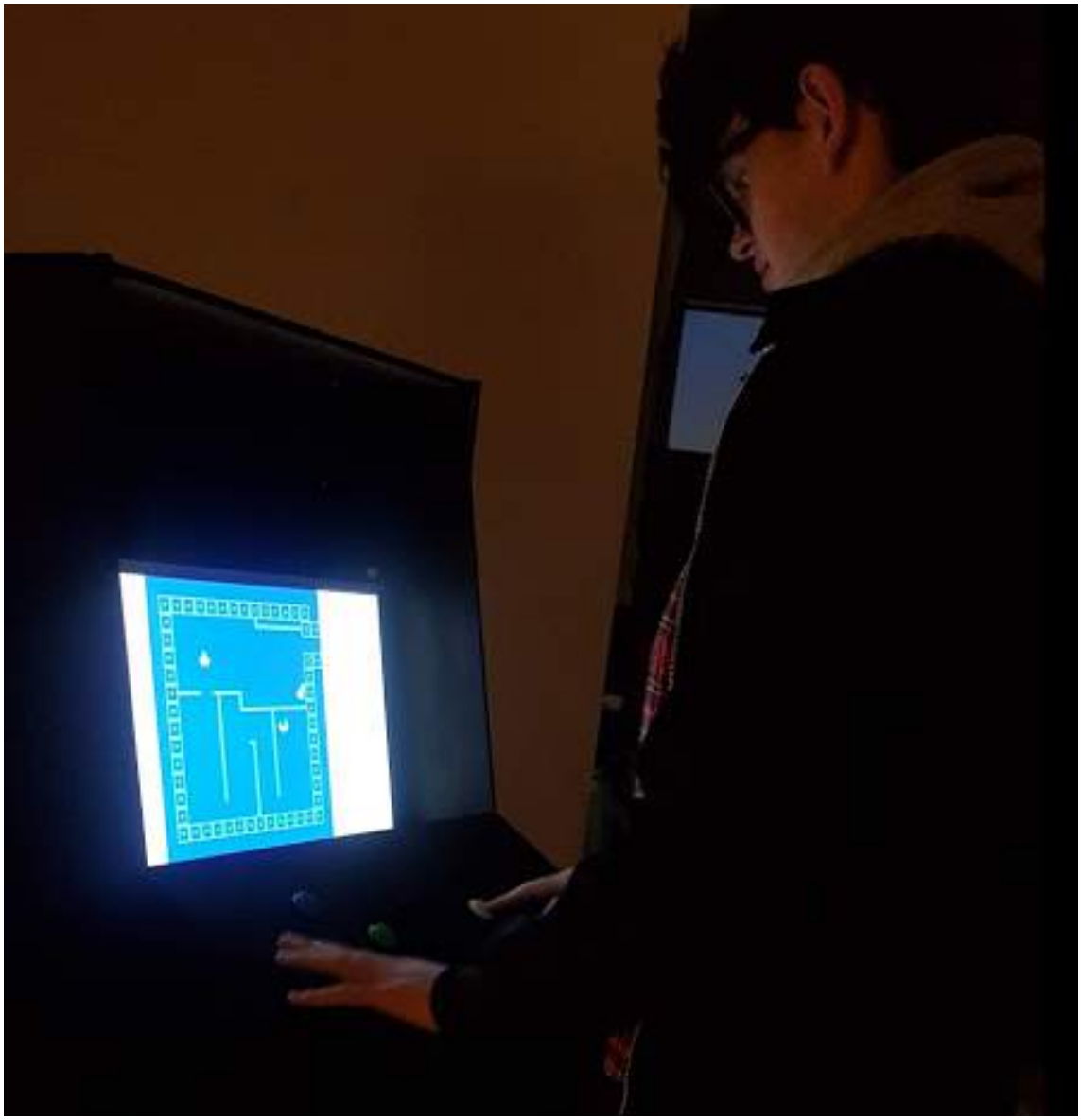

Figure 16: Image of a playtesting session with the *Arcade De Bruno* arcade cabinet for playing browser based games made with systems like Bitsy

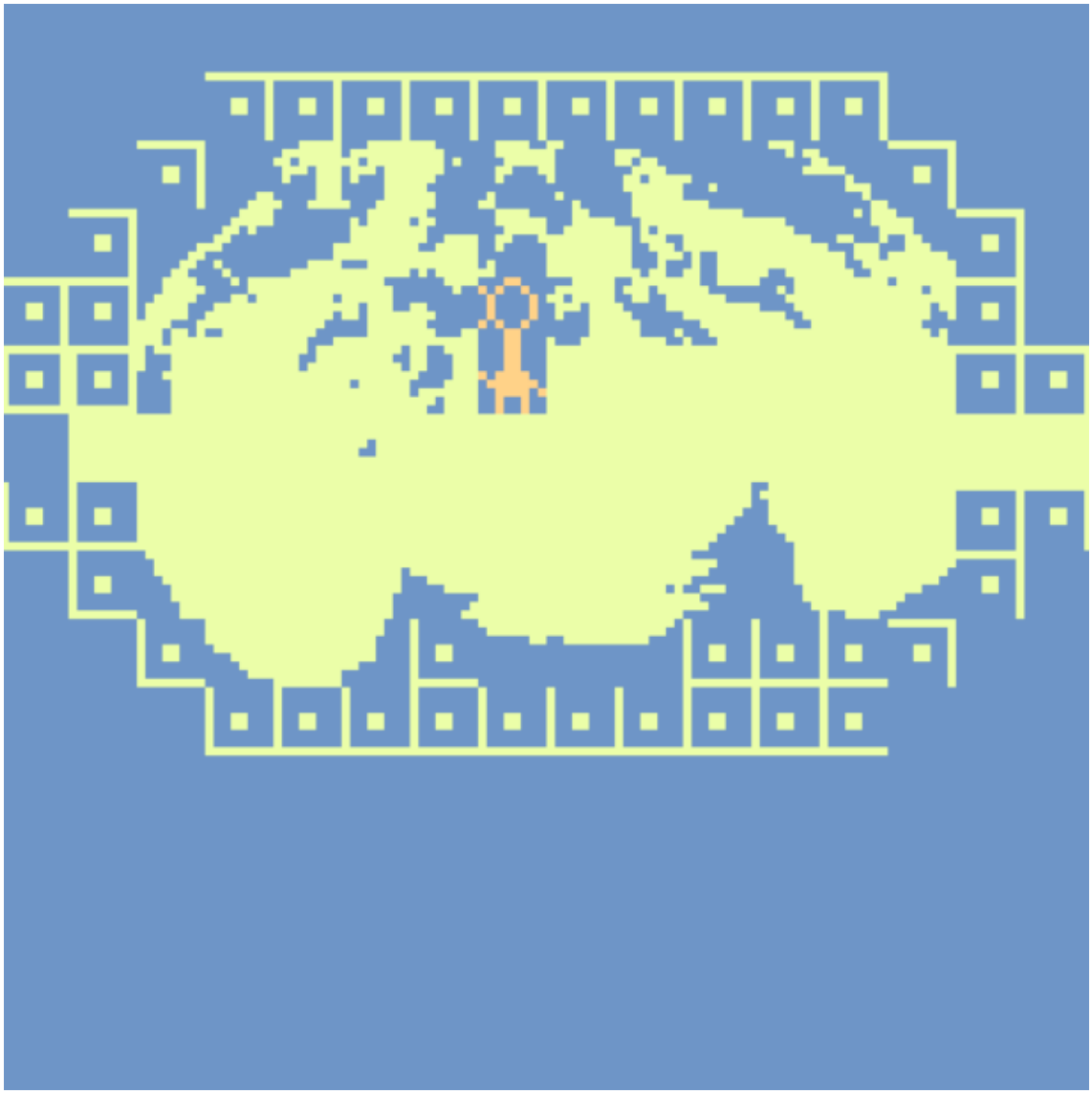

Figure 17: Still from the Bitsy game *Sugar Mice in the Wind* based on images of mouse brain scans provided by Dr Neil Dawson at BLS

Figure 18: Dr Neil Dawson demonstrating how to slice mouse brains for analysis in his research at BLS during the DisruptEncodeConsolidate Symposium

meaningfully in the world. It is perhaps no coincidence that ANT can be depoliticized and has been enthusiastically taken up by innovation hubs, management studies and wider technocratic approaches to organisation and governance. John Law questioned the hegemonic dominance of networks, and how social science was 'representing the world in a way that is not simply uncritical, but more strongly, in a way that colludes and helps to reproduce the way in which the world is already being made?' (Law, 2000, p. 5). The radical sensitivities it develops can easily become instrumentalised as technocratic managerialism, simply tinkering around the edges of the network.

In *Matters of care in technoscience: Assembling neglected things*, de la Bellacasa (2011) warns of a disempowering flatness and disavowal of structure, which inadvertently 'becomes a tool to oppose. . . a feminist vision of care that engages with persistent forms of exclusion, power and domination in science and technology' (Ibid., p. 91). It's a compelling warning to take care of how we follow human and non-human actors and ensure we do not lose productive antagonisms of care to liberal fantasies of consensus where all actors antagonisms and demands are accommodated. This seems to contrast with Latour's more recent work and performative lecture *Inside* (Latour, 2017b) calling for radical paradigm shifts in our understanding of the topology of the climate crisis which I explored in a workshop with my *Latourscope* kit.

Hacking And Intervening Ian Hacking (Hacking, 1983, pp. 186–209) looks in detail at a history of microscopy, re-opening many black boxes. He asks if we *really* see with a microscope at all, referring to the historical record of early maker Antonie van Leeuwenhoek, stumbling across the principles of light diffraction in a quest to resolve the details upon the surface of tiny aquatic diatoms which I first encountered in *Ok Sparks* (Dalziel, 2015) working with the Freshwater Biological Association in Cumbria (Pentecost, 1984). Diatoms refer to numerous genera and

species of algae, the informal name for a diverse group of ubiquitous photosynthetic eukaryotic organisms, organisms with a cell and nucleus, that take their energy from the sun. Diatoms feature tiny patterns of pores and perforations, slits and ridges on their surfaces that fascinated early microscopic practitioners. Several paradigm shifts, large networks of actors and historical material developments were required before microscopes would even be allowed in the laboratories as the public might understand them today, as it was often difficult to distinguish between new organisms and artefacts of the lens.

The *Foldscope* kit used in my research uses a glass ball lens similar to the first microscopes of Antonie van Leeuwenhoek's in the 17th century but fused with 21st century electronic manufacturing practices (Cybulski, Clements and Prakash, 2014; Prakash, 2014). These citizen science kits have spawned an ever growing enthusiastic community. It uses many black boxes and stacks of technologies to make over a million paper microscopes, and is essential in my research to help participants work with algae like *Euglena gracilis*. The *Foldscope* is part of a genealogy of accessible DIY microscopes I have explored, such as the OpenFlexure system, the FlyPi, Picroscope and the minimal maker microscope designed by Public Lab and Hackteria (Dussellier, 2013; Chagas, 2015; Mach, 2017; RiksEddy, 2017; Bowman, 2020), which I re-made and remixed in my research (Dalziel, 2021a). The Foldscope proudly situates itself in science communication and participation while claiming utility for all kinds of 'field' diagnostics and 'frugal science' (Prakash, 2010).

The layperson is now well used to seeing with microscopes, it is part of the public imagination, the public imaginary. When using a Foldscope however, there are constant handheld inconsistencies in the image, compared to the stable security of the expensive lab bench microscope. With the Foldscope research participants *feel* the problematic doubts that early microscope users must have had, but also the contradictory confidence that what you are seeing is real and a consequence of the physical 'interventions' your hands make and you 'see' results of, something that Hacking prioritises.

Hacking orientates us to the contingent nature of technology and the importance of both material and discursive history. With that historical sensibility to technoscience you can describe the *Foldscope* beyond the surface playful innovation of Prakash Lab, as part of a vast historical network of manufacturing infrastructure that must exist to facilitate the interleaving of the earliest renaissance ball lens technology with the 'capillary encapsulation lens mounting, carrier tape lens mounting' (Cybulski, Clements and Prakash, 2014, p. 3) at the scales of advanced capitalist production. Broadly from my perspective, STS reveals how technoscience is always situated and being enacted in dense networks of historical, material and discursive production and later I argue that critical making method of Interleaving supports this and makes participants *feel* those enacments, how things are done. This can be simplified into basic question of *Who benefits?* in STS, in Hacking and much more powerfully in Donna Haraway's work, leading to other historical and economic questions, what material conditions and arrangements had to have happened to allow the 17th century technology of the ground ball lens to be reproduced in such a way in the 21st?

Feminist technoscience

> Objects like the fetus, chip/computer, gene,... is a recent construct... (this) does not mean to be unreal or made up... Out of Each of these nodes or stem cells, sticky threads lead to every nook and cranny of the world. Which threads to follow is an analytical, imaginative, physical, and political choice. (Haraway, 1997, p. 129)

STS and broader socio-political analysis developed useful pathways into criticality, developing further technoscientific objects as performative ongoing technical and social *accomplishments*. This expands what makers are making, re-making, re-empractising, *reproducing* from first stitch to tapestry, 'hello world', the simple test code to show a software system works, to fully realised IoT platform. A crafting and configuring of material and bodily histories, social capitals, political commitments, ideologies but also the care and love that resonate with the observations.

Feminist technoscience can be understood through the foundational work of Donna Haraway, the idea of bodily, historical 'situated knowledge' (Haraway, 1988). For Haraway any perspective or knowledge is always a 'view from a body, always a complex, contradictory, structuring, and structured body' not a 'view from above, from nowhere' (p. 589). Scientific knowledge and practices are always in relations with a complex set of political, economic, epistemological conditions and racialised, classed and gendered bodies. This core idea questions nature/culture, male/female, subject/object binaries and crucially it makes technology, the hitherto neutral heroic enlightenment application of science, inseparable from bodily history but also discursive performance, how things are said, what stories told. Crucially Haraway acknowledges and opposes the unproductive Othering and *'demonology'* of cold war 'Big science', by early eco-feminists, where technoscience is rejected as an idealised evil that must be rejected. Feminist STS attempts to make technoscience available for analysis, critical engagement and political antagonism in order to challenge not only what technoscientific worlds are re-produced in scientific practices but what other possibilities are being excluded.

Lucy Suchman's 'located accountability' builds on Haraway's insistence on embodiment, 'partial, locatable, critical knowledges' (Haraway, 1991, p. 191). She places this accountability directly into the working relations of developing technology offering relevant perspectives on maker culture. Many makers in DoESLiverpool are also part of these complex relations and divisions of labour that makes up technological infrastructure, working and consulting with the wider technological stack of internet based technology, from web design to electronic product development. Suchman;

> it is precisely the fact that our vision of the world is a vision from somewhere – that it is inextricably based in an embodied, and therefore partial, perspective – which makes us personally responsible for it. (Suchman, 2000, p. 6)

This is not for Suchman a crushing responsibility but part of an emancipatory project to make technical systems differently, making 'room for an effective politics around gaining access to technological work and institutions' (Ibid., p. 11)

> locating ourselves within that extended web of connections, and taking responsibility for our participation;... Valuing heterogeneity in technical

> systems, achieved through practices of artful integration, over homogeneity and domination. (Ibid., p. 10)

Suchman's perspectives make room for the contributions of this study quoting Judy Wajcman in her book *Feminism Confronts Technology* (1991), calling for 'disruption in the engine rooms of technological production' (p. 164). Makerspaces, Microbiological teaching labs can be thought of as if not engine rooms, supporting docks and havens supplying such engines. In the case studies the 3D Print Club, that represents the intervention of my art-science practice, can be thought of as one such bodily disruption.

Suchman also uses the idea of 'configuration' to explore what is and is not made in technoscience and leads the way to my use of assemblage theory, described later. Configuration for Suchman is the way material realities and practices; embodiment, are conjoined with 'imaginaries'; the way social actors think and talk about a technology or a practice, or what Haraway describe as '... what stories tell stories, what knowledges know knowledges' (Haraway, 2019, p. 570): 'In the case of technology, configuration orients us to the entanglement of imaginaries and artefacts that comprise technological projects' (Suchman, 2012, p. 57)

Feminist technoscience provides a range of politicised analytical tools to explore the complex hybrids of nature and culture, like 'nature-culture' and how they shape and enact inequalities, always embedded and performative in ongoing bodily history making. It articulates the masculine domination and disciplining of women's bodies, but further, the domination and exploitation of not just this historic inequality, but the gendering and domination of 'Mother nature' itself. It powerfully challenges any technical practice, from biomedicine to manufacturing printed circuit boards to be accountable for all kinds of bodily history, not just gender and not just human. It reveals and responds to historical power and inequality, the indelible marks in time on bodies and places.

Most usefully for the study is feminist technoscience's critical stance following Marxist materialist footsteps on the bodily, historicizing, de-naturalizing and demystification of technoscience applied to the DIY-Bio Kit practices observed in the study. At the same time Feminist technoscience calls for new configurations and interventions, such as the *Civic Laboratory for Environmental Action Research (CLEAR)* founded by Dr Max Liboiron, the 'hybrid forums' of Michel Callon discussed below and the more generous methods called for by Law (Law, 2004; Callon, 2009).

Representing and Participating in Technical Democracy: Hybrid Forums

The lab culture which I described as part of the DIY-Bio phenomenon although rich and diverse is nevertheless peripheral to the formal research laboratories in universities and the commercial pharmaceutical biomedical industry. Such laboratories, are what Michel Callon describes in his book *Acting in an uncertain world* (2009) as 'secluded research' which, in his view, are given supreme autonomy to get on with the invisible work of science. Callon explores how scientists become representatives of both science and facts, much like how politicians are representatives of politics. Callon explores the democratic trade-off between how representatives both in politics and scientific expertise, represent people and knowledge while also effectively silencing them. He explores possibilities for more 'dialogic' and deliberative democracy through

looking at collaborations between 'laypersons' and 'specialists' in families affected by Neuromuscular disorders in what he and his colleagues call 'hybrid forums'. This presents a compelling and inspiring model for understanding art-science and interdisciplinary research as having a complex dialectical relationship with scientific institutions, where both secluded research and what he calls 'research in the wild' are necessarily related and dependent on one another and are both part of a successful 'technical democracy'. Callon sees hybrid forums as part of the demand for the 'democratization of democracy' (Ibid.). The 3D Print Club, and the *FlyFarm* project it fosters, coincides with Callon's studies of neuromuscular 'research in the wild', as the club began to form in person and over lockdown I was able to recongise an opportunity for such a hybrid forum to be brought into being.

I did not explicitly call it such a forum but carefully fostered and slowly developed the space for such a forum and space for art-science to emerge.

> hybrid forums take part in a challenge, a partial challenge at least, to the two great typical divisions of our Western societies: the division that separates specialists and laypersons and the division that distances ordinary citizens from their institutional representatives. These distinctions, and the asymmetries they entail, are scrambled in hybrid forums. Laypersons dare to intervene in technical questions; citizens regroup in order to work out and express new identities, abandoning their usual spokespersons. (Callon, 2009, p. 35)

Messy Methods John Law's explorations of 'mess' in method provided an early epiphany for embedded art-science and critical making having a role in inventive social science. Law bundles up some fundamentals like 'reality is socially or discursively constructed' (Bourdieu, 1996, p. 201) with feminist technoscience, making method central to the 'accomplishment' of scientific objective reality, rather than something 'out there, prior and waiting to be discovered' (Law, 2004, p. 6). Methodology is not simply the 'how' one knows or learns something but defines what it is possible to know, partially constructing the object of study. This helps delineate how kits bundle up ideas and practices and how with everything they include, they also necessarily *exclude*, *other* or *repress*. This underpins the explorations and arguments; the different patterns of what is included and excluded in kits, the invisible work that goes into them, the who, where, how and why of making can matter.

This is not always controversial or sinister, certain things excluded can just be not relevant or interesting. However artefacts and apparatus in maker culture emerge from often unacknowledged situated political and epistemological commitments. Bracketing off 'invisible work' and relations as externalities and reducing complexity can be necessary in many situations. But when learning about making kits and technology and the incredibly complex and messy world of worm gut-microbiomes and their undeniable relations to complex human and non-human practices, kit making methods might need to consider more. He describes a messy method and a method assemblage - complex assemblies of structures and configurations.

Auditing modules at BLS with these ideas lead to realisations of how the objects of study in many areas of microbiology, for example the study of *Leishmania*; the microbiota of the sandfly gut, the behaviour and life cycle of the parasite and its hosts,

are always partially connected to human practices and the biopolitical. The reason these parasites are objects of study at all is bound up in not only how they cause terrible suffering to human bodies but also in how the development of institutions for treating so called 'neglected tropical disease' in places like the Liverpool School of Tropical Medicine are connected to colonial histories of the slave trade (Shahvisi, 2019). In later discussions with Masters students I observe how supervisors call attention to the exclusions of what constitutes leishmaniasis as an object of study. Should the ubiquitous sachets of water for sale in many parts of West Africa be part of the study of epidemiology? Much of the understanding of the parasite and so the materials for teaching and intervening, are not only about microscopic human physiology or molecular structure, but extend to complex social practices and non-human mobilities. Having a garden full of stagnant water in potted plants, re-using mosquito nets for fishing, the exports of used car tyres harbouring mosquito eggs, sudden violence on infrastructure in war, all are multiple parts of insect borne diseases including their life cycle and gut biochemistry.

This leads us to consider seriously Law's *exclusions*, *otherings* and ***repressions***. In trying to understand the limits of method and what kind of *Other* 'messy' method could be, Law defines dominant Euro-American metaphysics: Independent, prior, definite, singular, constant, passive; 'realities enacted in Euro-American method assemblages are complex, but also that most aspects of that complexity are denied.' (Law, 2004, p. 145)

Law considers how reality is already 'crafted' and how one can use that *methodologically*, for him that means written vignettes, little stories that do the messy representation of the world for him when required. He goes on to list other representations, not as a metaphor, but as potentially useful ways of knowing and crafting knowledge:

> musical performances; surgery; sport; physical lovemaking; games; model-making... These then, are all crafted forms of presence. They do not ***have to*** be understood as allegorical methods of depiction ..But my point is that it is ***possible*** *to treat them that way* (Ibid., p. 146).

This potentially radicalises critical making, where the strategic selection of particular technoscientific objects to be critiqued and re-configured could lead to valuable social research and beyond that, political change, and part of what Chantal Mouffe calls counter hegemonic practice. The methodology of this research responds to Laws moves in STS toward 'artistic' social research and begins to develop a slow method for both discovering such relations and *intervening* productively. It commits to the *inventive* method for social research called for by Marres *et al.* (2018).

The Boundary Workers

> By reaching agreements about methods, different participating worlds establish protocols which go beyond mere trading across unjoined world boundaries. They begin to devise a common coin which makes possible new kinds of joint endeavour. But the protocols are not simply the imposition of one world's vision on the rest; if they are, they are sure

> to fail. Rather, boundary objects act as anchors or bridges, however temporary (Ibid., pp. 413-414)

My analysis of my research on the boundaries of art and science led to a resonance with Susan Leigh Star and James R Griesemer classic research paper on the Museum of Vertebrate Zoology at the University of california exploring how interdisciplinary tensions are managed by what they called 'boundary objects'; 'Boundary objects are both adaptable to different viewpoints and robust enough to maintain identity across them.' (Star and Griesemer, 1989, p. 387)

I adapt the boundary object loosely, not using all of Star and Griesemer's analytical toolkit, instead seeing similarities with many of the kits I discover, make and use in my research. What I do take from their work is understanding the role kits play in both revealing interesting practices and structures in both art and science in the study; that is, using them as a tool for thinking, and then using them to intentionally intervene in the study as tools for doing and making. I see this as a response to Star's original intention for them to be:

> ... a heuristic methodological category to think with as much as an ontological category of objects to think about, and also as a subversive concept blurring distinctions between methodology and ontology (Griesemer, 2016, p. 207)

My use of boundary objects leads to thinking of interdisciplinary practices as boundary work, acknowledging and exploring difference in configurations of disciplines and practices by making. In this way the kits developed are full of boundary *labour* gathering together different ways of working, materials, objects, methods.

> Often, boundary implies something like edge or periphery, as in the boundary of a state or a tumor. Here, however, it is used to mean a shared space, where exactly that sense of here and there are confounded. (Star, 2010, pp. 602–603)

The Radical Pedagogists

What can be hidden in considering 'practices' is how a practitioner gets to be part of that practice, how they learn. This research is fundamentally about exploring and developing strategic methods for collective learning. This makes theoretical work around learning theory important and in this section I describe what I learnt from the literature.

I began with polemical critiques of technology and power in pedagogy by the Philosopher, activist and Roman Catholic priest Ivan Illich (Illich, 1971, 1973) (Figure 19). Illich's critique of the pedagogical impact of the division of labour and development of specialisms and the repressive disciplinary aspects of education resonate with Foucault's micro politics. More radically Illich leaves Foucault's archaeological critique and makes passionate ambitious calls for the dismantling of educational institutions. He called for a re-think of education as an emancipatory social process in the tradition of another radical and critical pedagogist Paulo Freire. Illich's work demanding de-institutionalisation is clearly more revolutionary than

Figure 19: Image of a Deschooling Society pencil case designed by Boot Boyz (2020), as part of a series of products featuring canonical radical texts.

the radical pedagogy Barry and Born explore, which is a radicalism working within existing institutional structure. Maker models of education however share some of Illich's goals for new kinds of learning outside of educational institutions and what does stay with me throughout the study is an understanding of tools, and by extension, kits, in terms of their 'conviviality' to learning. I build on this later by thinking of the Critical Kits and Interleaving approach as building 'capacities' for knowing and caring.

My participation in 'Social Theories in Research and Practice' a module for educators at the University of Manchester, introduced the education related works of Pierre Bourdieu, Franz Fanon, Michel Foucault and Beverley and Etienne Wenger-Trayner some of whom I discuss further. I also consider some discussions around critical making in STS in the work of Joseph Dumit and Donna Haraway, constructivist learning in computer science with Seymout Papert and the 'tinkering' of maker culture the late Edith Ackermann considered (The Tinkering Studio, 2014).

Margaret Eisenhart in her journal article *Boundaries and Selves in the Making of 'Science'* (Eisenhart, 2000) explores the story of her experiences publishing the book *Women's Science: Learning and Succeeding from the Margins* (1998) in which she explored the barriers for women learning and progressing in science. In the paper she describes through a mix of reflecting on her own position and the wider practices, both material and discursive, how, in attempting to expand the boundaries of science and science education, inadvertently contributed to them. In my experience I made assumptions about my own and others art-science practice with respect to disciplinary boundaries without considering how much art-science may be involved in enforcing these boundaries.

In doing so Eisenhart describes an approach to social practice theory relevant to both STS and the learning theory I discuss in this section. Social practice theory opens up understanding learning beyond purely rational individuals as the unit of analysis; instead of the focus on individuals making rational decisions and choices based on interests, available information and moral and cognitive norms, the analysis looks to social practices; a focus on doing rather than thinking. They look at flows of activity instead of individual acts and collective consciousness and embodied interactions with others instead of individual deliberation or expression. It orientates learning researchers to material conditions and the dynamics and structures of how, where, when of people doing things together in the world. This perspective is important in developing my analysis of the established collective practices in DoES and BLS and the emerging practices of the NMC.

Eisenhart's approach to practice theory differentiates between a constructivist approach to understanding learning in science, like in the work of Piaget, Papert and Ackermann and the Sociology of Science in STS. The comparative table below quotes Eisenhart's explication of these differences which helped draw together STS, learning and social science for me in my analysis.

Table 2: Quotations from (Eisenhart, 2000, pp. 43–44) comparing her understandings of constructivists and sociologists of science through a practice theory framing.

Constructivists	Sociology of Science
'constructivists view science as a socially and experientially produced set of useful ideas about how the natural world works.'	'sociologists of science, along with some feminists and anthropologists of science, view science as a set of historical ideologies about how the natural world works.'
'science is not a fixed body of facts and theories but a set of ideas that changes over time as people produce new and more productive ways to observe and think about their experiences in the world.'	'science is neither a fixed body of knowledge nor an empirically tested set of good ideas but a 'technology' that tends to advance the interests of the historically powerful'
'science pedagogy is an exciting process of introducing students to natural phenomena, to ways of empirically observing and testing them, and to theory-building about them.'	'introduce students to the body of knowledge called 'science' and to social critiques of it: what is included, what is not, why certain things are left out or ignored, what might be different ways of thinking about science and conducting it, and so forth.'
'students encouraged to 'construct' their own ideas about the natural world based on their experiences and then to defend or modify the ideas in light of questions and challenges from others and their ideas.'	'students are encouraged to critique knowledge production and acknowledge how their own ideas are already constructed by societal norms and power.'
Features and Methods: 'Case studies of individuals, short biographies, and occasionally autobiographies have become popular methods of investigating what learners construct and how they use their constructions and revise them over time'	*Features and Methods:* 'Participant observation along with social, political, or literary critique.'
Social Practice Perspective: 'Ways in which we'***fashion***(the social constructivist part) social, political, and cultural discourses and practices'	*Social Practice Perspective*: 'The ways in which we are ***fashioned by*** (the sociology of science part) social, political, and cultural discourses and practices'

The Makers

There is a clear kinship between makers and scientists. Scientists and their origins as natural philosophers are in many ways the first makers, and in many ways act like the footsoldiers for the democratisation of science and technology (Ferretti, 2019;

Ingold, 2013; Nascimento and Pólvora, 2018; Ratto *et al.*, 2014). In the first visit to Rod Dillon's lab at BLS in 2015 prior to this study, I found many examples of maker and DIY practices even in a contemporary microbiology facility, which I recognise again and again in the interactions with Alexandre Benedetto, Dave Clancy and the BLS community (Figure 20).

Figure 20: DIY *Drosophila melanogaster* manipulation station in the BLS lab

Makers include many identities; hacker, scientist, hobbyist, artist, creative technologist, inventor, teacher, entrepreneur, engineer, IoT expert, developer, programmer, radical. Fundamentally across all these identities is the idea that anyone can Do It Themselves (DIY) making learning a core characteristic. The maker method is explored in its full specific complexity in the study, but can be simplified as learning by doing and experiment.

Seymour Papert was an educator in the constructivist tradition and a popular figure in maker culture. Constructivism is partly the experimental educational

tradition pioneered by teacher and philosopher Jean Piaget who explored young children's developmental learning, how they play and test the boundaries of their reality. Papert's *Twenty Things To Do With A Computer* (1972) is an important essay and series of ideas for teaching computer science to both young people and adults. Instead of teaching the formal abstractions of object orientated programming, the core approach to popular contemporary programming languages like Python and JavaScript, he developed a set of human readable instructions for drawing and interacting with simple virtual objects in the LOGO programming language, descendants of which are still used in computer education today. Simple instructions are setup; up, down, left and right, to move a virtual animal avatar, a turtle, so many 'steps'. The learner is then left to experiment with the avatar tracing out all kinds of patterns. What patterns of movement can be generated? How can one repeat instructions and iterate them with simple maths? The learner is encouraged to experiment, test and fail slowly *constructing* their understanding of the system and how it can be controlled or given a degree of autonomy. Reading this in the 21st century one is struck by its similarity to many introductions to programming languages in maker culture such as Arduino, Processing and Python. Indeed online lesson plans for the BBC's maker platform, partly developed with the Raspberry Pi Foundation, the *microbit* I use as an early kit and boundary object to kick start what would became the 3D print club, are remarkably similar to Papert's approach to learning through doing (Figure 21).

Another key practice of makers, in the Piaget constructivist tradition is the so called 'tinkering' of maker culture and STEM and STEAM learning. The *Tinkering Studio* is a makerspace and design studio located in the Exploratorium museum in San Francisco, California, arguably the spiritual commercial home of maker culture, and is dedicated to this idea ('The Tinkering Studio Exploratorium', 2000). Tinkering is about imaginative making with diverse existing materials often featuring small quantitative changes that can lead to sudden qualitative leaps. It's a material imagining, thinking of an idea but then grabbing the tools at hand to explore them. Some tools and materials need adjusting 'tinkering', some new practice have to be developed, it can be quick, it can be thought of as related to rapid prototyping, but it can also be a slow emergent potentially endless process. In maker spaces tinkered prototypes can stick around far beyond the life of the final projects they may have been assembled for and picked up again by other makers. This practice is also essential to the concept of the makerspace, things are left lying around, partly due to pragmatic repsonses to lack of storage but also to feed future imaginative labour.

Tinkering studio hosted a compelling conversation to camera with the late Edith Ackermann, at Liverpool John Moores University (LJMU) in 2015, shortly after my work there with LJMU OpenLabs, DoES and the open-source software festival I volunteered on, OggCamp.

A developmental psychologist at MIT and, like Papert, protégé to Piaget, Ackermann discusses tinkering and making but then differentiates scientific and artistic approaches to creativity by discussing how she understands 'play'. She presents a nuanced understandings of the fundamental difference and convergence of creativity in the playfulness of art and the curiosity of science but also offers a warning about 'bitter pills' of critique.

Figure 21: Prototype using microbit and 3D Printed LED Lamp for workshop in 2018 which led to the development of The 3D Print Club at the Neuromuscular Centre

> You cannot just use play or fun as a pretext to teach an otherwise bitter pill that they have to swallow... The most importance thing to me in playfulness is that it is a counterpoint to curiosity. And I think, especially scientists, think about learning is that they always think that it is important to be curious. And curiosity has to do with becoming intrigued when whatever you do, doesn't correspond to what you thought it was supposed to do, and you backtrack, in a way, to understand the reasons. Now playfulness is something different. Playfulness is about allowing yourself to leap; its about not to dig deeper in the hole to better understand where you are going but just to jump sideways to look at things obliquely as if you knew that when you do that you may come to see things anew... in playful environments you feel safe enough to explore ideas that would otherwise be risky. (The Tinkering Studio, 2014, from 0:32)

Maker kits, and the open-source practices that characterise some of them are all essentially extensions of this constructivist low barrier approach to learning through play. This interest in play is also related to Ackermann's notion of risk as a large part of maker culture. My first major work embedded in maker culture, *Public Engineering* (Brinkmann *et al.*, 2014) was based, like many group projects, around an elaborate game featuring robotics (Figure 22) and DIY versions of manufacturing process, offhand playfullness imbued with a sense of radical agency and empowerment for their participants.

Arduino, Raspberry Pi, ESP8266 are all ubiquitous maker platforms for play with technology. A vast entrepreneurial maker market exists constantly developed and used and modified by makers globally with companies like Ladyada and Pimoroni and JLCPCB supporting them. What all these platforms promote and commodify is maker agency; the partial opening up of Black boxes I described earlier through maker Cefn Hoile's *Shrimping.It* decontructed Arduino. These platforms, especially Hoile's intervention, promote the fludity and love like Mol and De Laet's Zimbabwe Bush Pump, Illich's conviviality and represent an opportunity to access the means of production of making. The Shrimping.It carrier bag platform was the economic base for my art-science project *ShrimpCraft* project exploring IoT and freshwater science with young people over 4 years across the North West of England key to my embedding in maker culture and economic sustainability of my self employment.

Landscapes of Practice

Learning theorists Etienne and Beverley Wenger-Trayner's work, return us to the importance of making boundaries in learning. They provide convincing metaphors that help understand my obsevations and were influential on my focus on practices as a unit of analysis. They observed in a range of settings and in some key works, the shifting 'regimes of competence' across the boundaries of 'old-timer' and 'newcomer' identities that make up a 'community of practice' all of which resonate with and are confirmed by many of my observations in my research.

> Learning in a community of practice is a claim to competence: it entails a process of alignment and realignment between competence and personal

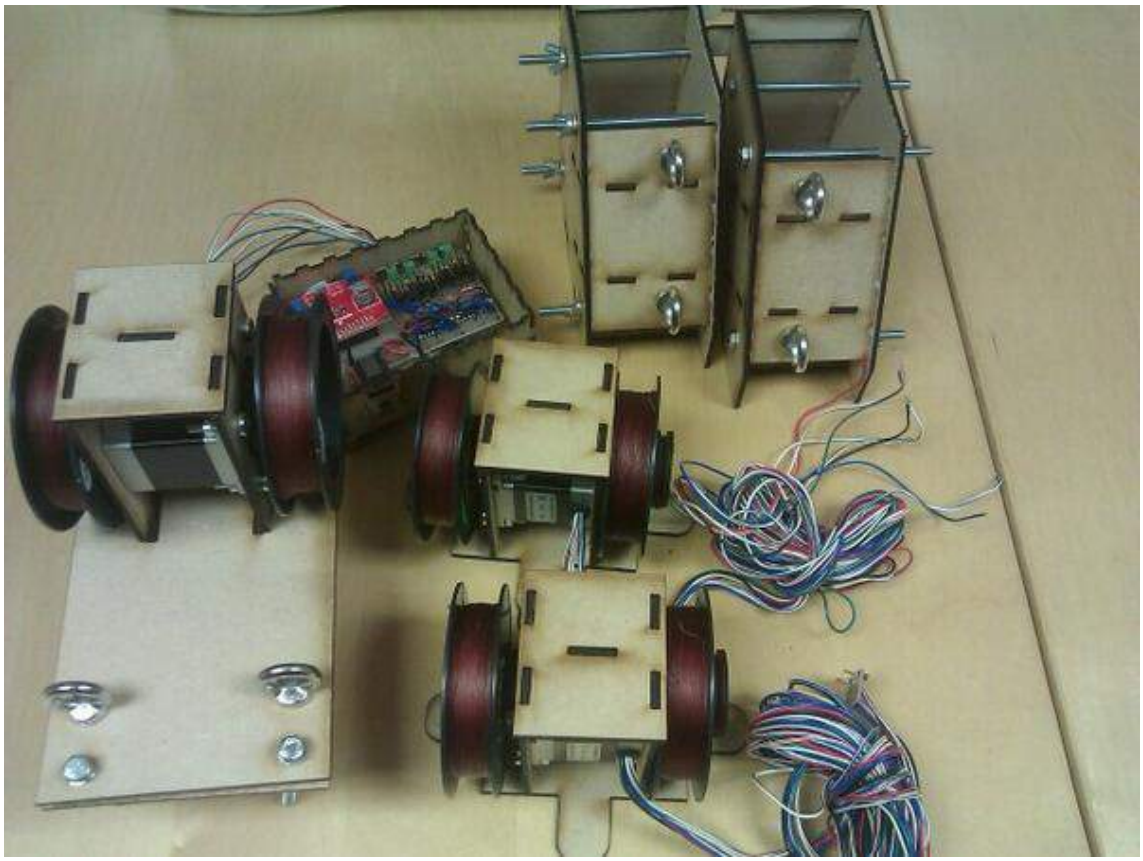

Figure 22: Image of lasercut stepper motors and pulleys for a tri-lateration crane used in the *PublicEngineering* project (Brinkmann, Dalziel, Laurenz and Fenner, 2013)

> experience, which can go both ways. When newcomers are entering a community, it is mostly the regime of competence that is pulling and transforming their experience – until their experience reflects the competence of the community. (Wenger-Trayner *et al.*, 2015, p. 14)

Wenger-Trayner's descriptions of boundary making, a kind of social *crafting* John Law talks about, are very useful in developing my sensitivity to practices. In the 3D Print Club case study this allows a sensitivity to the social work of shifting practitioner identity; how newcomers to 3D printing become competent oldtimers, how they become a community and develop productive boundaries.

> Boundaries of practice are unavoidable. A practice of any depth requires a sustained history of social learning, and this creates a boundary with those who do not share this history. Boundaries of practice are not necessarily formally marked, but they are unmistakable. Spend your lunch break with a group of computer geeks and you know what a boundary of practice is: you can't make sense of what they are talking about or why they are so passionate in talking about it. You might as well have landed on another planet... At the same time, boundaries hold potential for unexpected learning. The meetings of perspectives can be rich in new insights, radical innovations, and great progress. (Ibid., p. 17)

This adds nuance to the radical pedagogy, shifting registers and 'new subjects and objects' that Barry and Born observe allowing fine grained analysis of the crafting of interactions in the study. The spatial sense of practice also allows for multiple identities and collectives to interact and lead to a key realisation of how disciplinary boundaries in my research and practice are not breached or crossed but are landscapes and structures to be traversed and negotiated:

> Rather than hiding boundaries under an illusion of seamless applicability across contexts, it is better to focus on boundaries as learning assets... The principle is to systematically make boundaries a learning focus rather than assuming or seeking an unproblematic applicability of knowledge across practices. (Ibid., p. 18)

Interleaving Practices

The phrase and conceptual content of *Interleaving practices* which was developed from these reflections on literature and data in the study is actually already a part of learning theory, at first a disconcerting coincidence and then reassurance that what I have observed happens elsewhere. Interleaving practices is a method of learning, originally applied to studies of physical learning with basketball players but more recently in the study of cognitive learning in mathematics and geometry and grammar by Kelli Taylor and Doug Rohrer. An easy read summary is in the table below

> Interleaving Practices here refers to the advantages of learning many things at the same time - in contrast to "blocked practices" ... a heuristic of learning things one at a time, as if singular and seperate... interleaving improves discriminability. That is, because interleaving requires participants to repeatedly switch between different kinds of tasks, they must

learn how to pair each kind of task with its appropriate procedure (Taylor and Rohrer, 2009, p. 845)

Table 3: A comparison of Interleaving and Blocked Practice in Taylor and Rohrer's article

Interleaving Practice	Blocked Practice
Challenging, overwhelming	Easier to cope, methodical
Discriminate early to build relationships between activity	Ignore other practices until mastering one, hard to see relationships later.

The basic approach, is to learn potentially confusing or conflicting concepts and activities all together rather than the 'blocking' that can occur by learning skills one at a time. Learning everything 'all together', builds up the cognitive ability to differentiate and make and understand boundaries. It takes a leap of faith that learners can cope with this. But in reality we cope with that everyday. Coping mechanisms of boundary making around tasks and then instead of jumping across them, interleaving them with each other and building relations becomes an educational opportunity.

In this study however, interleaving is not concerned with the individual cognitive subject's efficient learning and is more concerned with the social practice approach but there are significant overlaps and it is easy to observe in the data that much interleaving of this kind is going on. Interleaving Practices is developed in this study into a complex tactical and strategic approach to collectivity in social science and art practice. What remains relevant from Taylor and Rohrer is how 'spacing' works in the observations of temporality and 'distractions' in DoESLiverpool and the 3D Print Club, where the space between tasks, their temporal arrangement, was important. 'Talking Rubbish', 'getting up in the morning', 'getting distracted', 'strategy' are spacing related codes that emerged in the initial analysis of the observations of making together. These 'distractions' are important parts of the social work of embedded art practice. Spacing also implies a lack of activity or break but in my study it is also a shift in mode, attention or register, useful to analysing the layered temporalities at work making collectively in case studies 3 and 4 in DoESLiverpool.

CHAT, Social Capital and Disciplining the Disciples

Vygotsky's dialectical approach to learning, that is, the complex understanding of activity and structure through interdependent relations, through his Cultural Historical Activity Theory (CHAT) (Roth and Lee, 2007), resonates with the relational view of the life sciences I explore in the 'Dialetical Biologist' section of The Interleaving Practitioner Chapter. CHAT helps reflect on the complex relations of microbiology and my observations of how learners approach this in BLS. Roth and Lee, in their reappraisal of CHAT, use a compelling visual in their paper, of threads made up of woven fibres that make up rope like structures in order to describe dialectical relationships, seperate, yet always related to each other, a unified opposition (Figure 23). This informed the development of the idea of interleaving in early conceptualisations,

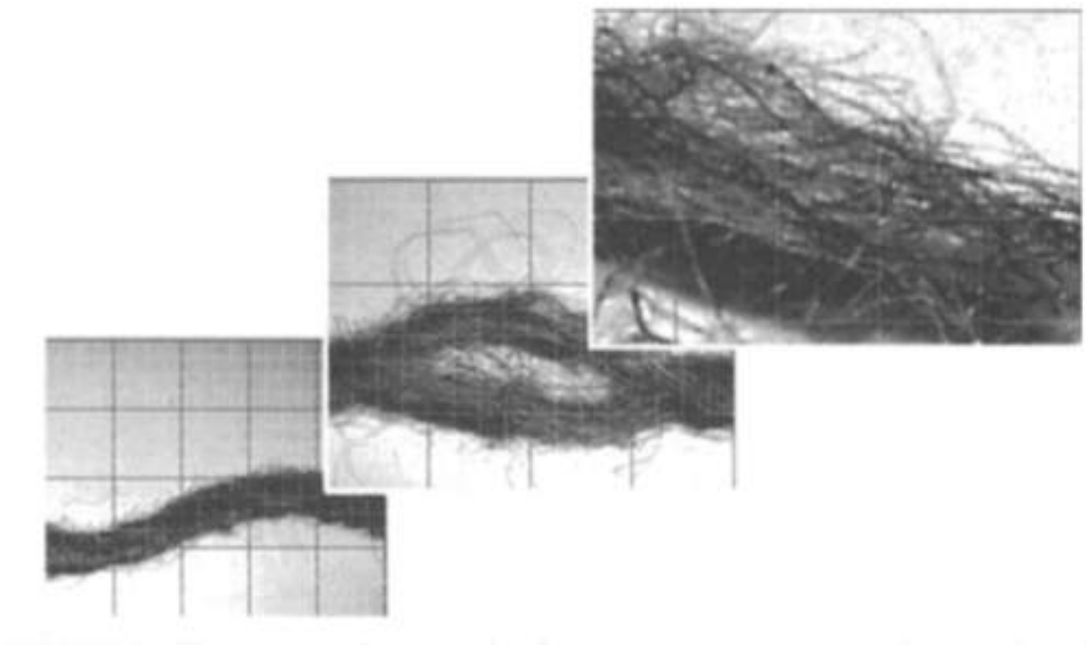

Figure 23: Figure from the article *"Vygotsky's Neglected Legacy": Cultural-Historical Activity Theory* (Roth and Lee, 2007)

Figure 24: Image playing on the Vygotsky article image, exploring the concept of Interleaving with the *leavening* practice of bread making

playing on the process of *leavening* in the making of one of the earliest technologies, bread (Figure 24).

Bourdieu's concept of social capital (Bourdieu, 1986) and how it circulates helps develop my understanding of unacknowledged class privilege and power in art and maker culture, while Franz Fanon's psychological and political perspectives (Turner, 2011) became useful in extending understandings of power and ongoing coloniality in a post-colonial world. This casts the crafting and reproduction of concepts like 'endemicity' in so-called 'Global Public Health' and 'Neglected Tropical Disease' as potentially damaging leading to other literature in my research (Richardson, 2019; Shahvisi, 2019). Fanon and wider post-colonial literatures and subaltern critique (Spivak, 2010; Young, 2001) make seemingly innocent DIY Bio kit making require far more critical perspectives. Well meant exciting solutions naturalise structures of power.

Critical Making

Figure 25: Image from participants of the *Critical Kits Symposium* (Dalziel *et al*, 2016) reviewing artist and maker kits

> why does critical thinking seem to make such sense and critical making seem to be so dissonant? My assumption was, and I've built a career on that assumption, that it's because we think of thinking and criticality as primarily a linguistic activity. And we think of making or material engagement as an habitual, a cognitive at best, if not anti-cognitive process. So, critical making turned into a research program, not a process or method. A research program exploring that specific aspect: why we don't think of 'making' as conceptually sophisticated and potentially critical, or at least informing criticality? And how would we go about creating academic work, pedagogy, among other things, that took as a starting point a more

> committed engagement with the material, specifically around technology? (Ratto, 2017, p. 92)

Critical making, is a key method in my art practice and in the Critical Kit portmanteau concept building on participatory workshops at the symposium in 2017 (Figure 25). Partially situated in STS literature, critical making is a phrase coined by researcher Matt Ratto (Ratto *et al.*, 2014) and used widely by other researchers working around maker culture, such as Garnet Hertz (Hertz, 2012), and in the field of Human Computer Interaction (HCI) such as Paul Dourish (Dourish, 2001).

Critical making can be understood as the implementation of many of the core STS conceptual tools; an understanding of how technoscience is historically and socially constructed and configured discursively and materially, that it is not exempt from ideology and power relations, performativity; the idea that theory and method partly construct the objects of research.

'Critical Kit Making' embedded in the situations of the study became the basis of my research through practice method, informed by this review. As this shifted in the course of the analysis, and the *Interleaving Practices* framework emerged, Ratto's widening out of critical making as a set of 'commitments' in practice, helped me think about the implications and the results for this study. Listening to Ratto, I hesitate to fully *define* a critical making method; messy or otherwise; just as Barry and Born's logics are not exhaustive. Instead for this thesis, critical making is presented as a tactical 'mode' of working in the Interleaving Practices methodology which contributes to Ratto's research program.

Making The Implosion One response to making critically is to *include more* - a basic intuition. In the symposium where the study originates artists want more from their kits and makers from DoES wonder if they should be much harder to use if this might exclude some people from the challenge. Joseph Dumit in his essay 'Writing the implosion' (Dumit, 2014), describes applications of Donna Haraway's STS methods in workshops and teaching. These 'implosion projects' are writing methods where 'everyday' objects of technoscience are written about in such a way to unravel a mass of entangled rhizomatic relations, networks and histories in objects like computers or the contraceptive pill 'How Is the World in "It" and How Is "It" in the World?' (Ibid). Taking this principle, participants write and re-write relations resulting in 'implosions' of thick description of the materials and invisible work that make up technical objects. Rather than exploding objects orientated to their potential affordances, that is, what they can do, these are complex implosions of internal contingencies. What happened to make this object the way it is? Who benefits? Methods like these resonate with my making practice in the same way as Latour's networks and Law's more generous methods. Ratto's and others critical making projects *make implosions* and point to a radical pedagogy based on a form of Art as STS method.

This is a powerful method explored in the case studies but causes problems; tracing out relations with ANT like implosions and ethnography is potentially inexhaustible and exhausting. Tracing this kind of complex material histories of practices in this way produces rich material for making emerging kits in my research. Part of the practices observed at DoES and incorporated in my method, is the documentation of projects

on the open-source project management platform GitHub. In my observations GitHub issues are writing practices for managing such implosions in the day to day development of technoscience. Later I describe how I exploit this practice in a workshop for learning how to design and build printed circuit boards (PCBs) (McEwen, 2020) where files for digital fabrication sit alongside complicated narratives and tools for mapping energy toxicity, distribution networks and labour relations.

The Organic Intellectuals

Marxist materialism

I understand Marxist material analysis (Marx, 1974), as foundational to critical theory and the critiques of STS, social science, learning and political theory. Broadly, from Marx and his interpretors (Harvey, 2018; Jameson, 1991; Wark, 2015), I follow a foundational materialism that runs through STS and the key learning theorists I described above. These literatures seek to historicize and unravel the social relations in technoscience, learning and kit making; placing them firmly in material and bodily history and part of material and discursive processes and complex historical and ongoing social practices.

Marx understands the social primarily, but not reductively, through historical economically determining structures that manifest as naturalised 'just-so' stories of how the world is organised but elide powerful class interests. These interests positions groups socially and materially in relation to each other, driving them to not only defend and reinforce those positions but *think* and *do* from them. This is useful in considering the position of myself as a researcher and my research participants and underpins the *Who benefits?* critique of feminist technoscience and STS. It also supports along with other post-Marxist or even anti-Marxist thinkers like Foucault, interesting political theory of new class formations in the work of Maurizio Lazzarato and Mackenzie Wark. Lazzarato explores fascinating power relations and novel coalitions in his description of the struggles of casualised and precarious culture workers in neo-liberal France 2004-2005 in his book *Experimental Politics: Work, welfare, and creativity in the neoliberal age* (Lazzarato, 2017) and offer a compelling understanding of how different political formations offer opportunities for change which informs some of my political conclusions. Another creative Marxist, Wark, in *Capital is dead* (Wark, 2019) posits new formations such as the vectoralist class, a new ruling class that control the specificities of the control of advanced capitalist data platforms. They then speculate on the revolutionary potential for data labourers that support those systems, with significant overlaps with the hardware and software workers I observed in DoESLiverpool and wider technical culture.

Marx's theorising of commodities and value creation, where the 'real' cost of labour and its effect on the metabolism of the earth, is elided and excluded, which then determine the extractive labour practices of capital is fundamental to asking troubling questions in my research like *Why are LEDs So Cheap?*. Wark also connects up nuanced histories of the implementation of Marxism in *Molecular Red: Theory for the Anthropocene* and contextualises the historical materialist threads of Haraway's work and her student Paul Edwards (Edwards, 2010) who provide further historical

perspectives on the technoscientific materials maker culture is built upon.

Marxist theory draws attention to how we are in relations with the world, and how those relations commodify, exploit, naturalise, produce and reproduce the world; the how, when and where and in whose interests. It contributes to an understanding of the ongoing contingencies and contradictions of advanced bourgeois society which are necessary for both Maker culture, technoscience and democratic interdisciplinarity to exist and offer up their innovative means of production to the possibilities I explore in the study.

> artistic practices play a role in the constitution and maintenance of a given symbolic order, or in its challenging, and this is why they necessarily have a political dimension (Mouffe, 2013, p. 182).

Ernest Laclau and Chantal Mouffe have a post-Marxist understanding of political strategy and an account of the political that develops and makes central Antonio Gramsci's idea of hegemony (Laclau and Mouffe, 2001). Gramsci, the Italian Marxist philosopher and former leader of the Italian communist party was famously imprisoned by the fascist forces of Mussolini at the beginning of the 20th century. In prison he made important contributions to political theory that continue to resonate today (Gramsci, 1992), and was particularly influential with respect to strategy, where hegemony plays a central role in a terrain of struggle. Hegemony can be translated literally as 'leadership', and put simply it describes how a set of social and material practices that include cultural norms and values and ways of understanding the world become dominant, in such a way that they become naturalised, intuitive and a kind of common sense. In order for this to happen other ways of thinking and doing must not only be excluded, an important part of STS perspectives, but actively fought against, defined as opponents and denied. In Mouffe's conception particulary this process is necessarily incomplete and part of a constant *struggle* for hegemonic dominance, just as important as class struggle which both Laclau and Mouffe complicate in their strategic orientation toward socialism and emancipatory struggle. Hegemony is not necessarily a singular position and can involve multiple coalitions and viewpoints; one could compare it to both the formation of dominant *imaginaries* and *situated knowledge* in STS. But what Mouffe would place at the centre of the inclusions and exclusions of STS and its multiple *Who benefits?* questions of the social is *antagonism.*

Mouffe, in her book *Agonistics: Thinking the World Politically* (2013) insists on the creative and democratic importance of a 'radical negativity' to any idea of 'the political' which she seperates from both 'politics' or broader notions of parliamentarianism. She takes the position that any social order is fundamentally precarious and contested, with different conflicting viewpoints and interests in antagonism. The political and its subjectivities, what politicizes subjects and people, for Mouffe must be actively constructed and not just organised. This takes place within an ensemble of social practices and discourses. She would understand design as a practice where conflicting processes work against each other until a particular arrangement asserts itself and aligns with Hirsch's approach to contestational design discussed earlier

For Mouffe, art is one part of a terrain of struggle and its role can be either as a counter hegemonic practice, or conversely, a role that reinforces prevailing hegemonic social orders. She considers whether 'an agonistic conception can help artists to theorize the nature of their interventions in public space? What can be the role of artistic and cultural practices in the hegemonic struggle?' (p. 14). Although Mouffe acknowledges the complexity of this terrain, her conception of art's reach beyond small scale tactical interventions is underdeveloped. However her strategic orientation, having to acknowledge limits and struggle, resonates with Haraway's recent popular refrain of 'Staying with the trouble' (Haraway, 2016). Recently Haraway partially contradicts and modifies this strategy more explicitly in an antagonistic turn, in the

recent film made about her life and work by Director Fabrizion Terranova: 'We do have to practice war: we do have to be for some worlds and against others.' (Haraway in Terranova, 2017). Barry and Born also invoke Mouffe in their 'agonistic-antagonist' mode of art-science. Mouffe insists on the impossibility of a final consensus where all conflicting opinion is resolved; that there is no 'final ground', a foundational 'base' where all thought is in harmony, and that this is a key element to democratic possibility. This problematizes Callon's hybrid deliberative forums, but usefully adds the language of struggle and demands, countering Callon's more technocratic, procedural language.

Mouffe's conceptions play a key role in the political conclusions of the thesis. Interleaving Practices contributes to inventive methods for art and social science and could be used as part of an ongoing strategic counter hegemonic struggle. Her explicit approach to positions and manoeuvres in the narratives of reality adds direction to the more rhizomal, network based approach of STS.

Affect, Solidarity, Cognition, Shared Material Interests

Jeremy Gilbert is a Professor of Cultural and Political Theory in the tradition of conjunctural and cultural analysis of Stuart Hall and various arrangements of New Lefts, at the University of East London. A student and critic of Laclau and Mouffe, in diverse prolific output including commitments to political education outside the academy, he summarises and explicates a range of radical left political theory most usefully in his book *Common Ground* (Gilbert, 2014). He uses these perspectives to inform approaches to collective democratic action to counter the dominance of individualism characteristic of our neo-liberal historical conjuncture.

Neo-liberalism is a complex historical turn in post World War 2 society, political economy and economics characteristic of the past 50 years of advanced late capitalism. This particular and peculiar forms of neoliberal governance across the globe have contibuted to diverse but dominant patterns of the construction of individualistic subjectivity that builds on the birth of the bourgeois subject at the very beginnings of modernity. Wendy Brown (Brown, 2019) argues powerfully for the connections between this subjectivity and not only a disavowal of the social, in the case of liberal polemicists like F.A. Hayek, but the denial of its very existence, in the case of Thatcherism. Brown considers the idea of the social as not a problematic topology like Latour, but fundamental to not just 'social science' but to any sense of justice or possibility for challenging the power relations that critical theory tasks itself to account for.

Gilbert persuasively argues for a strategic re-orientation toward democratic collectivity, across an ecology of fields of practice. Like Mouffe, he favours agonistic approaches to counter the hegemony of de-politicised neo-liberal individualism by focussing on the social and what he calls the 'non-fascist crowd' (p. 99). Particularly relevant to this study in addition to providing key outlines of radical political theory, is his discussion of Mouffe's call for agonistic art practices, Nicolas Bourriaud's *Relational Aesthetics* and Claire Bishop's critique of participatory arts (Bourriaud, 2002; Bishop, 2012).

In Gilbert's account, Bishop takes up Laclau and Mouffe's agonistics and makes

the critique that Bourriaud's relational art denies the democratic importance of the antagonistic. Being relational in art projects for Bishop can lead to staged communitarian celebrations of the rather banal social fact that people are different and think differently. Both Mouffe and Bishop argue for the importance of setting up radical spaces for embodied democratic dialogics and contestation, not just friendly get togethers for people who like novel cultural activities. For Gilbert, Bishop overlooks the nuance of Bourriaud's vision that resonates with what Gilbert sees as the creative possibilities for an 'infinite relationality' (Gilbert, 2014, p. 111). He argues that even antagonistic counter hegemonic approaches must not only encourage dissent, but also open up new productive possibilities for collective decision making. Gilbert goes onto critique Mouffe's assertion of dissent and radical negativity in art as counter hegemonic practice, for its lack of strategic ambition; 'either to tell its audience anything it didn't already know, or to engage in forms of productive relationality which might actually effect some long-term cultural change.' (Ibid., p. 191). He also counters his own view of infinite relationality as being reduced to endless 'tactical' discursive performances of relationalities and deconstruction of identities which actually contains and limits the possibility for political decisions, demands to be made or interests to be defended. Gilbert, in other work, re-orientates Mouffe's agonistic tactics to strategy by a few interesting moves. He considers that a more fundamental Marxist logic of popular shared material interests cannot be ignored and point toward novel solidarities and class formations (Gilbert, 2018) explored in detail by Maurizio Lazzarato's experimental politics which Gilbert and his colleagues are instrumental in translating and widening awareness of (Lazzarato, 2017).

I owe much to Gilbert's approaches to political education in this literature and his diverse podcasting projects. They are useful in my analysis of affect in the collective making in the 3DPrintClub at the NMC and their potential as strategic democratic spaces for collective dissent and affective methods for collective action.

Organic intellectuals

Gilbert's overview of arguments for the primacy of collectivity over individuality, from Judith Butler to Hannah Arendt contextualise and modulate the evaluation of the potential of the methodological conclusions of this study. He critically weighs and balances nuanced arguments around Mouffe's recovery of a Gramscian conception of artists as 'organic intellectuals'. This idea resonates with my observations of makers and life scientists acting intellectually and politically without ever articulating explicit political subjectivity. Their intimacy with theory-practice in their bodily and material interventions means their roles as intellectuals are always embedded in organic growing relations. Makers in the study from this perspective act as material activists, challenging how technoscientific objects are constructed, particularly when responding to the shifts around lockdown in the Wearable Technology Group at DoES, and the 3D Print Club.

STS theories of care, resonate with this. Let's return to Maria de la Bellacasa's challenge to Latour's approach to scientific facts as 'accomplishments' and 'matters of concern', instead demanding 'matters of care'. This demand builds on the dimensions of care put forward by political scientist Joan Tronto, 'everything that we do

to maintain, continue and repair 'our world' so that we can live in it as well as possible.' (Tronto 1993 p.103). Bellacasa explicates the basic STS question asked of technoscience, *Who beneftis?* and asks also, ' "Who cares?" "What for?" "Why do 'we' care?" and mostly, "How to care" ' (de la Bellacasa, 2011, p. 96). Her response is to be specific to 'ways of knowing on the ground' (p. 101). I keep this care orientation in the development of and my sensititivity to the 3D Print Club which as I write this, continues to care for itself beyond this research.

In the study life scientists are clearly committed and open to complex relationality. Interactions in the study reveal how teaching the life sciences can be a crucial space for critiquing the political shape of the world, particularly the vast complex challenges of care and concern in the anthropocene, the geological epoch most defined by human activity and often invoked by STS. Makers and life scientists deep intimacies with extracted materials and the non-human which include forms of care are a powerful, yet arguably untapped, political resource.

> The way in which caring matters is not reassuring. It doesn't open the door to a coherent theory, or to the comforting feeling that worries about technoscience would be solved... Care eschews easy categorization: a way of caring over here could kill over there. Caring is more about a transformative ethos than an ethical application. We need to ask 'how to care' in each situation. (Ibid.)

This Conjuncture

Conjunctural analysis is a method from post-Marxist cultural studies, developed by post-colonial political and cultural theorists such as Stuart Hall. The conjuncture allows analysts to consider intersecting historical and social developments across disciplines and ways of knowing, often seperated in other historical accounts. Economics, technology, media, the social, politics and subjective, affective and psychological aspects can be thought of together to form specific explanatory, even predictive, shapes of historical conditions and formations.

This complements the implosions of Haraway and in assemblage theory later in analysis, the understanding of the conjuncture of art, biology and maker practice of the study. Conjunctures help understand the limits and possibilities for DIY Bio and Bio Art while understanding the difference between *micro*-political *tactical* interventions and *strategic* moves that lead to *macro*-political movements that require active organising over longer periods of time. Radical possibilities could include the democratisation of access to the manipulation of living material beyond the 'control' of state institutions with the potential to open up powerful social enclosures like the pharmaceutical and biomedical industry to democratic social movements, public knowledge, debate, public experimentation and critique.

However the recent conjunctures of 2020 in the COVID-19 crisis, mid way through the study, catapulting biotechnology kits into every home in near every middle income nation state of the global north, have a real sobering affect on the reach and scope of the tactical art-science workshops symptomatic of my recent work (Dalziel and Hoile, 2016). However in my research I observed a fascinating response from DIY Bio and maker culture communities globally and local to the study at DoESLiverpool which

I explore in the case study, Interleaving Biomaterials. Understanding conjunctural arrangements and conditions and these recent events in the study point out the strategic limitations of tactical interventions. To go further they need all kinds of complex organised and sedimentary arrangements which contribute to my conclusions.

The Assemblagists

> . . . concern is no longer with what bodies or things or social interactions are, but with the capacities for action, interaction, feeling and desire produced in bodies or groups of bodies by affective flows (Fox and Alldred, 2015, p. 402)

I will finish with the final practitioner identity taken partly from Ghoddousi and Page; the *Assemblagist* (2020). I think of Assemblagists as practitioners that gather together many of the diverse sets of theorertical resources I have discussed in this chapter. The technoscientific kits I discuss in the thesis through the literature described in The Practitioners are understood as highly complex gatherings and interleavings of historical, material and immaterial components that can be grasped by describing them as an assemblage. The Assemblagist is a *speculative* practitioner made up of many of the identities and some of the literature this chapter has explored.

I understand the assemblage as a concept and approach to social ontology used in STS and many others in the humanities. Theoretically I trace its rhizomatic roots through Actor Network Theory, mess in method and configuration to the wildly ambitious and unwieldly work of the philosphical and political theorists Gilles Deleuze and Felix Guattari. A full summary of their projects are far beyond the scope of this study. However aspects of their work, particularly their understandings of molecular and molar political change, affect, scale, structure and relations seem indispensable in complementing STS perspectives on technoscientific practice, method and affect in this study.

Their interest in the natural sciences in concepts like the rhizome seem fitting for analysing and developing an art-science practice. I look primarily at their conception of assemblage and their concepts of *desire* and *strata* in *A Thousand Plateaus* and *Anti-Oedipus* (Deleuze and Guattari, 1983; Deleuze, 2001) and lean heavily on Ian Buchanan's archaeology and understandings of their work alongside diverse yet specifically relevant interpretations and mobilisations of their philosophical and political project. I non-comprehensively review some interpretations of Assemblage Theory, selected by my perception of how they responded to emerging concerns in the study. Three particular authors and approaches stood out from my perspective in Assemblage Theory most relevant and formed productive relations with STS work. Initially Manuel De Landa's theoretical elaborations *A new philosophy of society: assemblage theory and social complexity* (2006) seems to complement ANT like approaches, while Pooya Ghoddousi and Sam Page in their short paper on Assemblage Ethnography (2020) offer examples that resonate with my approaches to ethnographic method and participatory reseach. Buchanan's clear introduction *Assemblage Theory and Method : An Introduction and Guide* (2021) crucially offers an often polemical and scathing critical review of other versions of Assemblage theory backed up by some interesting examples of Assemblage theory in action.

I must stress that this review and invocation of Deleuze and Guattari's work has slowly emerged in analysis and discussion of my research and case studies. This developed and consolidated my perspectives on social ontologies, while Gilbert, key to my political speculations and a committed Deleuzian prompted my own implementation of their work producing a resonating critique of STS perspectives on social structure.

John Law acknowledges the similarities between Deleuzian *assemblage*, a partial translation of the french word *agencement*, and his work with Latour and Woolgar on actor-network theory (Law, 2008). As I described at the beginning of this chapter, ANT powerfully informed my use of ethnography and early on in the study, triggered a minor epiphany from Law's messy manifesto (Law, 2004) finding a body of approaches to method that resonated with my practice. Latour's scientific black boxes and inscription devices and other non-human agency and a relentless critical agnosticism for the sites of the social inspired my approach to analysing the social formations I have observed 'in the field'. However in Buchanan's perhaps, unwarranted, but convincing critique of Law, he argues that mess in method potentially collapses all things difficult to capture by social science into the big 'Other' of infinitely relational mess leaving an ultimately fleeting allegorical realism.

Deleuze and Guattari's work also differs from Law et al. in their pursuit of complex reality without analogy and pre-supposition, despite often describing the social world with all kinds of confusing multi-disciplinary terminology that threatens to contradict this ambition. They attempt to use concepts from the natural and life sciences like the 'rhizome' to understand the complex gatherings of material and immaterial, without being only metaphorical, analogous or allegorical.

Buchanan elaborates further, arguing that ANT and other 'rhizomatic' post structuralist materialist approaches such as De Landa (De Landa, 2006) restrict the properties of an assemblage only to the emergent dynamics of the material they are made up of. For Buchanan, there is no convincing account of intentionality or affect. If an actor-network's relationality is all that gives any shape or direction to anything like the intentionality or agency Latour affords his human and non-human actors then this seems like a problem. Latour's critical post humanism, a commitment to a flat topology of emergent moving relations is compelling, especially in its radical consideration of non-human agency and disavowal of reified distinction between the social and the not-social. What is unclear is exactly what that agency is, could or should be. This resonates again with Bellacasa's understanding of care, important later in this study. Remember for Bellacasa, Latour's agnosticism as to where agency might reside is detrimental to not only the direct accountability that so many 'progressive' political projects depend on, but in the very constitution of agency in his non-human actors, a key part of the ANT ontology. To 'Follow the actors' as Latour in entertaining meta conversations encourages us to do, (Latour, 2005, pp. 141–156) must mean understanding what is driving their agency and for Deleuze and Guattari's assemblage, that is the idea of *desire*

Productive Desire

For Deleuze and Guattari, desire and the concepts of *desiring-machines* and *desiring-production* must be understood in the context of their philosophical project which Buchanan descripes as a 'theoretical rapprochement between psychoanalysis and Marxism' (Buchanan, 2008, p. 39). They attempt to develop a materialism in the tradition of Marx with his understandings of social relations of production and a psychoanalysis in the tradition of theorists such as Freud and Lacan, or as Buchanan puts it 'establishing an effective connection between psychoanalysis and Marxism, more particularly individual desire and social control.' (Ibid., p. 51).

Both Marx and Freud, attempt in very different ways to historicize and de-naturalise the world as it appears. Objects, prices, commodities, political projects, emotions, fears, sexuality are not natural platonic eternal forms with an essential essence, but are *produced* like an historical accomplishment, through dynamic processes and practices. Deleuze playfully calls their project 'schizoanalysis', or 'materialist psychiatry' and it is easy to forget that in all their complex ideas of structural social assemblage their wildly ambitious and often incoherent project attempts to imagine a new kind of analysis of production without separating the unconscious from the material realities of history.

> We maintain that the social field is immediately invested by desire, that it is the historically determined product of desire, and that libido has no need of any mediation or sublimation, any psychic operation, any transformation, in order to invade and invest the productive forces and the relations of production: 'There is only desire and the social, and nothing else.' (Deleuze and Guattari, 1983, p. 29)

They do this by speculating wildly on the experience of schizophrenics whose extreme experiences often feature the understanding of their reality and selves as complex machines. In this way they conceptualise desire as a 'machinic' 'engine' of everything; desiring-machines that produce the unconscious and the social. I find this a convincing account of agency and intentionality considering what I observed in the study, the emotional care and desire to make and explore.

For Deleuze and Guattari, Desire is *productive* and underpins their approach to materialism. Desire is not just internal fantasy or immaterial copies of material objects in the mind that make up for a lack of something, not just imagined need or what Buchanan calls 'dreamed-of' objects: 'When Deleuze and Guattari describe their work as a form of materialism it is because the unconscious, as they conceive it, is productive, not because they emphasize material objects' (Buchanan, 2021, p. 58)

Assemblages are *arrangements* of desire and physical things are in some ways, incidental props of these arrangements, a completely back to front conception of the material and immaterial. This conception of desire (Deleuze, 2001) is at times bewilderingly confusing and difficult to summarise and again beyond the scope of this study, but a partial understanding was useful in understanding the practices across my research sites. What is compelling for my study and the critical making method that attempts to think through materials, is that they prioritise desire in such a way as to collapse the separation between the material world of the Real - reality in total, and the symbolic - signs, signifiers and language.

Deleuzian philosopher of science and colleague of Gilbert's John Protevi, brings productive-desire 'back' to collective politics which schizoanalysis ultimately aims to contribute to. Protevi describes his understanding of affective encounters, particularly in understanding the productive role of joy in political subjectivity. Protevi's conception of 'joyous affect', which I understand as an implementation of Deleuze's desiring-production, resonates strongly with my observations of collective joy in making.

> we should remember that both affect and cognition are aspects of a single process, affective cognition, as the directed action of a living being in its world... Affect is inherently political: bodies are part of an ecosocial matrix of other bodies, affecting them and being affected by them; affect is part of the basic constitution of bodies politic... Political affect then includes an ethical standard: Does the encounter produce active joyous affect?.. does it enable them to form new and mutually empowering encounters outside the original encounter? (Protevi, 2009, p. 51)

I admit that like the other Assemblagists Buchanan critiques, I 'cherry picked' the elements of assemblage theory that seem to fit my research most easily. Free and easy philosophical bricolage is a feature and perhaps a problem for this study. Why use assemblage theory? Why combine Deleuzian *desire* with William's *structures of feelings*? 'What would be the use of adding invisible entities that act without leaving any trace and make no difference to any state of affairs?' (Latour, 2005 p. 150). I can only say that the observations of kit making with my participants revealed fascinating messy relationships and new capacities that some Deleuzian concepts made a difference to understanding them in all their complexity and potential.

In the course of the study I begin to understand how both social science and the life sciences, particularly microbiology describes a vast complexity of modes of production across almost terrifying seemingly incompatible scales. Boundaries around scale, nano, micro, macro, molecular, bodies, classes and groups become necessary to deal with the mess. Disciplines are developed with similar boundaries to deal with this complexity and to produce 'disciples' and specialists to understand them. In thinking through embedded art-science and STS, I answer my research questions by speculating through theory and practice on a kind of practitioner that interleaves these specialist perspectives and ways of knowing of seemingly incompatible scales and processes and produce some kind of affective experience that fosters understanding and care.

Lumpy Coalitions

A common theme in the analysis Critical kits generate is understanding the structure of actors and social worlds observed. They are lumpy, colloidal and gloopy in their contingent relations, behaviour, scale, similarity and difference. Like the evolution of individual biological living cells biologist Lynn Margulis theorised, they are persistent assemblages of different living bodies in collaboration and coalition, like Protevi's eco-social matrix. I contributed to a publication and workshop *Temporalities of Care in Conservation Environments* (Boschen et al., 2022) organised by members of the Lancaster Centre for Science Studies for the Society for the Social Studies of Science

4S 2022 meeting. Sharing and comparing my analysis of how complex practices of care develop over time in DoESLiverpool with researchers Edda Starck and Mariana Cruz A. Lima own research in rewilding and indigenous agro-forestry, these became 'lumpy coalitions'.

Structure for Deleuze and Guattari is predictably complicated by the concept of *strata* and *stratification* that is connected to their post-Marxist approach to history. Buchanan introduces strata through the work of the great biologist and public intellectual Stephen Jay Gould to understand stratification. Gould is famous for his critical work on the Burgess Shale, a rich fossil record that describes the early Cambrian explosion of living organisms that form the anatomical basis for nearly all subsequent complex organisms. He makes a brilliant critique of a popular evolutionary tautology that assumes a progression up the 'cone' of complexity with the human at the top. He instead argues for 'decimation' as the contingent factor in evolution shifting the popular biological imaginary of the 'survival of the fittest'. Buchanan uses Gould's thinking to explain strata's role in Deleuze and Guattari's thought:

> Gould argues, though, relations of dependency must also take into account that which has disappeared from history – our present is the sum both of the paths taken and the paths not taken. In short, we should not assume that the assemblages of today are more perfect forms of the assemblages of yesterday. What this detour via Gould helps us to see, ... is that strata are first of all a way of problematizing appearances. Strata are the conceptual means of transforming that which seems to have been given by either god or nature into something that is the product of multiple processes and forces over time. Strata transform nature into history and history into nature. (Buchanan, 2021, p. 26)

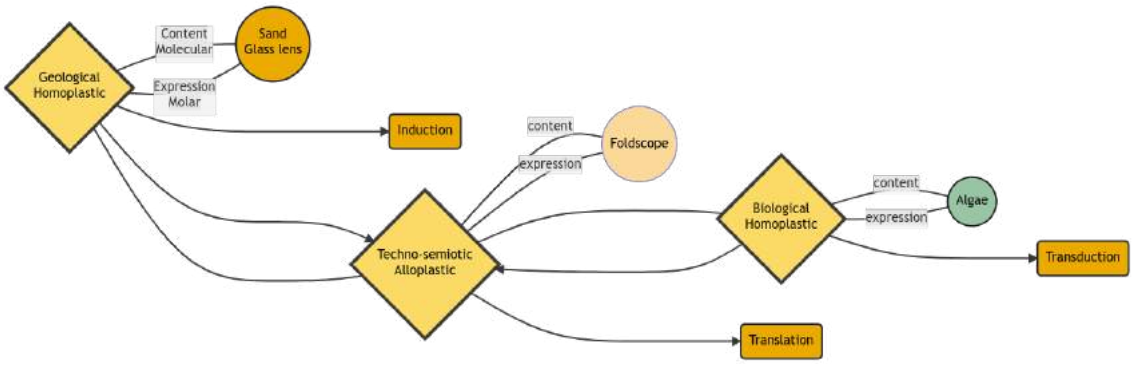

Figure 26: Diagram of Deleuze and Guattari's conception of *strata* applied to the *Foldscope*

Deleuzian *Strata* (Figure 26) can be split into three types; Geological, Biological and the Alloplastic. The Alloplastic is the human imagination and discursive social strata or as Buchanan usefully describes it, the 'Techno-semiotic' strata.

> 'we' humans depend on the properties of the earth for our existence (geology) and 'we' depend on the properties of our bodies for what 'we' can do on the earth (biology), but 'we' constantly exceed those limits in the outpourings of our minds. This is the essential difference between geological and biological strata and the techno-semiological stratum –

> the production of signs (both symbols and language) enables the third stratum to translate the other two and in a sense range beyond them. (Ibid., p. 29)

Strata is a way of mapping the anthropocene not in an heirarchical way with the human exceptionally at the top of the cone of evolutionary history but as a map of dependencies that are contingent on each other but in different ways. Put simply we depend on our bodies and the few kilometers of soil and air on the surface of the earth but they do not necessarily depend on the outpourings of human practitioners minds. In our current crisis our dependence and extraction of the geological threatens to reduce all three strata into a new homogeneous geological epoch. My diagram summarises the strata but their stratification system goes into complex differentiated detail of processes that form a totality of human existence on the earth, constraining and sedimenting the machinic desiring-production described earlier.

For me strata is useful in problematizing ANT like relations by introducing particular kinds of concrete relations not just abstracted connections. The Foldscope, a kit that dominates the explorations in the study, has a set of dependencies can be mapped very simply in the Strata diagram in (Figure 26). Sand and other minerals are required for the glass and exotic materials of the microscopes simple ball lens and synthetic plastic coated paper; the geological. Algae and the bodily interventions of folding and using the microscope to see microorganisms on a slide, the biological. And the imaginative understandings of algae and other microscopic organisms and all the possibilities for understanding the world, what the Foldscope company describes as 'curiosity worldwide', is the techno-semiotic and technoscientific outpourings of the alloplastic human.

What the Foldscope does cannot be reduced to the geological and the biological but it is fundamentally dependent on these two very different structures and processes. Again I pragmatically take what I find useful to problematise overconfidence in my understandings of the structures I analyse in the thesis and leave the more complex processes to further study. Deleuze and Guattari teach us that relations are not just lines on a diagram they have complex and different capacities and are part of different structures and scales that are not interchangeable. Buchanan pauses in his chapter on *The Problem of Strata* and considered why they developed this mapping of dependencies challenging simplistic structural and spatial analogies. By doing so he asks a fundamental social and political question that should be shared alongside the key STS questions of technoscience, *Who benefits?* or 'whatever could have happened for things to come to this?' (Buchanan, 2021, p. 47)

Commensal Complexity

Assemblage theory has not been included lightly although it is clear to me that this thesis is only the beginning of an ongoing engagement with Deleuze and Guattari's work that may benefit future work in the intersection of art and STS. My Assemblagists and their use - or mis-use - of assemblage theory have helped me articulate Interleaving Practices and Critical Kits as *assemblaging* practices.

I will go onto describe how Interleaving has the potential to help Practitioners orientate to the actual practical lived experience of being part of assemblages -

experimenting with inventive approaches to both understanding and intervening in the social world. I may be adding to Buchanan's well documented library of 'monstrous' remakings of assemblage theory. Nevertheless it productively prevents understanding interleaving as some sort of magical social relational glue or commitment to endless relationality.

Assemblages hold many lumpy possibilities together. Their components can relate or depend on or benefit each other, but these relations are not always necessary. This account resonates with my research into the life sciences and particularly in the alloplastic and biological realms of the Biomedical technoscientific kit. Taking assemblages seriously is an extension of the early discussions with Dillon on the importance of commensalism, mutualism, and even parasitism, summarised in Table 1 on page 68. Deleuze and Guattari's unwieldly theory follows these key shifts in life science, that any formation and process must be understood in the context of vast commensal and parasitical relations, giant rhizomal networks and holobionts. It's a relentless seemingly excessive committment to complexity and emergence. However The Assemblagists positively gather and bundle together a strange coalition of approaches to social complexity. They seem to foster primarily positive, affective capacities for both researchers and research participants and this partly informed some follow up interviews with research participants that included a kind of co-analysis, reflecting on my observations together.

> One of the key potentials of an assemblage approach – especially in their ethnographic application – is to participate in creating ties in the real world between the researcher and participants through exchanging affects that create trust and blur the boundaries between researcher and researched. (Ghoddousi and Page, 2020, p. 6)

Practitioners, Practice

It could seem like there are too many practitioners. What is a practice? It's what bodies do over time, like biology it is a history of coalitions doing things 'together', antagonistically or otherwise. All these practitioner's provide something in the way they develop sensitivity to the world and to the study.

I must finish with a reminder that these identities are only playful allegories for rendering theory into practice and de-privileging theory so it is a bodily engagement. At every point I have attempted to enact theory-practice-praxis somehow through making in the situations of the study. This study has compelled me to understand identity; disciplinary or otherwise, as slippery and emergent, not a reified ever descending schema of intersectionality but a set of evolving capacities. Ultimately this thesis uses an excess of theory to relate the findings at the intersections of the study to avenues for further research in STS, art and political theory and the life sciences.

Why bother with identity at all? Like kits, model organisms and black boxes they are handy packages for a writing practice to represent things but like all identities, they are historical constructions and patterns of doing things in the world. The awareness of being a practitioner doing things in a landscape of practice of some sort

and of the boundaries of that practice and others is productive but I must stress the practice is more important than the identity, collectivity more important than heroic individuals.

Many of the Practitioners discussed are not artists but provide a historical overview of theory and practice that are put forward as resonant elements of what artists and art-science practitioners could do, what the boundary of art is and is not, what is the boundary of one practitioner and all the other practices. The Practitioners described here are *interleaved* in the subsequent research and through my art practice and by the end of the thesis I posit a novel speculative practitioner prototype, *The Interleaving Practitioner*

Chapter 4: Doing What They Do There

In this chapter I present 5 case studies to discuss and analyse the interactions and observations and draw out the key features of my research I introduced earlier. Each case study presents what happened in my research and then discusses the emergence of Interleaving Practices, through my art-science practice and the literature and theory presented in The Practitioners Chapter.

After each case study I interleave a summary discussion and set of reflections that show the development of Interleaving Practices and Critical Kits as a method and approach to art, technoscientific making and social science. I prepend these section titles numerically to show how they relate to each case study section. Each interleaving allows the reader to follow my discussion of what it means to be an Interleaving Practioner and how it responds to my research questions.

Case Study 1: Folding Representing and Intervening

Figure 27: Collage of research interactions at BLS 2020

This case study is from the beginning of my research, exploring how I became sensitive to the practices of BLS, a busy life science teaching and research department, reviewing and participating in practical and theoretical life science modules (Figure 27). It introduces my research through practice methodology, embedding and 'Doing What They Do There', and how I use kits and critical making to *Fold-In* and *un-fold* theory, materials, practices, relations and feelings.

I was given my own laboratory and bench space alongside researchers, students and teachers. Early on in the study I began to use the 'Foldscope' (Cybulski, Clements and Prakash, 2014) kit, part of my research into the field of biomedical kits presented online in the Critical Kit Library. It was shared amongst research participants in the BLS labs (Figure 28). The kit was useful for an art-science practitioner, a newcomer to the busy crowded laboratory. Affordable and relatively easy to use

it represented features of my art practice and maker culture: novel modifications and use of relatively accessible materials and innovations of maker engineering, easy democratic entry into a technical culture, in this case, microbiological technique. The Foldscope is an ultra low cost microscope made by Prakash labs designed as both an educational experience and a potential diagnostic tool. The original engineering paper by Prakash, Cybulski et al., describes their 'long-term vision to universalize frugal science, using this platform to bring microscopy to the masses.' (Cybulski, Clements and Prakash, 2014, p. 9).

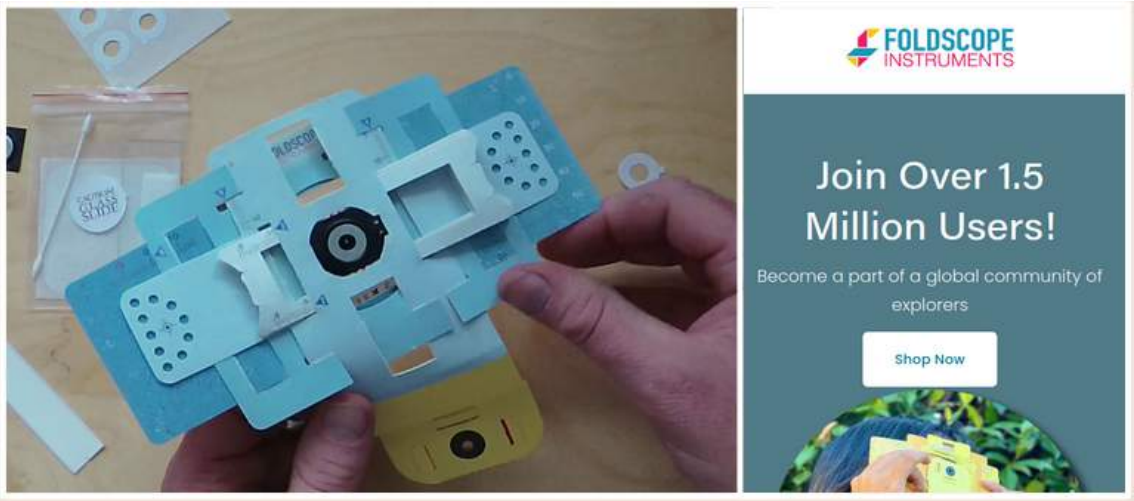

Figure 28: Still from Foldscope assembly video instructional (Dalziel, 2021), and image from the Foldscope Instruments online shop (Prakash, 2014)

I observed that all kinds of participants inside BLS and in the wider situations of the PhD research; STS students, artists, young families at maker events, engineers, computer scientists, biomedical researchers and undergraduates, enjoyed using, thinking-with and talking around these kits. As an artist with a nuanced relational, contextual practice embedded in maker culture, the Foldscope became both a useful tool convivial to my participatory art-science and an embodied shortcut to explaining my practice and research. The kit resonated with Ian Hacking's study of representation in microscopy (Hacking, 1983) where he stresses the importance of 'intervening'. In Foldscope use, the slightest bodily movement gives immediate undeniable feedback to your intervention with the microscale - what many participants describe as at times a rewarding but frustrating experience. When Hacking wonders in what way we 'see' with microscopes, participants here reported how they 'feel' their way to the images prompting rich conversations amongst participants about scientific craft practices.

The Boundary Labour of Critical Kits

The Foldscope kit performed clearly as a useful boundary object, resilient and 'plastic enough' (Star and Griesemer, 1989) for diverse practitioners from different disciplines to work and talk around. Just as Griesemer describes boundary objects as 'a heuristic methodological category to think with as much as an ontological category of object to think about'. Critical kits help find out what is going on, as much as they are

a useful kit for intervening. It's use in the study revealed complex assemblages of materials, disciplines, limitations and possibilities.

Responding to interactions with teaching and research into insect disease vectors for the mitigation of endemic disease in BLS, the boundary work the Foldscope does also reveals a dominant narrative, that is, what the kit 'scripts'. This scripted imaginary shared by many biomedical kits is the hopeful story of innovative frugal science and the radical democratisation of science for *'the masses'*. In terms of disease diagnostics, this arguably refers to the particular 'masses' of low and middle-income countries (LMICs) outside of euro-American whiteness, where many so-called 'neglected tropical diseases' (NTD's) like Leishmaniasis and Dengue Fever are endemic. Interactions with the kit supported a masters students meta-analysis of biomedical diagnostic literature who I shall refer to through the pseudonym Diana. Her study compared open-sourced maker approaches with conventional implementations of so called Point of Care (POC) diagnostics for mitigating endemic NTDs. One significant example in the diagnostic literature is Rajchgot et al.'s review of the Foldscope (Rajchgot *et al.*, 2017), making qualitative and quantitative comparisons with the so-called 'gold' standard of conventional lab diagnostics using high powered microscopes in laboratory conditions. The review highlights that despite the Foldscope's relatively comparable results with regards to the specificity and sensitivity of individual diagnostics, it excludes many of the standard and important practices of biomedical slide preperation. For POC diagnostics, these are crucial practices - preparing slides of human blood, stool, urine and tissue, often requiring centrifuging, staining, filtration, all vital to fulfilling its diagnostic potential. Prakash et al. in the original paper (Cybulski, Clements and Prakash, 2014) stress the Foldscope should be made 'application specific' in such contexts, but nevertheless Rajchgot et al. make an important point that the democratisation of the Foldscope is limited to slide observation only. They also make a compelling hypothetical economic critique. Despite the initial ultra-low cost of the diagnostic, the low throughput of samples over the years required to make an impact on endemicity and complementary costs of technicians or health workers in the field, the cost-per-specimen for diagnostics could be significantly higher than conventional 'gold standard' microscopy.

Kits like the Foldscope are convenient and attractive packages for doing and knowing; for intervening. Artists and scientists alike are drawn to them. But this convenience in some situations can obscure wider collective configurations. Here it is the necessary scaling of assemblages of actors and agencies that constitute successful intervention in endemic disease mitigation. Lucy Suchman in her work on configuration could well be describing the required networks of human and non-human actors that are much more complex than a simple scalar of diagonstic shipments, 'how scale is enacted in and through complex socio-technical assemblages, as they draw together and multiply entities through time and across space' (Suchman, 2012, p. 48).

The ultra low cost and affordances of the Foldscope are a genuine achievement, with radically democratic, educational and diagnostic potentials but like many kits it also partially depends on certain 'externalities' that it cannot intervene in. When used to fix a puncture or implement a feature in software certain externalities in kit making are not a problem, but when used to intervene in complex biopolitical situations, they can make us feel like we are in control, literate, effective and resilient when we are not.

It is an almost banal observation that kits must necessarily exclude to achieve their utility - a kit cannot ever include 'everything you need' to do something, there is always a *strategic* trade-off which has political consequences and commitments. What cannot be underestimated, especially with respect to strategy, which I discuss later, is their affective power. This kit amplifies a rhetoric of 'curiosity', a keyword for Foldscope marketing and democratises progressive practices of science education, but they also could potentially elide the nuance of the 'wicked problems' (Buchanan, 1992) of complex disease vectors or exclude awareness of forms of coloniality and inequality (Richardson, 2019). These kind of trade offs are found analogously in all kinds of biomedical kits (Dalziel, 2019b) that the wider PhD study considered, and recall Star and Griesemer's playful heuristic and methodological approach to boundaries (Star and Griesemer, 1989). They make kits important critical tools for thinking through and making with technoscientific objects, in what they reveal about themselves and the other actors that use them.

Lab From A Chip

Figure 29: Assembling *LabFromAChip* kits (Dalziel, BLS, DoESLiverpool 2020)

My artistic response to BLS *folds-in* the practices of *microfluidics* essential to 'Lab On A Chip' technology a relatively recent innovation in biomedical technology (Figure 30-31). A Lab On A Chip implements complex microbiological and biochemical processes onto 'chips' similar to the printed circuit boards of computer hardware (PCBs). Instead of conductive paths that connect components, tiny microfluidic channels direct flows of fluids to control bio-chemical reactions. They manifest kit-like imaginaries with implications for transforming everything from bio-engineering to field based diagnostics (Wheeler, 2001). Critical making in the lab with DIY low cost approaches (Tsai, 2006; van Schaik, 2015) to this technology revealed how attempts to democratise this technology, for example in the Metafluidics project (Kong *et al.*, 2017), are limited and often elide the actual material difficulties for doing microfluidics. In this case, what is hidden is described in one biochemical journal as the 'world-to-chip barrier' (Longwell and Fordyce, 2019), the complex assemblages of practices, knowledge, infrastructure and technologies required to

prepare materials so they can be processed by the chip in any useful way. Critical making highlights this through the material practice of attempting microfluidics with makerspace technology.

Sharing these experiments with Alex Benedetto, a senior lecturer and researcher at BLS, reveals a technique he uses that I re-empractice as the basis for a critical kit; a deceptively simple, cost effective alternative to making microfluidics. He uses the cut grooves in the surface of old vinyl records, the now largely redundant medium for music reproduction, as moulds for producing cheap robust, transparent, high resolution impressions of microfluidic channels using Polydimethylsiloxane (PDMS) silicon. PDMS is a versatile silicon polymer that as a liquid penetrates the tiniest of spaces, and once cured at room temperature is elastic, strong, non-toxic and optically clear and so ideal for constructing microfluidic structures. For Benedetto a biologist with an engineering background, this aids the efficient and cost effective management and observation of nematode worms, a model organism used in Benedetto's research into ageing, keeping them safely secure in the vinyl groove impressions (Coburn *et al.*, 2013) (Figure 30).

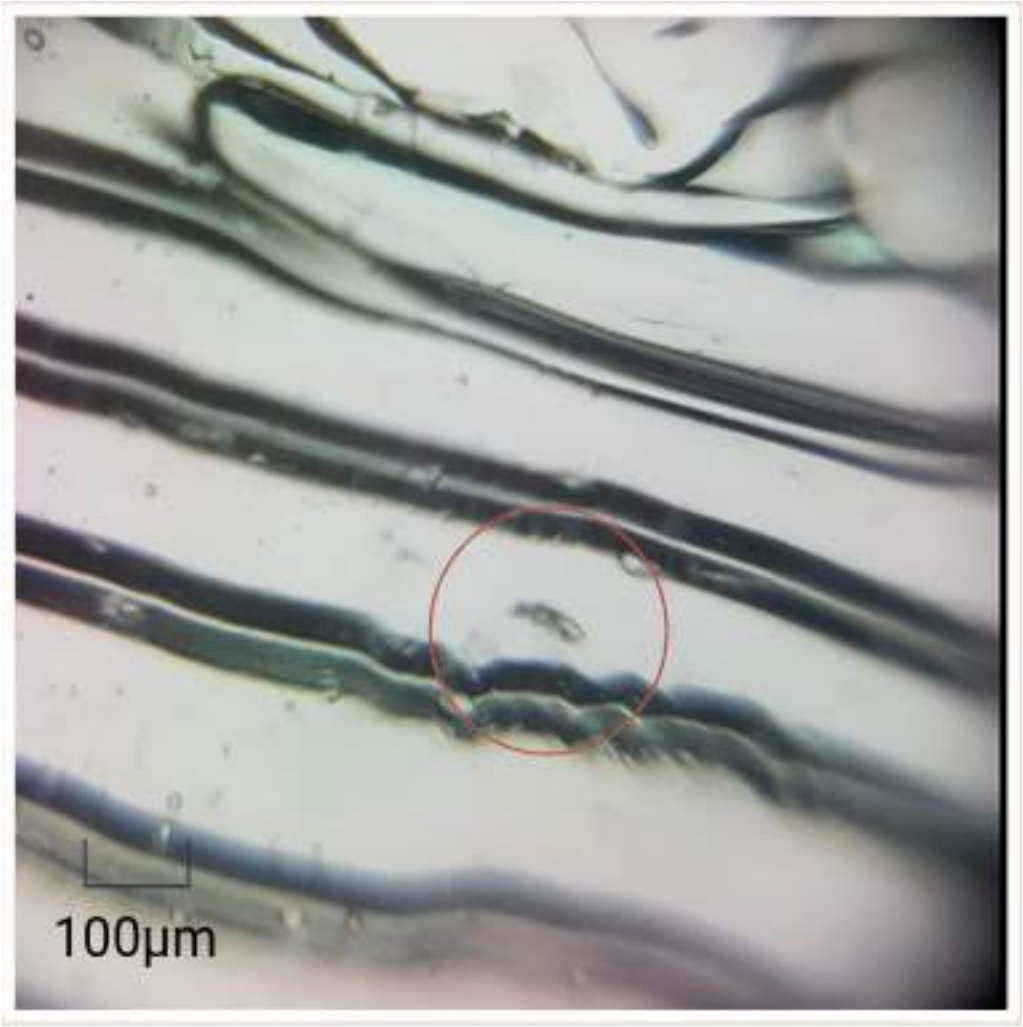

Figure 30: Algae in a *LabFromAChip* structure (Dalziel, 2021)

My critical kit response is a Lab *From* A Chip kit (Dalziel, 2019c) that includes a set of add-ons and instructions for the Foldscope to use Benedetto's PDMS moulding

technique to make microfluidic structures from everyday technoscientific objects like a vinyl record or silicon chip. It became a playful *intentional* boundary object, a détournement of microfluidic practice (Figure 29). It allows users to *experience* microfluidics as a craft practice outside of its scientific context, to make 'hands-on' microscopic spaces from the surfaces of the contemporary world. The kit includes a silicon 555 timer chip, used in maker electronics in addition to a fragment of an old 'Lovers rock' 7" 45rpm single. These everyday artefacts became micro moulds in which to experience microscopic non-human scales using another model organism the algae *Euglena gracilis* included with the kit. These algae are fascinating ubiquitous heterotrophes, smaller than the width of a human hair, motile like an animal but photosynthesising like a plant. Participants reported how they could 'feel' for the surfaces and scales of their material world with various affective outcomes.

One participant, a scientist at BLS, observed how after living with the kit for a while, periodically experimenting with it with his family, how it 'changes the quality of a walk'. Working with it is described as frustrating in comparison to the bench microscopes he is used to, but ultimately the minimal materials of a folded card and glass lens prompts the understanding that even the smallest object is full of biological life.

The boundary work this kit does is both epistemological, a critical tool to describe and 'know' something, and ontological, making bodily experiences in workshops (Figure 31), and fostering affective feelings for materials and algal non-humans.

You can think about all kinds of analogous 'world-to-chip' boundaries with this Critical Kit. What is the boundary between the human and non-human? Between plant and animal? Between a scientific way of knowing and an artistic way? Between efficiency and the loss of embodied understanding and experience? By feeling for the limitations of DIY microfluidics there is a real sense of the labour of making connections and controlling sub micro-litre liquids. Clearly not every flow; of data, viruses, people, can be controlled at all times, they cannot be so easily abstracted or reified out of history when intervening with them 'hands-on'. When Foldscope advertise their ambitions, 'amplifying curiosity worldwide' they also amplify a useful embodied affective scepticism.

This case study explains the affective and role of kits in the research. It begins to explain how critical making can un-fold dense networks of relations, increasing sensitivities to the complex invisible work of scientific practice.

Interleaving 1: Learning to Interleave

Between the boundary of each case study I will interleave a discussion and some analysis. Let me start by exploring some aspects of the boundary labour these art-science kits contain. In the art-science practice I brought to BLS, I became sensitive to disciplinary boundaries, following and re-empractising different practices but only so far, enough to get a 'feeling for the organisms' (Keller, 1983), a feeling for the relations and the differences. I began to understand the bodily experience of being disciplined with microbiological technique, of working in a lab. Different disciplines and their practices, micro engineering, statistical analysis, bioinformatics, the craft

Figure 31: Using the *LabFromAChip* kit at a workshop at the MA in Art and Science at Liverpool John Moores University (LJMU)(Dalziel, 2021)

of counting and growing and caring for non-human organisms, moved alongside each other, forming frictions or interesting questions. They gathered together and then moved apart. Microfluidic moulding became similar to another artistic technique. One artist research participant acknowledges the similarities of microfluidic moulding to the brass rubbing used in their own work. Then, struggling to find a consistent 'chip to world interface', the disciplines separate as my art and maker skills fail to reproduce the standards of engineering in the laboratory. Like the situationist *frottage* of the Dada artist Max Ernst, different disciplines are stacked and overlayed; but then actively *'fold-in'* practices and different scales. In the LabFromAChip kit microbiological technology; microfluidics and model organisms, *fold-in* with artefacts of musical technology: 7" vinyl record fragments, 555 timer chips, something new comes together, they *interleave practices* productively.

Interleaving Practices is a term which emerged independently in this study but as I have said in The Practitioners chapter, is partially connected to the cognitive learning studies of Kelli Taylor and Doug Rohrer (2009, p. 845). Similarly both Wenger-Trayner and Star and Griesemer understand the boundaries of practices as a productive kind of 'discriminability'. Learning differences and building relations between practices and their taxonomies is part of knowledge production. Boundaries are not always normative restrictive bounds that need to be crossed or denied, they must be negotiated but not always without Mouffe's antagonisms. The discriminatory boundary is a 'learning asset' in Wenger Trayner's convincing contributions to learning theory. Their spatial analogies of 'landscapes of practice' are compelling metaphors for understanding the scale, stability and complexity of practices that go on in the field sites. A lab or a makerspace landscape may be as complex as any thousand year hillside, but they are also clearly stable enough to be easily differentiated and recognisable. One is used to thinking of these social objects, like 'lab', as a more or less singular whole. With the analogy of landscapes it is easy to also understand and describe this whole, as made up of complex changing nuanced components that are not uniform, frictionless and flat, but include and depend on sedimented processes and interconnected boundaries across different modalities and scales.

Novel transgressions of boundaries are powerful art-science imaginaries. In the bio-art of Stelarc and ORLAN discussed earlier, these transgressions are spectacular performances and cuts on and into the body. My approach instead offers strategic opportunities for more nuanced intervention in technoscientific practices and boundaries in the making. With Interleaving Practices, the approach to bio-art is more concerned with getting entangled with ongoing social and collective formations day to day, negotiating boundaries productively without spectacular transgressions. My *LabFromAChip* kit gathered together and facilitated different practices without transgressing the boundaries between them. Art-science pioneers like Stelarc make affective challenging interventions, leaping and transgressing, but ultimately they are not involved with the intimate, collective and necessary labour of interdisciplinary boundary work.

Critical kits are still performative however, like the spectacular bio-art, but performance on tiny stages, little re-enactments of microscopy, non-human care and microfluidic practices are 'performed', but in quite a different radical register, less like Stelarc and more like the artefacts of Eduardo Kac (Kac, 2009). Material exploration pushes gently at the world-to-chip barrier and produces affect and learning. In my

own previous work it is the boundaries and *constraints* of the game Minecraft and 'good' practice in the Internet of Things and maker culture that drives creativity, while also revealing the complexity of the field of practice. Kits in maker culture necessarily, like all material making, have constraints of time, budget, cultural norms and limits. Such limitations include the limits of digital fabrication equipment and what materials are easily available to a specific community and shape what is possible. Paul Dourish talks about not just how technology increases what is possibile but what affordances can be made 'at hand' (Dourish, 2001). Working within the limits of what can be 'in the bag' of the kit is an interesting space for things to happen.

Instead of transgressing or synthesising disciplines, the Lab From A Chip kit tries to *fold-in* the productive boundary labour and necessary limitations that Foldscopes and microfluidics in the case study contain. Critical Kits are *intentional* boundary objects to build on existing boundary work and prompt more. The Lab From A Chip kit folds-in other practices through playful détournements of microfluidics and maker culture into new technoscientific objects to handle rather than hybrid trans-disciplinary or extreme limit experience.

Following Star and Griesemer's Boundary projects, this boundary labour of making kits with the awareness of the Interleaving of practices means that they also find things out about their users and their landscapes of practice and their own roles as actors in Latour-like networks, as much as they are objects to functionally intervene in a certain way. By making the LabFromAChip kit I discovered how particular things worked in the lab. Kit making became something like research through participatory design or what one participant at 4S2020 called appropriate 'research formats'.

Critical kit making as a research format attempts to interleave all kinds of complicated historical relationships: complicated supply chains, the history of physical media, the exploitation of materials and human labour in technologies and manufacturing and learning, or the vast amount of plastic waste generated in contemporary biological teaching practices. Haraway calls this relation building an 'implosion' that Joseph Dumit discusses in teaching practices (Dumit, 2014), a sensitivity to otherwise unacknowledged traces of technoscience, what Haraway has called the 'sticky threads (that) lead to every nook and cranny of the world.' (Haraway, 1997, p. 129). Critical kits attempt to *fold-in* such threads into the material learning experience of what is included and excluded in the kit. Crucially kit *making* ensures that both this discovery is embedded in hands on material engagement, not just in a cognitive writing practice.

Making critical kits in the BLS case study reveal how diverse practices that temporarily *stick together* but stay *separate*; that *interact*, but without *synthesis*. They *interleave practices* and *fold-in* with each other without erasing difference - like in the multi-species labour of leavening and kneading bread.

This manipulation and sensitive folding-in is key to understanding the relationship between critical kits and Interleaving as a research methodology for inventive social research.

Figure 32: Image of 3D prints and designs made by the 3D Print Club at the Neuromuscular Centre, Winsford UK 2021

Case Study 2: The 3D Print Club

In this case study my analysis leads me toward the idea of the *capacity* for *care* through *inventive* forms of interaction with 5 participants who make up a club for 3D printing at the Neuromuscular Centre. I learn *strategic* lessons in maintaining long term relationships a key necessity in embeddedd art practice. The participants who became supporting friends and through caring for our 3D printers we cared for each other, following distractions and making productive failures together collectively. I conducted informal group interviews with the same 5 participants during online making sessions. At times these sessions became a form of co-analysis reflecting on previous activity. I also record a making session with the group and Dr David Clancy from BLS a researcher and lecturer using the behaviour of fruit flies for research into the biology of ageing.

I am already embedded at the Neuromuscular Centre (NMC), sharing the specific bodily developmental histories that lead to the neuromuscular condition Becker's Muscular Dystrophy (BMD). The NMC provides physiotherapy and exercise, training and personal development for families living with similar but diverse neuromuscular conditions 'to have healthy, productive and fulfilling lives' ('NMC', 1990).

The 3D Print Club emerged from a simple introduction (Dalziel, 2018) to 3D printing delivered as a volunteer responding to community interest (Figure 21). The artist facilitates the club, but there is no art production; instead, 3D printing is introduced as a kind of world hacking, modifying wheelchairs and the environment influenced by both STS and the social model of disability; how the technical configuration of the world enacts disability not genetic difference. The initial meeting slowly evolved into an informal club. This is characteristic of my practice, setting up activity without necessarily having an artistic objective but responding to and nurturing social situations. Over subsequent lockdowns in the UK, which forced all NMC clients to shield due to their extreme vulnerability to COVID-19 symptoms, these monthly meetings became weekly video meet-ups and as the members began to take on recognisable maker identities they consented to becoming research participants and together with them I began to design and print a diverse range of objects (Figures

32 and 34).

Getting Up in the Morning

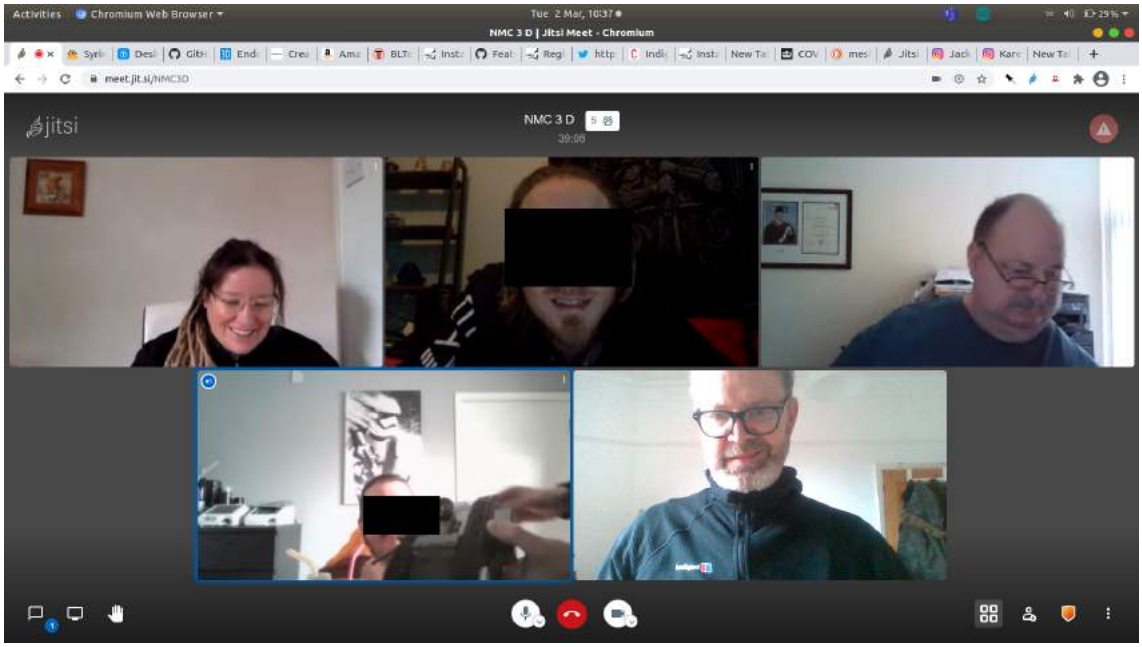

Figure 33: Image from a 3D Print Club online meeting

> DIY PPE, Model guns, mood trees for visualising emotions, Wheelchair joystick, game controller and frame adaptations, drink holders, custom pop up Kerb ramps, Christmas decorations, drinking straw holders, Mazes, environments and experiments with fruit flys, Screw threads, gaming trophys and paralympian badges, geared and moving systems for desktop toys, trinkets and desk sharing notifications... (Quotation from one of my journal entries)
>
> for me to go in there and see suddenly see what's going on, the impact is much greater... It's amazing, it's absolutely amazing... the group has flourished (Supervision meeting with author, commenting on a recent visit to an NMC open day, August 13th 2022)

Participants talk about the importance of the club for 'getting up in the morning', meeting at 10am every Tuesday (Figure 33) and, conversely, the frustrations and emotional turmoil of ongoing technical issues that get in the way of a good print. Design, engineering, pandemics, genetic science, caring for each other and model organisms all became part of a rich landscape growing from a single workshop (Dalziel, 2018). Popular pathologising myths of technical people being obsessive and verbose about technical matters alone, are confounded in the group by the ease with which participants talk clearly about their emotional experiences in the club. Characteristic of many online club meetings is how they laugh and joyfully show successful and disastrous printing efforts - sarcasm and playful insults and in-jokes cut into serious design discussions, fast paced shifts in tone which can be bewildering to an outsider.

Figure 34: Image of the 3D Print Club Prints at second post COVID-19 lockdown meeting

Risk Management

The fostering and mobilisation of existing informal interest groups like clubs, is significant for how it informs the approach of interleaving. Artistic vision, production or aesthetics are deferred in favour of social and cultural participation, deeper engagement and equitable understanding. There is a risk of exploitative subterfuge, but practitioner and participants are reflexively alert to this and commit to mutual social demands.

The 3D Print Club is an *intentional formation* of such a group not without other risks. Elsewhere in the PhD study, a club for scientists *ClubBioMed* (Dalziel and Dillon, 2020) and a *PaperJam* (Dalziel, 2019d) for artists and environmental scientists loses momentum despite initial enthusiasm, membership, websites, time, kit distribution and effort. This risk is important when considering the limitations of Interleaving Practices as a strategy for interdisciplinary work. It's an intricate slow social process that requires investment in work and time spent on things that might not seem, nor turn out to be, relevant. It makes research objectives and outcomes emergent and difficult to predict, and of course, fund. Confounding the boundary to what is or is not relevant, or a valuable outcome, is at once, using software development terminology, a 'feature' and 'bug' of Interleaving and a problem shared by many methods (Law, 2004). It requires flexibility, abandoning research objectives when the situation demands it. In the case study, a productive art-science discussion while making together about how scientists might use 3D printing in their experimental lab work (Figure 35) is suddenly discarded for an urgent question about what is the best motherboard for an Ender3 printer firmware upgrade, so it's possible to do bed levelling automatically; otherwise difficult for makers with limited upper limb strength (Figure 37).

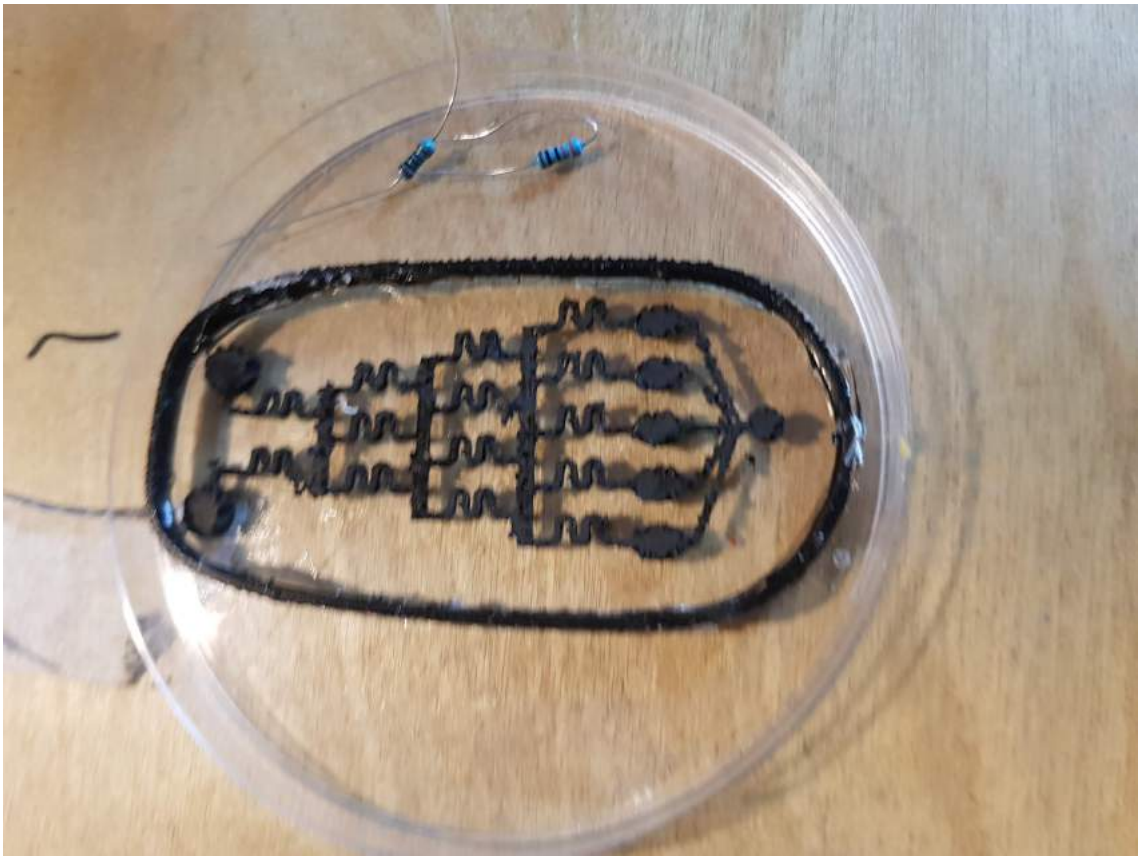

Figure 35: Image of 3D Printed microfluidic moulds made from popular ABS print filament, embedded in a PDMS silicon mould, dissolving in an acetone bath as part of a microfluidic making process

These bugs and diversions generate potentially frustrating detours but the Interleaving practitioner must learn to understand them as strategic encounters, part of a tactic to 'qualify as a player', as Thomas Osbourne comments in his contribution to Barry and Born's indispensable book on Interdisciplinarity art-science. (Osbourne, 2013, p. 82).

Diversions

Figure 36: PPE prototyping in crisis: Image of McEwen displaying completed PPE kits as a 'selfie' for social media. Image credit: DoESLiverpool

There are other unavoidable diversions, like a global pandemic, that cannot be post-rationalised as strategic. Successful growth of the club was certainly influenced by lockdown and the new challenges, sensitivities and solidarities it produced. The vital physical and emotional support that the NMC provides for its community was suddenly removed in both subtle and devastating ways. In many ways the club partially filled this gap for its participants and could contribute to an aggregate of social activity that partially make up the NMC communities identity and the structure of feeling of that organisation.

A crisis in the supply of Personal Protective Equipment (PPE) early on in the pandemic in the UK led to maker culture responses. The DoESLiverpool community for example, spun up a production line and charitable funding in just 8 weeks to safely manufacture face visors to support the PPE shortage for support and front line workers in the UK National Health Service. At peak performance manufacturing and packing 900 visors a day ('DoES Liverpool Visors', 2020) (Figure 36). The 3D Print Club followed DoES's lead closely to support the NMC community and staff, who are particularly vulnerable to respiratory conditions leading to distributing over 100 face visors to the NMC with a carefully constructed website (Dalziel and Briggs, 2018).

Intervening with Interleaving

Articulating interleaving also supported the Club's development. When distractions and emergency diversions took place, an awareness of the slow strategic interleaving of difference and interests as a method means Interleaving practitioners can hold their nerve and not panic. It was a long unpredictable journey however from intervention, running an introductory 3D Print workshop using a borrowed printer from DoESLiverpool and persuading trustees to push for funding for a reliable printer for the club. The further, generating enough engagement for individual participants to invest in their own. The club members now have access to 4 printers, going well beyond my initial expectations. Intervening through Interleaving means you embrace diversions as productive and meaningful, often deferring the ultimate horizon of an art-science or research goal. This favours collective learning, which ultimately generate richer unexpected opportunities. Kits and Critical Kit like projects emerge, but are not forced in a pre-determined direction, instead interleaving sensitises the practitioner to appropriate emergent opportunities for intervention that can be seized.

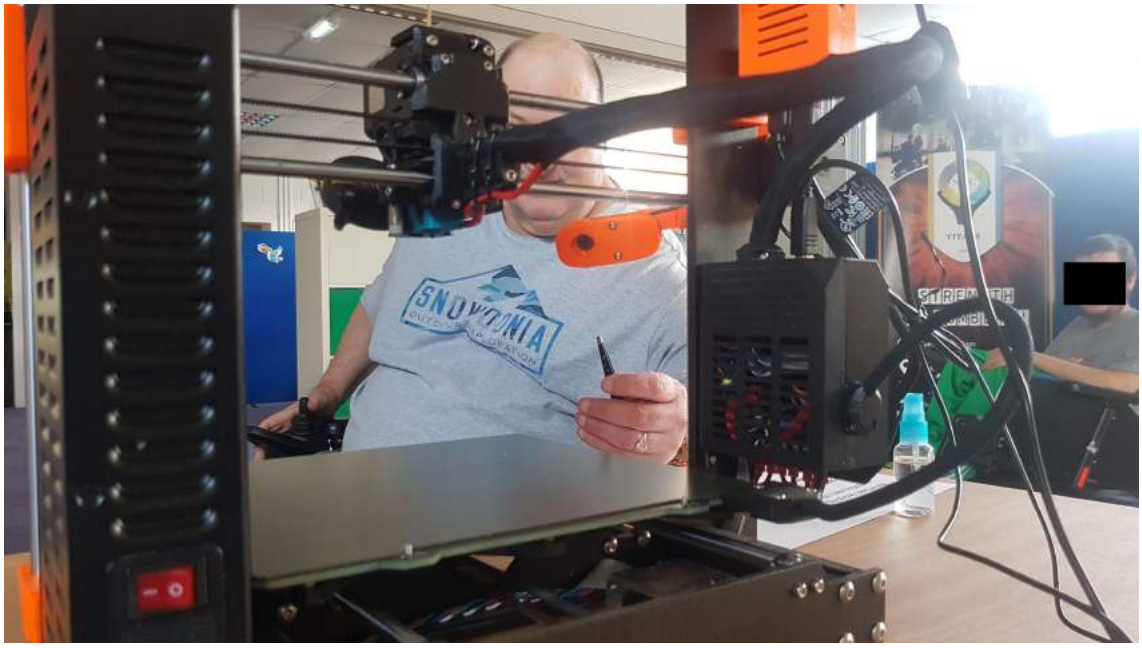

Figure 37: Prusa bed levelling experiments at first post-lockdown open day at the Neuromuscular Centre

Michel Callon et al. describe 'dialogic' collaborations between 'laypersons' and 'specialists' in families affected by Neuromuscular disorders in the form of 'hybrid forums' (Callon and Rabeharisoa, 2003). They claim such forums are alternatives to the democratic trade-off of how *representatives*, both in politics and scientific expertise, *represent* people and knowledge, effectively silencing them, precluding their bodily capacity to represent *themselves* collectively. This optimism for a technical democracy can be recaptured in the 3D Printing Club where boundaries of layperson and specialist shift. Given enough time all categories and identities are revealed, of course, as an ongoing social process. No individual is innately 'lay' or 'specialist' although stumbling across the manipulation of fruit fly phenotypes in a lab or elegant 3D printed wheelchair hacks, can give that impression. Interleaving articulates a

methodological space for social process, a tactic for the hybrid forums of the 'research in the wild' Callon describes. Slow interleaving prepares the way for democratic engagement from the ground up. The approach is to build on shared material interests, here through 3D printing and capitalise on the collective joy observed in the case study, to develop a unique playful Critical Kit for thinking about experimental genetics with humans affected by genetic difference.

Fly Farming

Figure 38: Image of a *FlyFarm* kit maze component

The *FlyFarm* is the opportunity for intervention here; a critical kit that explores the craft practices of the genetic experimental science of neuromuscular conditions with actors who are both the subjects and objects of the condition. Here practices observed in BLS involving 'model organisms' the non-human collaborators of biomedicine, existing *Drosophila melanogaster* models of Muscular Dystrophy (MD) (Lloyd and Taylor, 2010) and the practices of experimental biologists who use 3D printing (Fingerut *et al.*, 2017) are interleaved intentionally with the bodily experience of the club, humans, like myself, living and attempting to flourish with neuromuscular conditions and emerging maker identities.

The interests, desire to help, and competencies developed mean the club happily design and print kits for experimenting with model organisms (Figure 38). Over lockdown the artist's colony of white eyed Drosophila died from a funghal infection so new sources of the organism are needed. The makers friend, eBay, reveals an ecosystem of suppliers of a *Drosophila* strain with vestigal wings primarily sold as a 'natural live food' for fish and reptile enthusiasts, a whole new social formation with a new set of craft practices (Figure 39). These became a 'stand in' for the fly model of MD which basically express a similar inability to fly; a model of a model organism, they populate the designed environments. Further eBay markets

Figure 39: Strain of *Drosophila melanogaster* with underdeveloped wings, sold as live food on EBay, similar to Drosophila expressing the mutation on the dystrophin gene complex that causes Muscular Dystrophy

reveal themselves, a laser cut ant formacaium kit, clearly manufactured with maker practices. Like the LabFromAChip in the first case, existing kits like this are remixed to 'fold-in' maker, manufacturer, distributor and experimental biologist's practices and platforms. The *FlyFarm* is a 3D printed and modified formacarium kit with HD camera and Raspberry Pi system allowing computer vision to track (Romero Ferrero *et al.*, 2019) and livestream, (Lennon, 2020) providing a safe environment for fly colonies to survive and breed while observing their behaviour. A section of the environment allows different 3D printed landscapes to be experimented with, circular and pyramidal mazes to explore, chambers to fill with different food. Standardization and low cost allow multiple experiments with different fly strains with fine control of environmental variables and the ability to monitor results remotely.

What Geneticists Do All day

The *FlyFarm* kit prompts a frank discussion online with club participants and a researcher and lecturer at BLS (Figure 40) about the nature of genetic research and just how little biologists know about genetic development despite huge almost unimaginable detailed maps of genetic structure. Understanding the structure of the dystrophin gene complex alone, mutations of which cause Neuromuscular conditions, is a vast project and apprehending all its ongoing developmental interactions means the horizon of practical genetic therapy for people with Muscular Dystrophy is in the far future. He is an experienced researcher exploring the effect of mitochondrial genotypes on lifespan in *Drosophila* by developing novel strains of the organism. He describes what geneticists do all day; the 'lucky guesses' and 'hunches', that can be 'felt for' with relatively low cost breeding 'knock-out' genetic experiments with *Drosophila* and existing bioinformatics which may then be pursued as rigorous expensive research and trials. He is intellectually honest and downplays his expertise without dumbing down. He suggests new experiments and tips for caring for fly

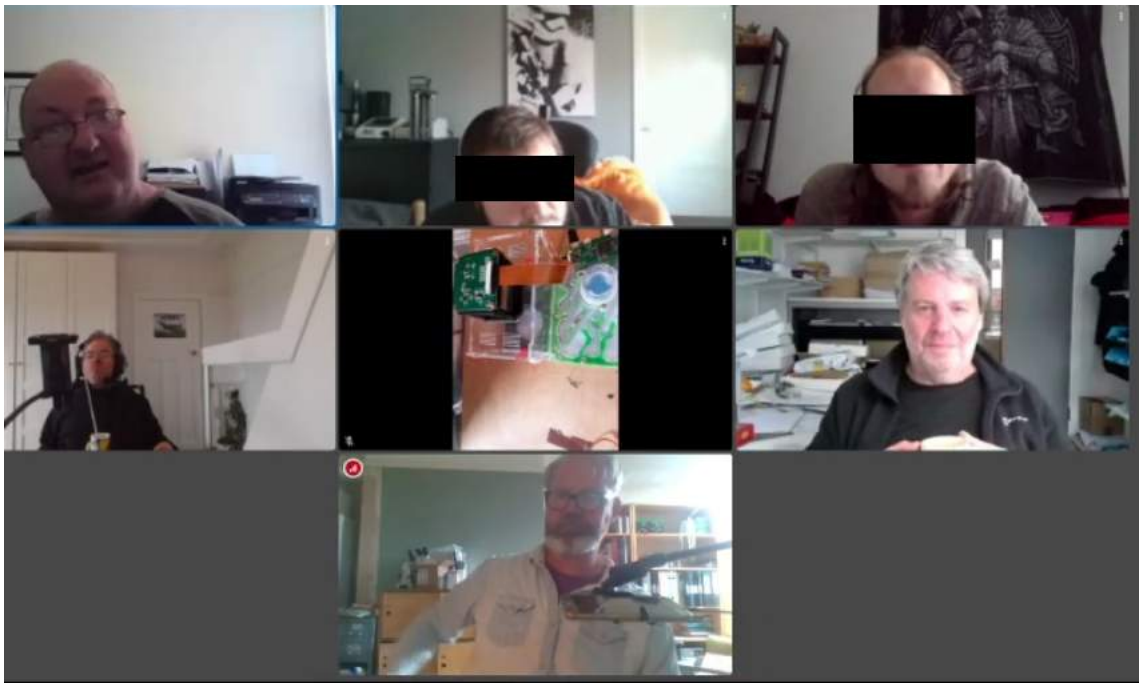

Figure 40: Image of the 3D Print Club interleaving with Dr Dave Clancy at an online meeting

colonies and is surprised to discover the versatility and affordability of the printers used and the fly colonies available on eBay.

The *FlyFarm* kit is an inventive prompt for generating feelings for the complexities of observing model organisms and relating to genetic difference and experimentation. It intervenes in the representations of genetic neuromuscular conditions. Maker and scientist can gather round it and prompts frank conversations about their respective practices. New social objects emerge (Figure 41) and at the same time, it developed complex and unexpected capacities to care. In caring for their 3D printers and model organisms the participants also cared for each other.

Feeling for the Model Organisms

Printing up their designs the club watch *Drosophila melanogaster* close up, together. The very first time they recoil physically on camera in disgust and make cruel jokes, a visceral response considering it is on video seperated by dozens of miles and lockdown restrictions. Gradually there is a shift in tone. The surprise that scientists might worry about harming these seemingly unimportant organisms subside. The maker as helper perspective kicks in. How can we keep the flys alive and happy? Participants discover the importance of care in experimenting with model organisms that complicate basic assumptions of exploitative scientific relationships. Initial kits are 3D mazes and obstacle courses where participants jokingly suggest placing bets for 'winners' and 'losers'. BLS researchers explain how important it is to reduce fly stress and participants, and artist are surprised this is important to such lowly creatures. It leads to a tonal shift when designing environments, no longer competitive race tracks but habitats for colonies to thrive. Experiments to compare mobility of fly

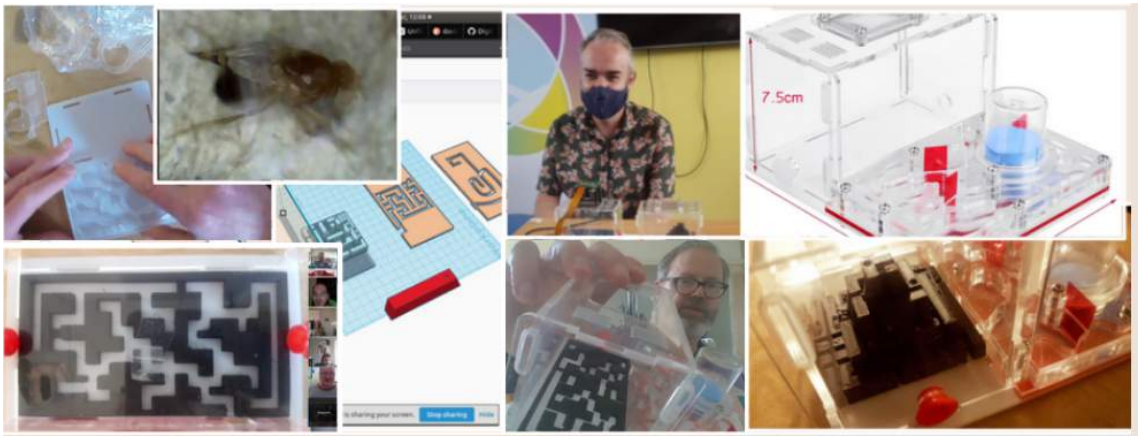

Figure 41: Montage of *FlyFarm* kit activity

strains are discarded for supportive 'interesting' landscapes. Instead of the harsh cellulose of PLA a popular 3D printing filament, moulds are printed allowing more organic materials to make up their designed habitats.

These affective shifts; from disgust, to black humour, to concern, to care; take place through material engagement, critical making. Another dominant characteristic of 3D printing is observed; the tricky labour of care and maintainence of 3D printers. In the study every meeting includes a caring moment, both for printer behaviour and fellow participants feelings, even in the form of a joke or sardonic check-in. Later in the study they ask after my fly colonies as a matter of course, a common conversational feature in the common room and coffee breaks at BLS. 3D printing with limited mobility often requires carers, family members, friends or sometimes paid professionals to assist. In the NMC carers often distance themselves in workshops in the centre to prioritise the experience of the cared-for, not dissimilar to the ethnographer prioritising participant's experience or embedded artists deferring their artistic objectives. With one participant, their carers became much more visible and engaged as they are involved in maintaining and running the printers, joyfully demonstrating successful prints as much as anyone involved, becoming, visible and active.

I mapped out the arrangements of care in the case study (Figure 42) using elements of Tronto's conceptualisations of an ethics of care - in particular, her ideas around the maintenance of 'our world', and the concept of 'caring-with'. To be clear, and not to critique Tronto, care is not understood as some kind of ethical behaviour of reified moral characteristic. Care here, is something to be constructed collectively and strategically as part of an historical social process; building *affective* and *material* means of production for the *capacity* to care, a modality that is in *opposition* to individualised moralism. This then is the strategic value of the tactics of collective making and interleaving; building new bodily capacities for care.

This shifts understanding of immediate and intermediate tactics and objectives for both the Interleaving method and the Critical Kits. These kits don't aim to immediately explain, nor necessarily educate creatively. Their pedagogy and politics is part of a much longer game, a further horizon. In the interactions with Clancy, no interdisciplinary scientific or artistic questions of much consequence are neither

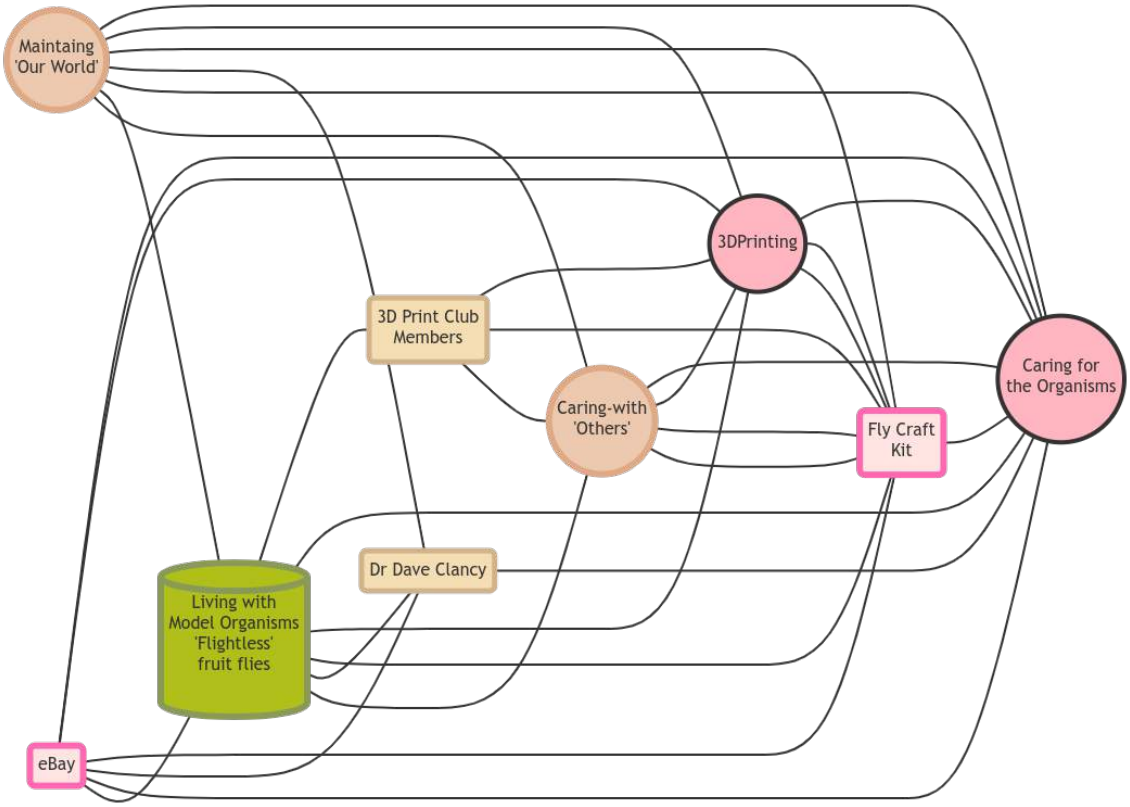

Figure 42: Care diagram

asked nor answered, instead a different question is formed in the background; what productive coalitions of knowledge, care and concern can be interleaved?

Interleaving 2: Printing across Boundaries

Case Studies 1 & 2 and their associated kits are in the milieu of art-science, but much of the activity is not, deferring to the desires and needs of participants (Figure 43). Art-science seen through the lived experience of Interleaving Practices remains a term of convenience. Based on the complexity I observed making these kits, research into the different forms of practice associated with them and my own experience presenting my work as art-science, the term feels limiting. It reduces complex logics and registers of difference into some kind of simplistic disciplinary divide across 'two cultures'. Art-science practitioners somehow transcend or bridge this divide through an innovative logic. All terms and categories are of course, necessary boundary work or convenient generalisations in order to discriminate from other similar things. Nevertheless art-science could be telling a comforting transgressive story. From my perspective on these observations, the idea of transcendental bridging across disciplines conflicts with the actual slow, complicated exchanges, negotiations and collective labour of working alongside difference and other ways of knowing. Practising in the gatherings of disciplines in this study was about collective care and *productive* boundary work, interleaving art, science and the humanities with all the component participants. Barry and Born's modalities and logics orientate us to the actual possibilities - and limitations - for different practices to be productive. An

Figure 43: 3D Printed Hands free Drinking Straw Holder

art-science binary is quite quickly left behind. 3D printing, paper microscopes and low fidelity microfluidics enacted boundaries but also productive interleavings and unfoldings of different kinds of knowing with curious ontological shifts.

It is important to acknowledge the constructed historical nature of the formation of categories like 'playfullness' and 'science', 'art' and 'creativity'. Eva Zerubavel, in her study of 'lumping' and 'splitting' puts forward

> the need to approach classification from a comparative perspective that can highlight our cognitive diversity as members of different thought communities... To underscore the social nature of lumping and splitting, we should likewise note major disputes surrounding the way we classify things. (Zerubavel, 1996, p. 428)

Her approach is another understanding of structure that is spatial like a landscape, describing the heterogeneity of practices observed in the study. From Latour to Zerubavel, spatial structure leads us to speculate on a particular category of practitioner, a 'cartographer' of relations and difference. This critical geographer of social space, attempts to explore and differentiate the complex spatial archipelogos of the world and its practices.

An *Interleaving Practitioner*, much like the STS Amateurs of reality, could be like this cartographer. The Critical kits I developed then are cartographer's tools, a compass to guide and respond to boundaries and directions. Such a practitioner needs to be open to all of Barry and Born's logics and registers of interdisciplinarity and more; or if appropriate, less. I came across many examples in the study of all of these modes, often switching between registers effortlessly. It is important to recall that Barry and Born's convincing logics are not intended to be exhaustive or mutually exclusive (Barry, Born and Weszkalnys, 2008). It is also possible, as discussed earlier to over privilege and stage interdisciplinary play, without acknowledging that people work across disciplines without controversy, friction, transgression or radical synthesis all the time, consistent with what I observed in the 3DPrintClub and on much bigger scales at BLS and DoESLiverpool.

The Interleaving Practitioner feels for the cartography of relations as they happen and with those sensitivities they feel for opportunities, critical moments and employ tactics for affective positive capacities to build on. Embedding in maker culture for over 10 years means there are many opportunities but they are often orientated to further embedding and interleaving, they are not instantly used as art objects, the outputs in terms of artistic production are almost endlessly deferred. In earlier work, discovering the Internet of Things and how to connect the game and phenomenon of Minecraft to real objects and switches resulted in an exhibition and difficult to manage queues of excited children and parents. More importantly for my concern wtih embedding, was an opportunity to embed further into both the culture of both IoT and Minecraft. This 3 year period of work with Minecraft as a learning ecology for doing ethical IoT was in many ways the pre-cursor for Critical Kit making. Instead of just developing a kit which would connect minecraft to the real world in the simplest most efficient way I tried to *fold-in* the complexity of a learning ecosystem that was coalescing around the game at the time; Gemma May Potter's *PatternCraft* (Potter and Whale, 2017) is an example of just one approach, included in my *BioTrumps* card game. The end result was a custom PCB designed to

interface with the Raspberry Pi giving the user a multitude of options in setting up communication networks of sensors over a range of radio frequencies, while folding in a history of radio communication practices particular to a forgotten site of learning in Wray Castle, a National Trust property in Cumbria that had left its scientific heritage largely unacknowledged (Dalziel, 2015).

This interleaving approach is wary of the impact of inclusions and exclusions in both world and kit. Making in this way, anticipating and encouraging complex relationships results in a deeper nuanced understanding of the field of practice. The Critical kit is less important than what the kit reveals. This is similar to the 'implosions' of Haraway and Dumit and other forms of inventive historicizing critique but also the cultural probes and annotated portfolios of Bill Gaver and other forms of research through design. Like boundary objects they are materials to think with, as much as bundles of ontological objects to use. They are a form of learning and critique through making, the core of Ratto's and others critical making projects.

In the next section I explain in detail how developing a Printed Circuit Board (PCB) as part of the *LabFromAChip* project generates these 'implosions' of relations and how through Interleaving of practice attempts to *fold-in* the relations that come to matter that can then *un-fold* to understand what happens in the makerspace. Critical Kits are the specific materials that support this folding and unfolding. Making critically develops awareness of the arrangement of materials, boundaries, practices and desires at work in the kits and in the social landscapes they are embedded in.

Case Study 3: The LabFromAChip PCB

In this case study I follow deeply the learning from the previous case, increasing capacities to care, fold-in and un-fold dense networks of history and relations in the makerspace. It uses interviews with Adrian McEwen and Hwa Young Jung and observations at DoESLiverpool and the orginal Critical Kits symposium.

Making the Implosion

The actual material histories and complexities of even the most basic electronic component used in the most humble maker project or lab bench instrument can be difficult to track, recapture or fully appreciate. Critical kits can be part of an approach to recuperate and foster understandings of that complexity by making and thinking-through-materials.

The microfluidic moulding practices I observed in BLS was an opportunity to begin to understand and fold-in this complexity. Myself and researcher Benedetto, who introduced me to the PDMS vinyl process, began to imagine in our conversations, the vast scales of engineering even the simplest technoscientific object contains from the perspective of *Euglena gracilis* and *C elegans*, the nemotode worm important to Alex's research. Even the most common contemporary man-made fabric from that scale would contain vistas of impossibly uniform mountains and valleys of interwoven organised material. What took place at the scale of local and geo-political history to make these microscopic landscapes possible?

I looked for a common electronic component entangled in maker practices that our model organisms could interact with through this moulding process. The *LabFromAChip* kit facilitates moulds from the surfaces of 'silicon' 'chips', perhaps the earliest imaginary and archetype for computer culture. Each seemingly singular chip is a composite arrangement of electronic circuits of discrete semi-conducting transistors, 'integrated' in a modular fashion, with standard pin configurations and spacing to connect to other components, often refered to as an Integrated Circuit (IC). They are made up of complex layers of exotic materials, arranged to control and respond to the potential difference of energy across a circuit. They are the base for all electronics, signal processing and logical control.

These ubiquitous, domesticated 'silicon chips' are nevertheless contingent on vast technoscientific infrastructures, a kind of 'planetary computation' vividly described in Paul Edward's book, *A vast machine: computer models, climate data, and the politics of global warming* (Edwards, 2010). Edward's 'implosion' project, begins and ends with critic John Ruskin's dream of a 'vast machine' capable of observing and understanding the weather of the planet in 1839, at the dawn of industrialisation. He discusses the material arrangements required for a global computation paradigm required to make contemporary climate science possible. This paradigm is also necessary for me to be able to design and send enineering files from a makerspace in Liverpool to a PCB fabrication house in Guangdong, China, and then receive high quality circuit boards populated with chips and components in the post three weeks later. Edwards unfolds the historical abstractions and colonial extractions of labour that led to the technical capacities of advanced capitalism, but emphasises particular conjunctions of geo-political events. In particular he discusses the technical innovations and imperial competitive drives of two World Wars and the Cold war to make planetary computation possible. Maker culture from this perspective is fully entangled in these ongoing troubling contingencies, every component full of historical traces and implosions.

These chips are incredibly complex configurations of 'black boxed' components, embedded in highly efficient, regulated, standardised yet flexible modular systems. It is no surprise then, that the 'modular system' approach is one of the most distinctive features of many of the technically minded kits considered in my research. The modular system can be seen as an inheritance of post world war systems theory paradigms; perhaps one of the most significant theories in terms of its role in computation, logistics, finance and advanced capitalism. Systems thinking in computer science built the computational hardware base that feeds upwards into the superstructures of all kinds of 'modular' design and practice - from civic toolkits to the built environment to the 'innocent' maker electronic kit 'for everyone'. In the final case study I explore some of the limitations and consequences of the modular approach when well meaning maker innovations meet the messy complex ecological systems of so called 'neglected tropical diease'.

A mind boggling number of transistors must be produced at a difficult to imagine scale to make them available for euro-American makers to use at affordable rates. Vast networks of human and non-human processes and actors, and unbelieveable quantities of raw material must be organised over time and sedimented property, land and labour relations to make silicon chips 'work' apart from good engineering and design. It is possible to use collective critical making as spaces to talk and

think about these implosions of networks, historicizing these incredibly useful black boxes of electronics while using them. Being sensitive to these implosions generates potential critical kits all the time that remaining unrealised.

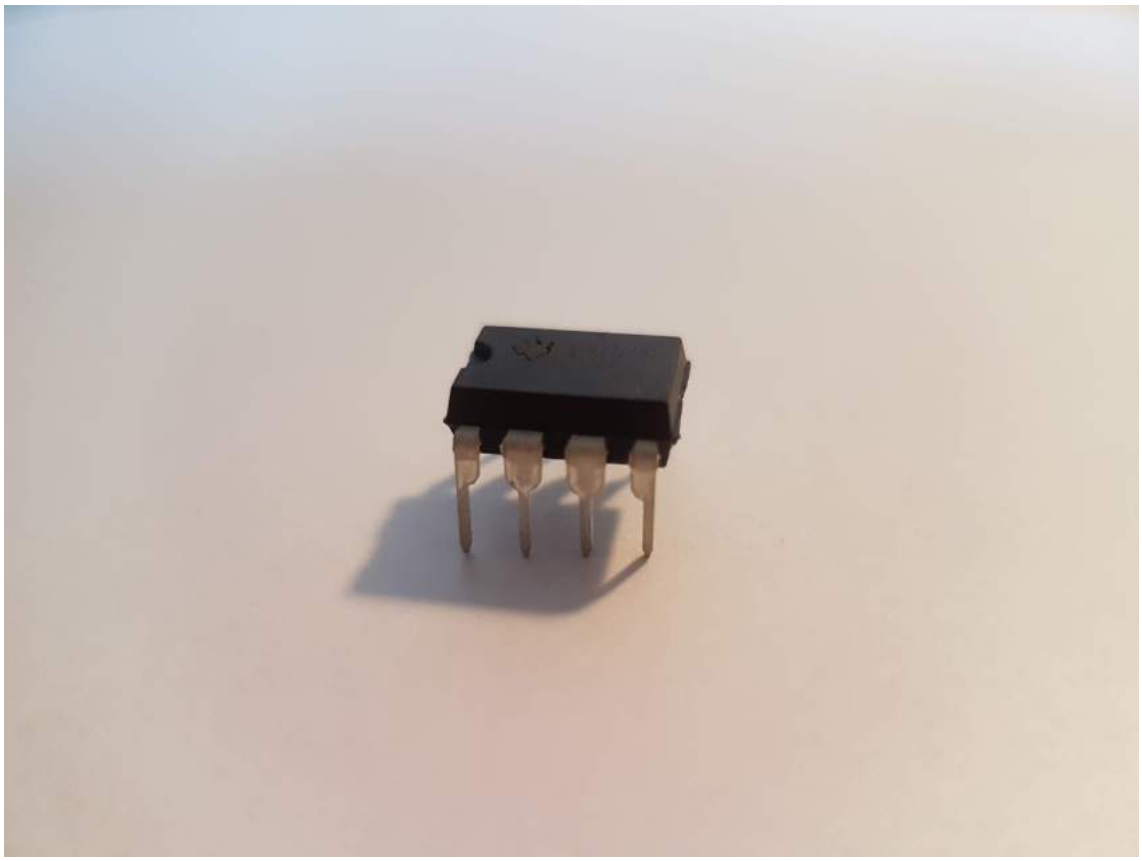

Figure 44: Image of 555 timer chip

I selected the humble 555 timer as a chip (Figure 44) to base moulds over. Although relatively simple, tiny and cheap it can be used to make sophisticated systems of feedback and control. It can process electrical signals over time and can be used in everything from traffic lights to audio synthesis. It is also often used as a heuristic tool for newcomers to maker culture to learn how to control sensors, motors and actuators using hardware a form of resilience and good engineering, leaving software to handle more abstract tasks.

All ICs and electronic components have tiny marks, serial numbers and manufacturer logos imprinted or formed in relief on the IC surface to distinguish it from other components. It is a maker art to tell the difference between a NPN or PNP transistor for example. Carefully submerging or coating this surface using the fine grained PDMS, itself an exotic folding of silicon polymers, supplied in the *LabFromAChip* kit reproduces these markings (Figure 45). Participants using the kits remark how they 'feel' for this tiny scale intimately yet mixed with frustration, the moulding process at the very limit of its resolution. Users are able to exploit sub-micrometre differences and boundaries between paint and chip surface barely larger than the width of *Euglena gracilis*.

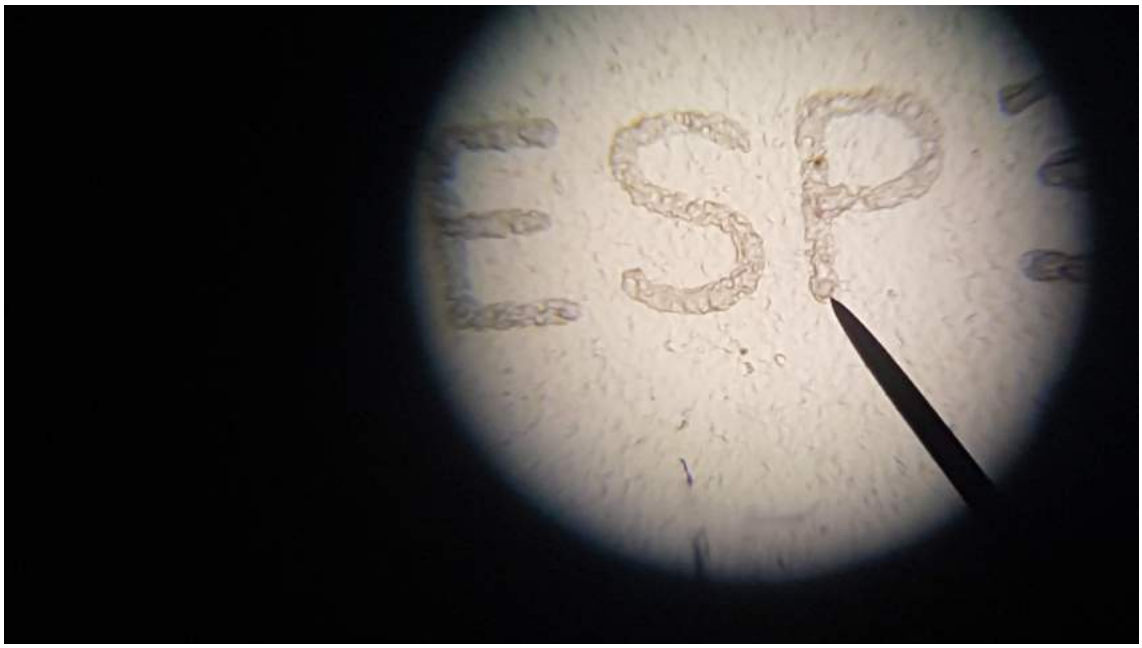

Figure 45: Microscope image of a PDMS silicon mould from the surface markings of an ESP32 microcontroller chip

Prompts and Cues, Folding in Energy Toxicity

As I described in the method assemblage, the prompts and cues for this implosive form of making originate from reflecting on materials and practices found in my research and used in making. These reflections might be part of observations or interactions with participants. What became significant is written in notebooks and a digital journal, lead to material experiments, tactical opportunities to *fold-in* the reflections and subsequent implosions of relations. Significant experiments emerge as GitHub repositories of making files, guidance, how-tos and a log of issues to track 'bugs'; that is problems to be resolved, progress to date and possible 'enhancements'. This is the Interleaving Practitioner taking on a practice, GitHub as a found format, re-empractising. In software culture this is so project 'maintainers' can address problems and accomodate users desires and critique. The larger and more detailed and active repositories in my research were indications of where the most significant work was taking place. In the next section I analyse the community's GitHub prompted by this practice.

These prompts were based on research in maker culture as it was filtered through the specificities of DoES and evolved into tiny experiments and prototypes. A presentation by technologist Chris Adams (Adams, 2019) at the DoES hosted Festival of Maintenance became part of reflections on 'value' and 'cost' of usually hidden maker supply chains and necessary externalities. These externalities are crucial to making components like Light Emitting Diodes (LEDs) affordable to makers in the higher income nation states. Adams' idea of 'energy toxicity' *folds-in* externalities which I make into supplementary `README.md` files (Figure 46) and supply chain maps using maker mapping tools like Sourcemap (Bonanni, 2010) (Figure 47). These were added to many of my research projects documented in GitHub over the period of the study, most significantly in the PCB workshop developed with McEwen to develop

ThingsCon 2018 Designing out Waste Based on the MET Matrix from TU Delft Design Guide	Extraction of Raw Materials	Design & Production	Packaging & Distribution	Use & Maintenance	End of life Disposal
Materials Material as an input mined, grown, harvested)	*What are the materials used?*	*What processes are used to make it?*	*What kind of packaging is used for the item and in transit?*	*What consumables are used by the product? What is needed to keep it working?*	Which bits can be recycled? Are their local recirculation schemes for them?
Energy Energy used in each stage as an input	*How much energy is used to get the materials you use? How did they get to the point of assembly? How far did they travel?*	*How much energy does the manufacturing use?*	*How easy is it to transport? How does it travel? Where does it go?*	*How much power does it use? How much energy is used to clean and service it?*	*How much energy is used to treat the product or prepare for re-use?*
Toxicity Emissions, effluent & waste as an output	*What are the waste products in extracting the material? Where do they go?*	*What happens to the waste materials? How much is created? Can it be safely used elsewhere? Are their toxic emissions associated with Production*	*What is emitted by methods of transport? What happens tobr packaging afterwards?*	*Where do the consumables go after use? Is the product itself toxic to use over long periods?*	*Which bits cannot be recycled? What happens if the product is not treated correctly at end of life?*
Labour Relations What are labor relations like?	Who is doing the Extracting? Is it safe for them? Do they exchange their labor for a living wage? Does the extraction damage where they live?	What's the relationship between raw material and design labor	Is this out-sourced? Can you track the out sourcing?	Who can afford to use this? Are the users aware of the people who make it?	What are the working conditions of the people who dispose of the items?
Is the Labour unionised?					

Figure 46: Screenshot of the Energy and Labor Toxicity Matrix file as part of experiments with sustainable electronics and tracking the cost of supply chain networks and externalities

the *LabFromAChip* PCB. (McEwen, 2020).

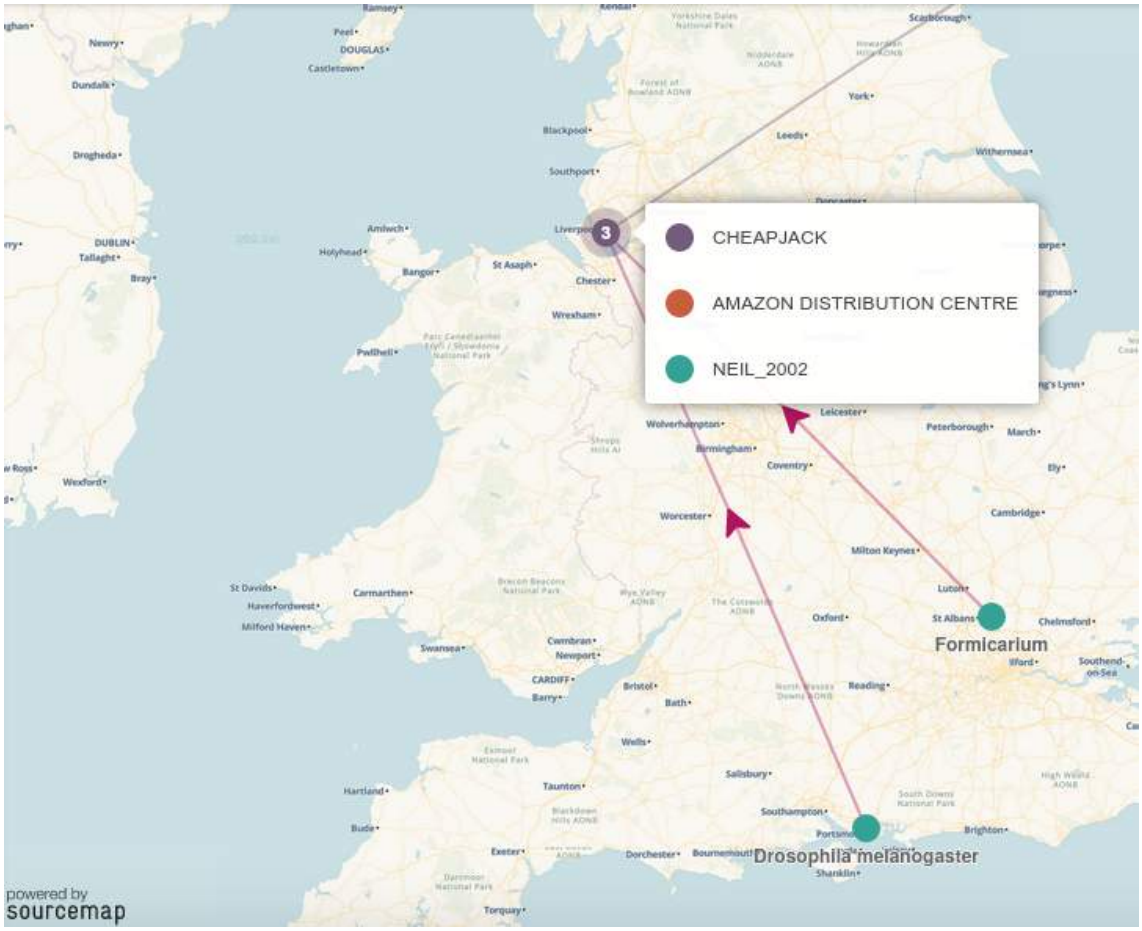

Figure 47: Image of a map showing the geographical source of *FlyFarm* components

Many of the things *folded-in* are not just material components or discursively 'relevant' concepts, but practices grounded in embedded interactions with related projects and communities. The 'Festival of Maintenance' (James and Turner, 2019) that hosts Chris Adams presentation emerged partially through my part in a working group set up to follow up informal discussions about 'maintenance' and 'care', at Liverpool MakeFest, where I had contributed an early microfluidics workshop (Dalziel @cheapjack, 2019; Dalziel, 2021a) and participated in an open debate. This chain of events is easy to post rationalise as contingent and so, strategic. The festival of maintenance would have happened without my contribution, driven by the desire of the maker community and key members of the movement like Dr Laura James. However being continually open to make things not by simply following instructions but by embedding and interacting in collective discourse and activity around it, following and supporting diversions consistently provides creative opportunities in my research.

Instead of simply hiring a qualified technologist like McEwen to make the PCB design (Figure 48), I co-design and co-host intricate workshops with him to introduce makers to the practice of small scale PCB manufacturing (McEwen, 2020). This is the Interleaving approach, to further unfold the labour and social history of making and learning together in the space.

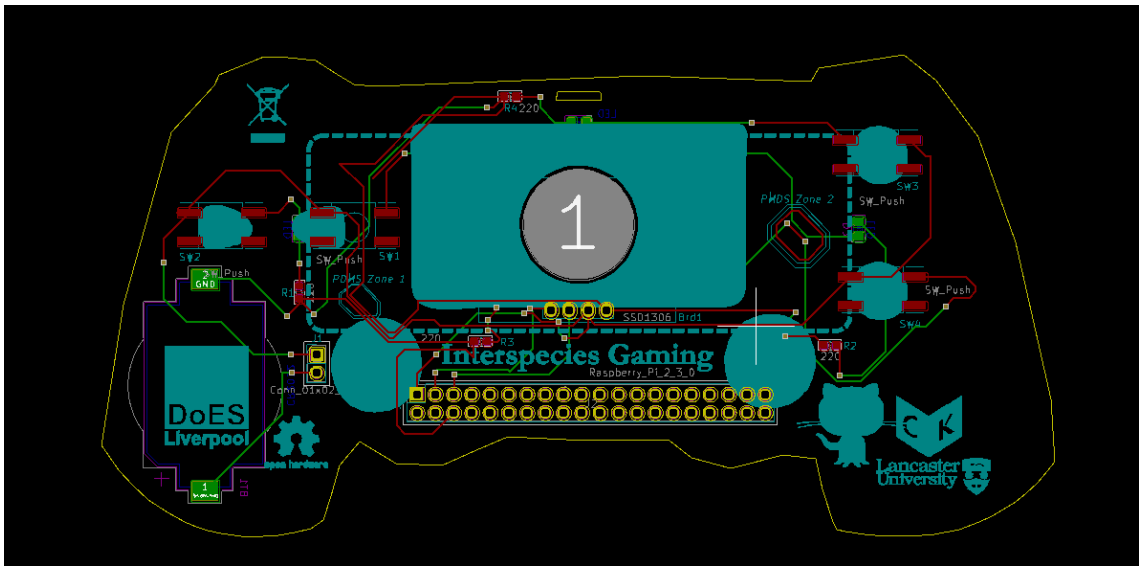

Figure 48: Render of the *LabFromAChip* PCB prior to sending for manufacture in China 2022

Folding In and Unfolding: Making the Story Of The Materials with The Same Materials

The reflections above are informed by the implosion practices of reading and writing and understanding the methods and perspectives of Science and Technology Studies I describe at length in The Practitioners chapter. But primarily they also come from the slow collective reflection while making, sharing stories of electronics. This material experience, physical embodied cognition, also folds-in, interleaves. The kits fold in the nuanced making practices of BLS and DoES and the nuanced physical experience and history of social learning. I learn the basics of microfluidics by making the *LabFromAChip* kit and then the basics of using 555 timer chips to develop a PCB and then can understand how makers make PCBs together (Figure 49).

The simple design (Figure 48) illuminated a prepared slide as part of a printed circuit board (PCB) that held the slide together with a Foldscope. It was light enough to be handheld but robust enough to hold the slide, Foldscope and potentially a phone to take images from the 'scope. It also supported the addition of a cheap 128x64 OLED screen that can be controlled with a raspberry pi zero control sequences of lit pixels to interact with the light sensitive algae. Onboard buttons illuminate the slide from a left, right, top, down arrangement of LEDs. This means when *Euglena gracilis* are properly prepared they respond to LEDs in such a way that it is possible to 'control' them. This folds-in another practice, biotic games and the concept of Interspecies Gaming developed with Isabel Paehr of Artist collective TopicBird at the DisruptEncodeConsolidate symposium at the beginning of the study, described in the Practitioners section. Even the design of printed marks and tracks of conductive areas and their surrounding insulation are shaped with the unusual design parameter of what kind of microfluidic moulds they might produce in addition to their capacity for functional logic control. The PCB itself provides the moulding patterns - it became the chip that the lab is from. (Figure 50)

Finally it folds in maker 'badge' culture. Local and national family friendly maker

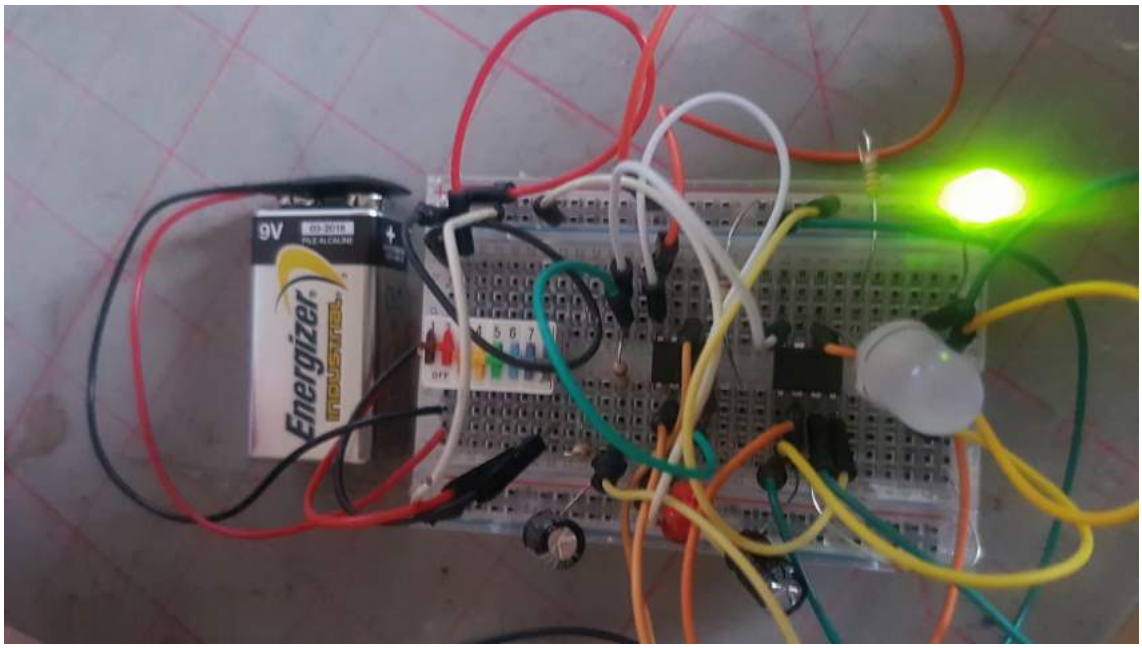

Figure 49: 2 x 555 timer traffic light kit made from surplus components found in DoESLiverpool originally donated by the National Oceanography Centre

events like Maker Faire Newcastle and Liverpool MakeFest that myself and makers contribute to collectively, are important moments for maker culture to connect beyond their local spaces, share practice and reveal to unfamiliar general publics their possibilities and identities. Lasercut name badges with electronics featuring an event design are worn with pride and affection and form cohesion at such events, where maker identity is at its strongest. Other similar technical events, less family orientated, include the european hacker friendly, Chaos Computer Camp and Electromagnetic Field Camp. These have taken the badge making practice to ever more elaborate and sophisticated extremes. Badges display names, but allow you to play games, connect to the internet or run operating systems on tiny screens (Clough and Lloyd, 2015) (Figure 51) The PCB design I made is lanyard compatible - a wearable name badge following in these affective maker traditions. (Figure 52-53)

> They [implosions] require promiscuous knowledge; they seem to accuse one of not having done enough homework. Anxieties arise, some look for an exit. Even worse, the connections may threaten the well-made world one lives in. One senses a potentially dangerous demand in them. (Dumit, 2014, p. 345)

This then is how to *make* Dumit and Haraway-like implosions; a model for an STS method without naming it as STS, what one participant in an STS 'Making and Doing' session with the *LabFromAChip* kit at EASST4S2020 in Prague called a kind of 'folk STS'.

Interleaving practices and critical making are potential ways of embedding STS inspired method inside maker culture, to increase the capacity for intervening in a radical pedagogical mode. In my observations, maker culture and STS already have this mode baked in. Makers are driven by curiosity and enthusiastic but fundamentally agnostic and open desires for 'better' inventive technology; much

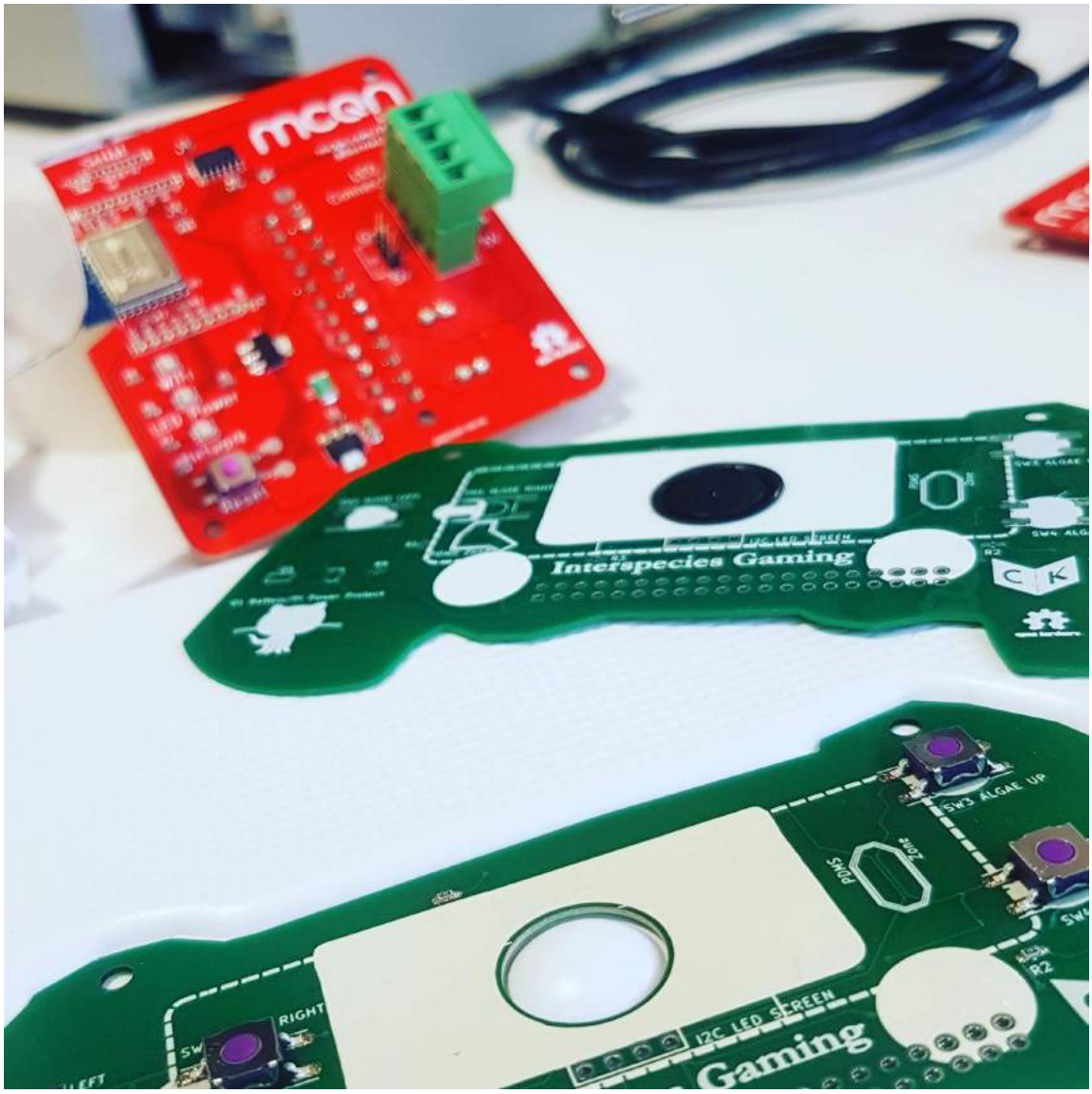

Figure 50: *LabFromAChip* PCB after 'cooking', heating up surface mounted components

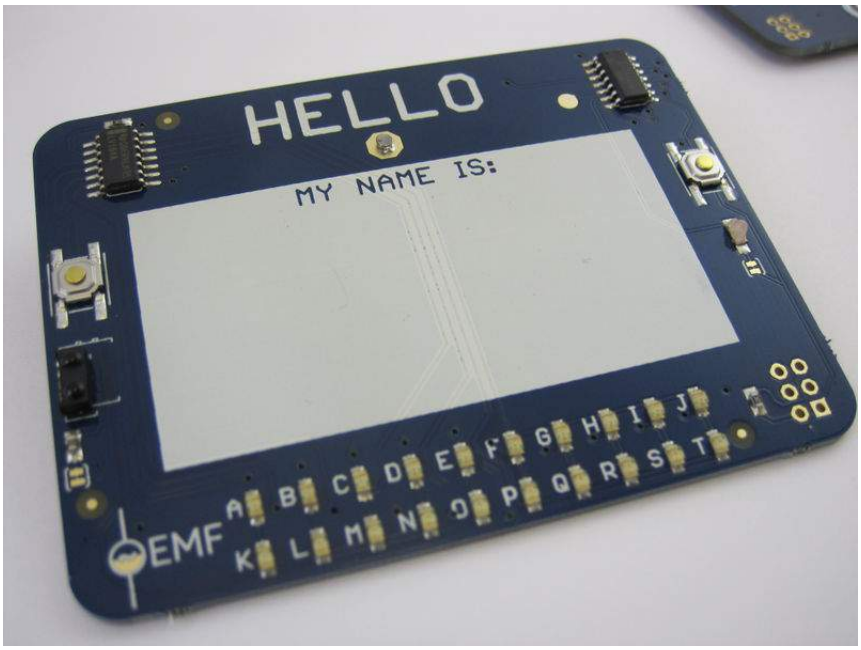

Figure 51: Maker name badge PCB image credit: EMF Camp Badge wiki contributor Thinkl33t

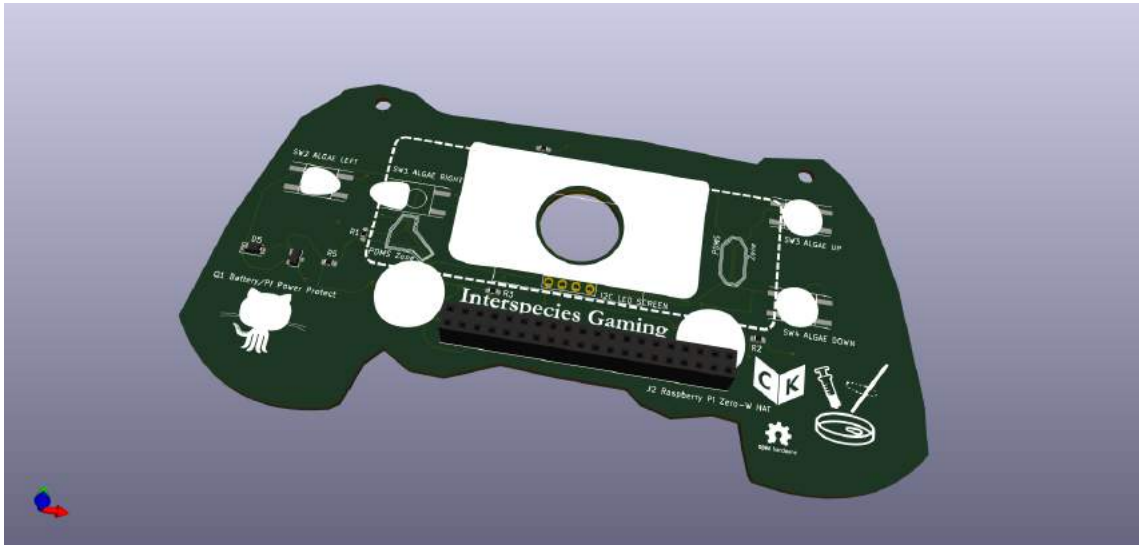

Figure 52: *LabFromAChip* surface mount PCB render in KiCAD software

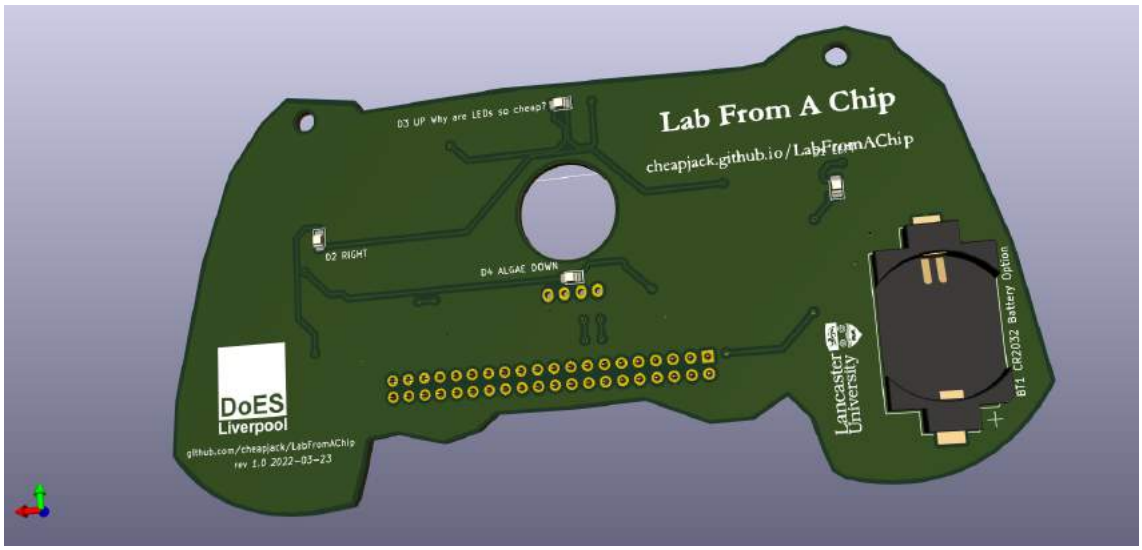

Figure 53: *LabFromAChip* reverse PCB render in KiCAD software

conversation in DoES includes strong critique and a healthy discourse for making technology efficiently and ethically. STS' basic approach is to ask fundamentally '*cui bono'* questions: 'who benefits?'. Such questions can sometimes be elided by assumptions in maker practice. Critical making attempts to interleave critique within maker culture's desires. My approach to critical making aims to build on the practices of critique already present at DoES.

The PCB project, interleaved with its set of workshop materials made with McEwen, run live in lockdown on a video platform. These are not just useful tutorials but also a strategic experiment to foster friendly and safe critical spaces to explore ethical making, energy and labour toxicity together. This is the potential of the approach to provide practical tools and tactics for developing critical making beyond academia, embedded in technoscientific making practice. Later in BLS I discover how innovative academic papers and projects using maker approaches to molecular diagnosis for endemic disease fail to document important nuanced local knowledge that would make these prototypes 'work' in the Low to Middle Income Countries (LMIC). The practices of verbose documentation, issue tracking and online making together, which were instrumental in the *my-first-pcb* workshop, could prove useful in capturing this nuanced local knowledge and would be a rich area for further research.

Each interleaved 'component' in the PCB represented an aspect of maker culture observed and became a tactic for learning how to develop technology. Technically it teaches open-source design, power management, knowledge of components, hardware logic and how to manufacture something. It also represents and fosters a sense of a technoscientific ecosystem, how to be compatible and work at different levels of complexity. The kit embodies many of the practices and material thinking of the overall thesis, telling the story of the methods and the materials with the same materials and methods.

Tactics: Should Critical Kits be Easy to use?

A so far unacknowledged question must be addressed. How difficult should learning be and what to learn? In the original symposium in November 2017, a provocation to both makers and artists present was to discuss the question, should Critical Kits be easy to use?

Too easy and prescriptive a kit, what participants call 'closed' with too much 'hand-holding' reduces interactions to a linear series of instructions to replicate, mindlessly reduces participants to human pick and place machines that makerspaces dream of, the devices that assemble PCB's at scale. If they are so open, with no prompts or instructions then there is little challenge or 'friction'. Too difficult and they inhibit learning and alienate newcomers. One of the earliest maker educators, Seymour Papert developed his Piaget influenced constructionism as the ideal maker learning paradigm. Reviewing his paper he wrote with Cynthia Soloman in 1972 their examples remain almost identical in approach and content to the tutorials found on the popular CodeClub website (Foundation, 2020). For Papert and his maker inheritors, making with technology and computing should be learned through practical experimentation and failure within a system to build real complex understandings that can be then applied to more complex systems. The focus is on an educational experience and shared history of learning. Kits can provide 'all you need' for that experience or just point you in the right direction but it can be a hard balance to achieve. The conversation below between my colleague Hwa Young Jung (HY) and McEwen (MC) published online in 2017 (Dalziel and Winterburn, 2016) sum up this contradiction and tension.

> **MC:** 'I don't think that a hard to use kit is the only way to engage deeply with people. A good kit would provide routes in for all - that's not the same as being dumb'
>
> **HY:** 'Yes, I concede. Just because you can't use a difficult kit doesn't mean you are stupid. However, I'm instead asking if difficult kits are being sidelined in favour of easy gains with very simple kits that do not engage beyond a few minutes and doesn't add to knowing more about something other than self congratulatory backslap. . . they should be difficult to use because people have to think HARD about what they are doing with their lives
>
> **MC:** 'They need to be easy to use so that people can engage with them - particularly if they are to be used in isolation from the creator/artists - otherwise their point might be lost (Exchange between participants at the Critical Kits Symposium, 2017)

Interleaving 3: Folding In

Interleaving Practices can be understood as a *strategic* method. It anticipates opportunities to *fold-in* all kinds of complex learning and labour. In this case a makerspace practice, the ability to design and fabricate printed circuit boards (PCBs), with the making practices of the biomedical lab. They can also fold-in what might

be otherwise excluded as externalities. My study revealed how some technologists like McEwen and many of his colleagues at DoES, try to include these externalities, in their attempts to make a democratised Internet of Things ecosystem, or Adams attempts to de-carbonise the web (Adams, 2019).

The utility and ease of a black boxed device that consistently performs is deferred for time spent on developing learning resources. The simple modular soft circuit for the Wearable Tech Workshop are part of my practice but also considered as a part of a strategic encounter among many, enfolded and interleaved with the making process in order to understand how makers respond to more formal group workshops than normal messier drop in evenings. But it also builds capacity mutually. Each encounter attempts to produce a space for learning and critique, but also a sense of care. How do we get these components cheaply and why? How can we scale products ethically? How can makerspaces make critical interventions in technological production?

One criticism of this approach is that in some respects the interleaving of different practices and material encounters happens all the time. One may ask the reasonable question of how that can be differentiated into a specific method with testable propositions to deduce conclusions, if it is strategic, what does it analyse or predict? Interleaving and critical making *sensitises* and *orientates* practitioners to critical work rather than offer specific testable predictions or guarantees. It is strategic by building capacities for interdisciplinarity and critique but might not lead to an autonmous art object or definitive understanding.

Case Study 4: Interleaving Biomaterials

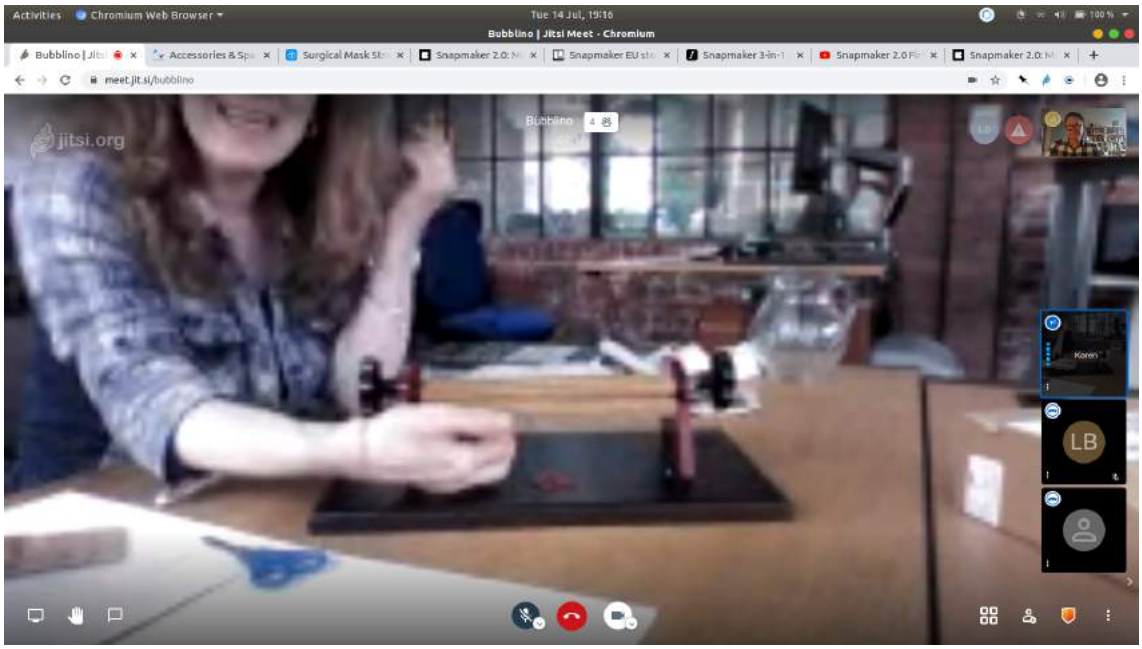

Figure 54: Princess pleater demonstration at a Wearables night

In this section I present the analysis of observations of interleaving in interactions with DoESLiverpool and the Wearable Technology Interest group and other activities

in the space and online during pandemic lockdowns. I interviewed two DoESLiverpool directors, McEwen and Jackie in the final year of the study which became a form of co-analysis of what went on in the space. This analysis contributes to the understanding of Interleaving Practices and Critical kits as a method for revealing what goes on in complex social assemblages.

In DoESLivepool in the case studies 3, 4 and 5 there was some resistance to the idea of strategy from some research participants in interview. For them, strategy implied top down planning things out for some dubious end goal, perhaps accepting or supporting conservative mid-term gains; such as funding with strings attached, or forming a difficult coalition with large institutions that restrict action. Instead they favour developing a *culture* through doing, the ongoing maintenance and care of present capacities. There is a relation between culture and strategy but I argue that making and maintaining a culture with care ultimately *is* a strategy and perhaps part of how DoESLiverpool's community although not really growing continues to *flourish* on their own terms.

Microbiologists do this in an analogous practical way all the time very carefully to understand the behaviour of the otherwise invisible. On the macro scale of lab work, they must apply for funding in a competitive capitalist market often forming uneasy coalitions with the commercial world. On the micro scale, they isolate communities of bacteria and other organisms on a growth medium in a petri dish that includes agar, a jelly like material derived from red algae so that the microbial communities grow to a legible size. I explore how this day to day practice became an art-science activity for undergraduate biologists thanks to a unique approach to teaching microbiological technique by Dr. Rod Dillon and Prof. Jackie Parry, in the Lost in the MicroMart section of Chapter 5.

Both culture and strategy across macroscopic and microscopic scales resonate with political theorist Rodrigo Nunes calls for an ecological approach to political organising for the ongoing crises of our historical conjuncture, described in the section Organizing through Interleaving in the final concluding chapter.

The sprawling discussions that follow explain my deeper understanding of social structures and assemblage not just in a spatial sense like in Wenger-Trayner's landscapes of practice but complex collective *care-full* approaches to *temporality*, from pragmatic triage to Futuregazing full of maker *desire*.

Introduction

The Wearables group evolved from regular weekly 'maker nights' that is an essential driver of the DoESLivepool community. Maker night originally drove the formation of DoES, when a small group of the tech community in Liverpool coalesced around an evening hosted by local universities, organisations or pubs. Some of this group began to share office and workshop space and went on to form a Community Interest Company (CIC). Maker night has been a regular Thursday evening event for most of the organisation's life, where the workshop is accessible to 'anyone'. The existing community, Wenger-Trayner's 'oldtimers', are encouraged to stay and help; while 'newcomers' are welcomed. Newcomers hear about the makerspace facilities and

community from an idiosdyncratic mix of word of mouth and advocacy inside and outside the technology community and wider Arts and Crafts ecosystems of Liverpool.

DoES is a unique mix of freelance software and hardware developers, hobbyists, craftspeople, engineers, IoT companies, start ups, translators, designer, entrepreneurs, artists and embedded systems engineers with a shared interest in affordable co-working and a supportive technical community. Over time the community acquired digital fabrication equipment through a mix of pooled collective resources, donations and other mutualist negotiations. Lasercutting and 3D printing and the software development skills of the many freelancers based in the co-working area attract designer, artists and crafts people from across the city. Governmental, academic, arts and cultural organisations form informal relationships with DoES of varying depth and complexity, from simply sending digital artists along to visit or use facilities, using event spaces and communal knowledge for local and national initiatives, long standing relationships with an organisation's technical team or direct creative projects like the project I collaborated on with FACT, REACH and the Crafts Council, *DesktopProsthetics* (2015).

On top of this is a loose network of organisations and interest groups who use the meeting rooms regularly such as Livlug linux user group, a sewing club, board meetings for SME and NGO's, Extinction Rebellion and Liverpool Jelly, a regular pop up co-working event. The Wearable Interest group was originally formed as a similar but irregular group to maker night, but to introduce people outside and inside the commmunity to the use of e-textiles and hybrid mobile technologies that included Internet of Things technology, small scale manufacture of Printed Circuit Boards (PCBs), fashion and textiles. Various members projects used the Wearable group to explore and develop fledgling projects and it often feeds into regular maker night activity. For example I ran a wearable hackday with the group to explore an unrealised project about affective touch with a local neuroscientist.

The group contributes to many DoESLiverpool community projects that are particularly hybrid and interdisciplinary mixes of technical culture, art, science, engineering, IoT and craft practices. Recent examples include prototyping responsive sensors for hang gliders, helping a local designer build a dress made from recycled plastics building on work with another interest group, 'Plastic Playgroup' and an interactive LED system for performance for local carnival performers, Brouhaha.

Strategic Encounters with Materials

During the course of the study I setup a 'Biomaterials' sub group within the Wearable group with co-director Jackie, a bi-monthly evening session on alternate Tuesdays (Figure 54) to appeal to the engineering sensibilities of makers and inspired by a book found in BLS (Figure 55). The field of DIY Bio is as varied and complicated as what Callon might call the 'secluded' biomedicine of any institution, in some cases like Biomakespace in Cambridge they are connected and run as part of a Biomedical institute ('Biomakespace Cambridge', 2016). Activity ranges from one of the oldest online BioArt groups the Slime Mould Collective (Barnett, 2009) to makers finding bioplastic alternatives to plastic, open-source microscopy, DIY/maker implementations of electrophoresis, PCR and experimentation with CRISPR or

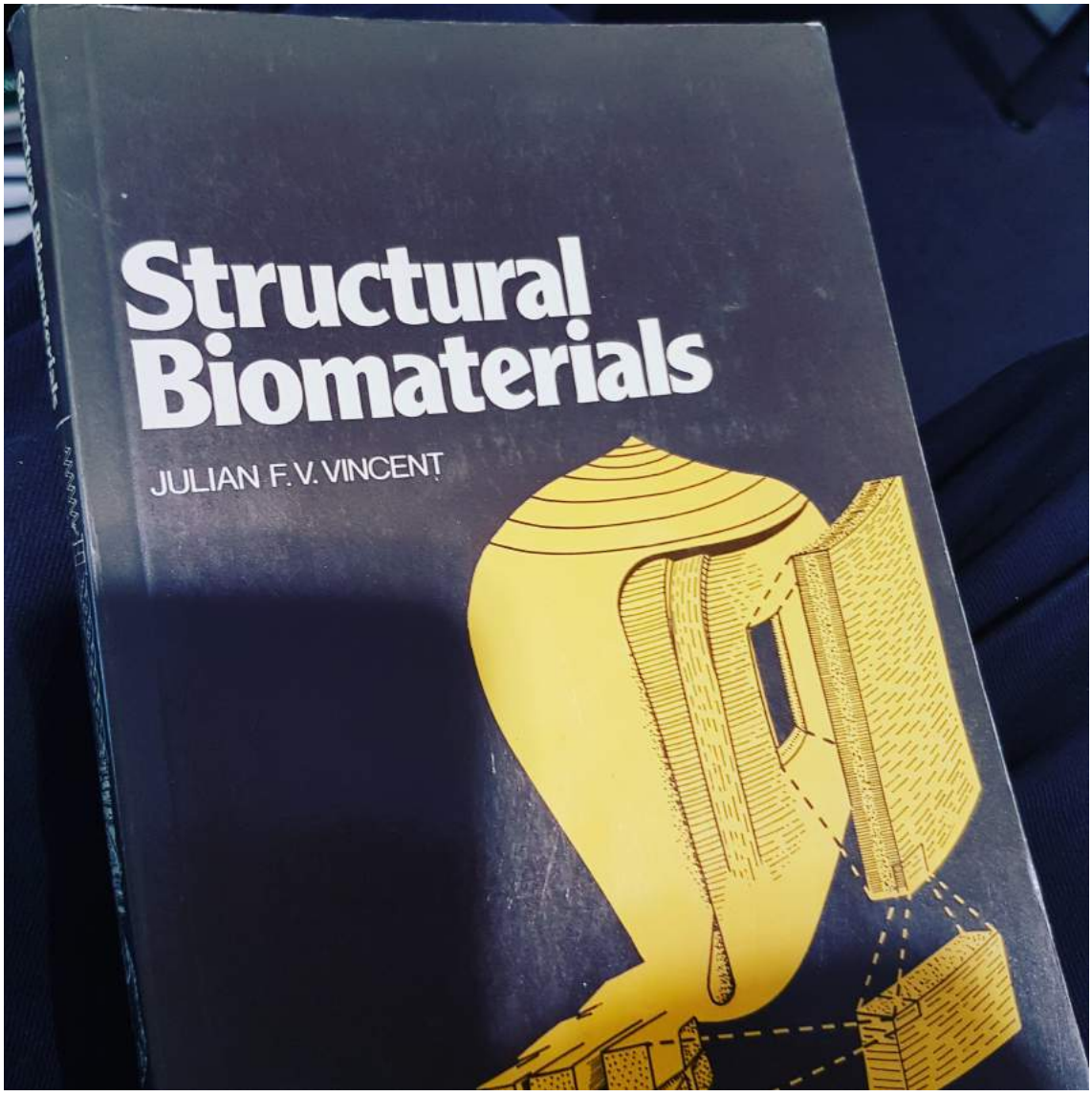

Figure 55: Cover of book on the physical properties of living material 'Structural Biomaterials' by Julian F.E. Vincent

just the cost saving pragmatists of Lab On The Cheap (Lemma *et al.*, 2021). My approach was to swap the DIY Bio term with the less controversial 'Biomaterials' to avoid the common wildly enthusiastic and over ambitious attempts to do DIY genetic engineering. As part of my research I began to consider how Rod Dillon and Jackie Parry's undergraduate art-science module MicroMart might be run in a makerspace, maker faire or art festival. Despite beginning to document the process in GitHub (Dillon and Jackie Parry, 2014) this was quickly abandoned; health and safety concerns and lack of infrastructure to manage basic but nevertheless formidable minimal safety requirements for microbiological culturing techniques meant this practice could not just be 'dropped' into the space. My approach was to introduce easily transferable microbiological practice I observed and responded to at BLS and from the DIY-Bio practices I discovered in my research and through relevant literature. Initially I prototyped, sourced and re-made maker culture alternatives to expensive lab equipment. Centrifuge, scales, microscopes, electrophoresis tanks; all have their fascinating maker versions made using popular maker materials and methods - 3D printing, Lasercutting, CNC milling, Arduino and Raspberry Pi sensor and actuator control.

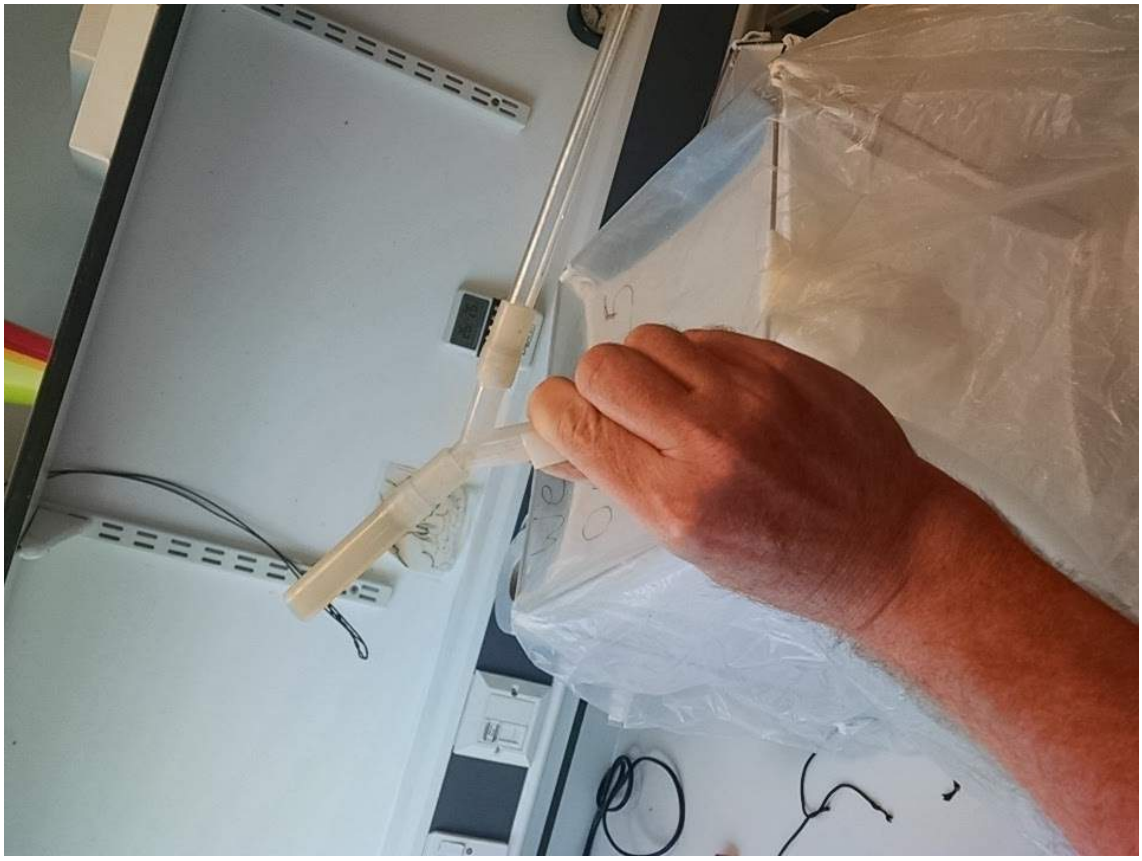

Figure 56: DIY Insect Valve made by Dillon for transporting infected Sandfly

In BLS however, not all the equipment is expensive and highly standardised like the inscription devices Latour categorises. Scientists often setup creative experimental apparatus very much like makers (Figure 56). Although DIY Bio might be described by someone like Michel Callon, as a form of 'research in the wild', with makers a category of 'public' taking microbiology out into 'the wild', there is also a DIY maker approach *inside* Callon's 'secluded research' of the institutional lab, which in BLS,

are not nearly as 'secluded' as one might assume. They are besest by precarious resource issues and need to find 'just good enough' data and 'just-in-time' solutions like makers or artists might. Transporting and manipulating fly colonies crucial to the study of endemic disease often need bespoke DIY solutions that make lab benches as creatively messy, disruptive and ad-hoc as any makerspace.

Figure 57: Biomaterial subgroup rackspace at DoESLivepool

DIY re-enactments of lab practices, experimenting with lasercut and 3D printed microscopes and appropriating microscopes bought for inspecting electronics to understand algae and yeast soon revealed what was at the core of the wearables group's and many makers practice. It is a commitment to exploring playfully what materials can be used in technology, like Kombucha leather (Figure 58-60). This playfulness is partly an engineering necessity if computing is to be freed from server farms and desktops and worn like clothing. Wearables was seen as a way of doing technology differently, a shared interest in the community. Exploring biomaterials, which fits this sensibility, can then be used in existing maker practice and sit comfortably and safely on a makerspace shelf (Figure 57) was a more sensitive and appropriate approach than setting up a DIY Bio laboratory.

Flexible circuits and e-textiles were already an established practice in the Wearable group, but prompted by my interventions, participants began to experiment with *growing* materials such as Kombucha leather (Figure 59), bio plastics and mycelium bricks (Figure 61-64,66).

Fermenting Encounters

Straight away together with participants I discovered interesting new social negotiations and relations to make these two materials 'work' in the space. In DoES like many makerspaces, limited space requires members and communal works in progress to be stored in open racking around the space shared by regular and permanent desk

Figure 58: Kombucha leather prototype lamp (Jackie, 2019) Image credit: Jackie

users. Kombucha leather is grown by a mix of yeast, bacteria and tea fermenting to produce a fizzy yeast drink. In the fermenting process a byproduct is a thick bacteria and yeast layer of organic materials known as a SCOBY, an acronym for 'Symbiotic Culture Of Bacteria and Yeast'. These slimy layers can be removed from the fermented drink and then dried out and pressed into shape that given time can then be lasercut. However fermenting is a time and space consuming activity and can also give off a not entirely pleasent smell and in our case attracted wild fruit flys in the space in the summer. Office users tolerated this but it soon became not just too messy or smelly a technology for the space, but required large amounts of dry warm air and horizontal drying racks to prepare consistent material for lasercutting, not feasible in a shared office space. This felt like a missed opportunity having developed a local supply chain - a local start-up producing kombucha drinks from an industrial estate in nearby Toxteth agreed to provide us with their large SCOBY by-products.

Similarly experiments growing mycelium sheets (Figure 61-62) proved difficult to contain potentially hazardous spores so other experiments re-using cork was explored (Figure 63-64). Maker and co-working culture in DoES is tolerant of experiment and open to innovation but it generally requires dry relatively benign ambience not smelly spaces. What was interesting was that tolerance for leaking lasercutting acrylic fumes was higher than the harmless smell of fermenting yeast.

The Materiom project (Corbin and Garmulewicz, 2018) was a response by a group of makers and researchers in the midlands of the UK to develop shared open-source standardised recipes for making biomaterials in maker communities. There are many Instructables and instructions available online explaining how to grow and make materials but there are no shared spaces where certain material standards can be developed or maintained and presented in a way open to beginners making with these alternative materials. We began using 3D Printed moulds to experiment with Materiom recipes recycled cork, algae, coffee and eggshell composites and bioplastics

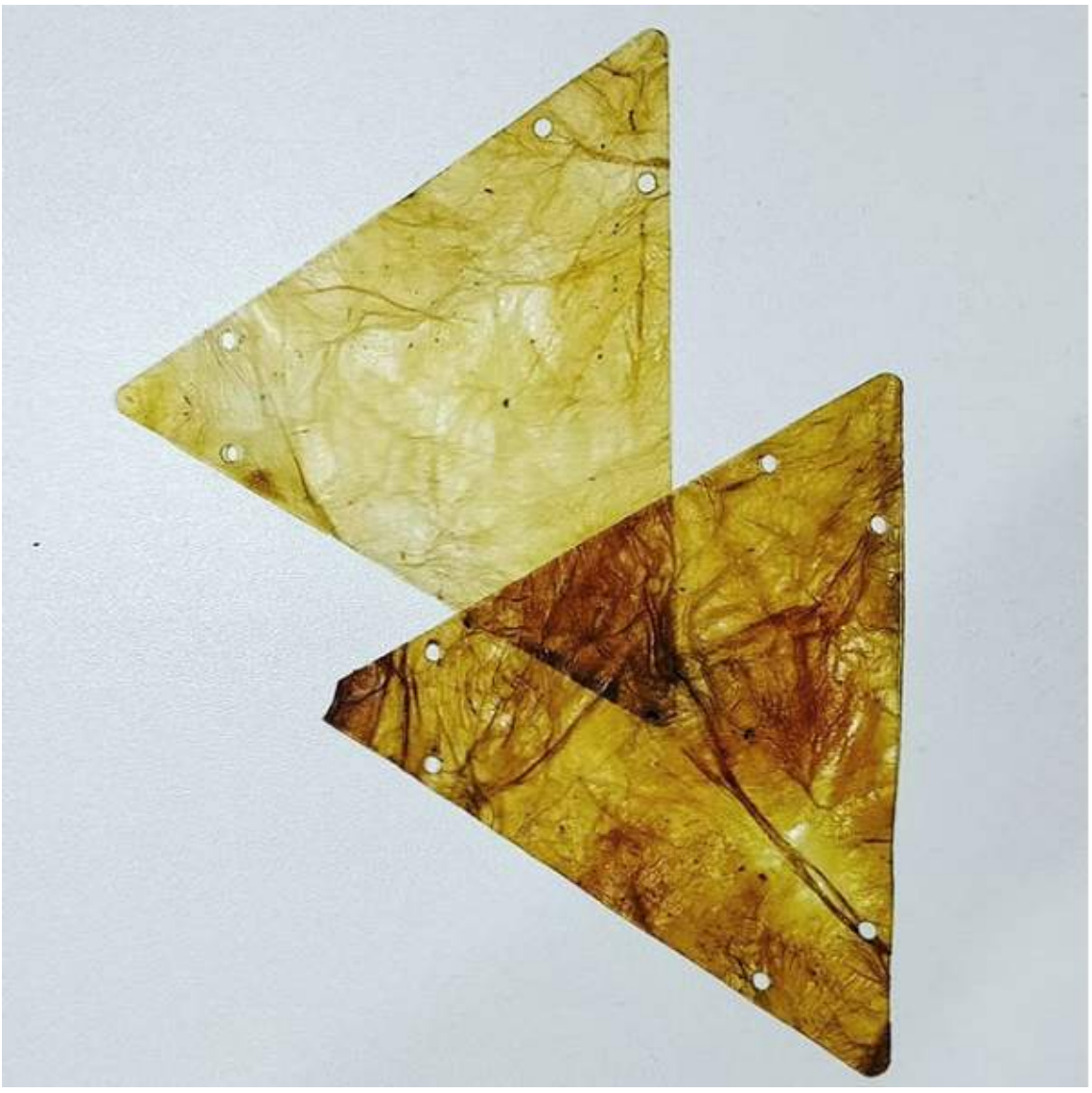

Figure 59: Kombucha leather experiments. Image credit: Jackie

Figure 60: Kombucha leather experiments

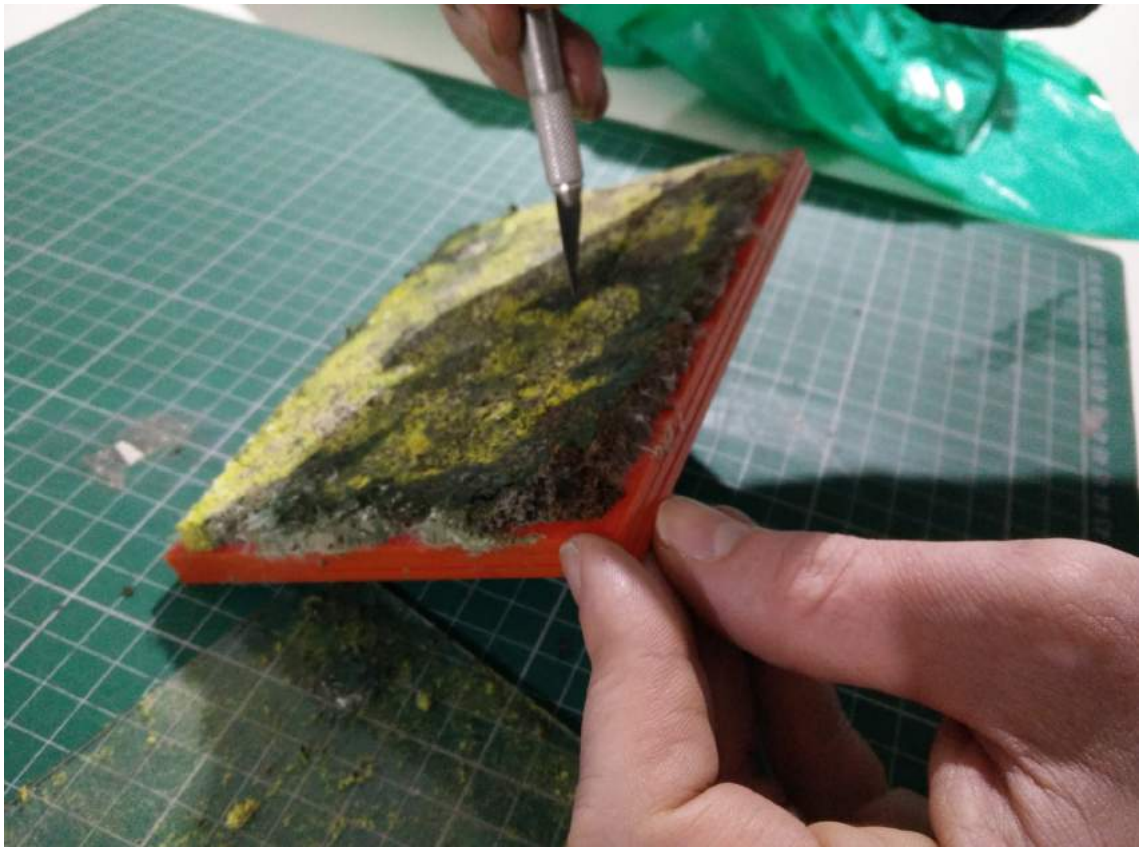

Figure 61: Mycelium growing material experiments

Figure 62: Mycelium growing material experiments

that use the complex molecules of sugars and proteins such as agar agar and Agarose (Figure 61).

Materiom is a serious attempt to develop maker capacities for biomaterials, and it is significant to this study that they used a Kit format and rich documentation. Toward the end of the study myself and Jackie took part in a series of workshops developed by Materiom and the makerspace STEAMHouse with a biomaterial kit, called the *BioBox* (King and Powell, 2021) (Figure 65). These kits distributed core materials and substances to get started in Biomaterial making and growing. They work within a more formalised logic of innovation however. The workshops that myself and Jackie attend are articulated as a strategy to foster the development of new innovative maker markets and intellectual property. They have a worthy and clear strategy; to capitalise on makers, artists and designers curiosity and material experimentation in order to introduce alternative sustainable materials into the maker ecosystem, and wider creative industries.

My use of 'biomaterials' had different strategic goals to Materiom, to expand the repertoire of making in the space in a way that would intervene in practices and reveal working practices. I wanted to understand how the introduction of the messy, wet complex indeterminancy of biological material; experimenting with algae, growing Kombucha leather and experimenting with DIY microfluidics (Figure 67-69), could make a difference in the maker practices of the space. From the Interleaving perspective these can be seen as *strategic enounters with materials*; taking time and care in the present with specific materials to interleave different practices for later

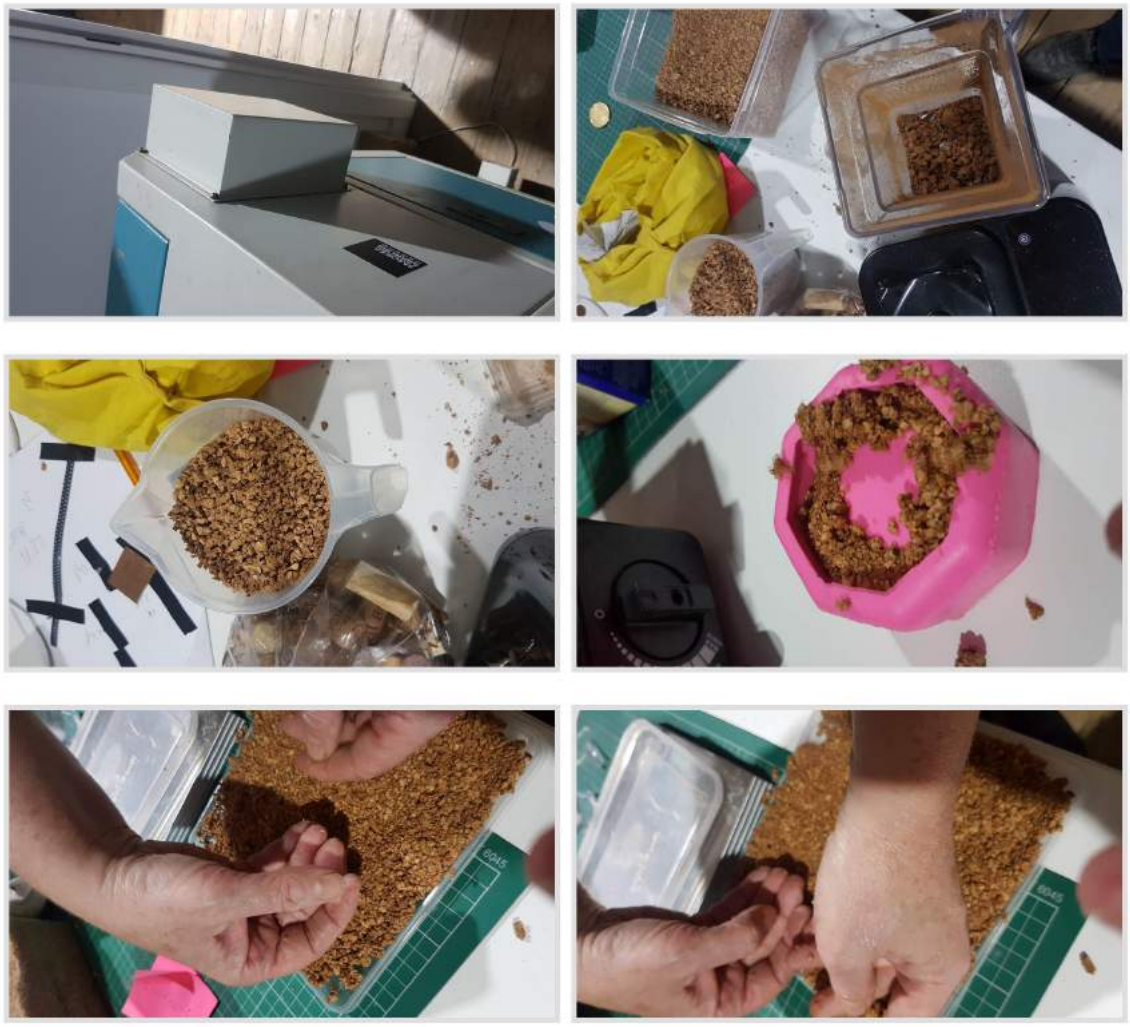

Figure 63: Cork composite moulding experiments

Figure 64: Cork composite moulding experiments

Figure 65: STEAMhouse BioBox kit (King and Powell, 2021)

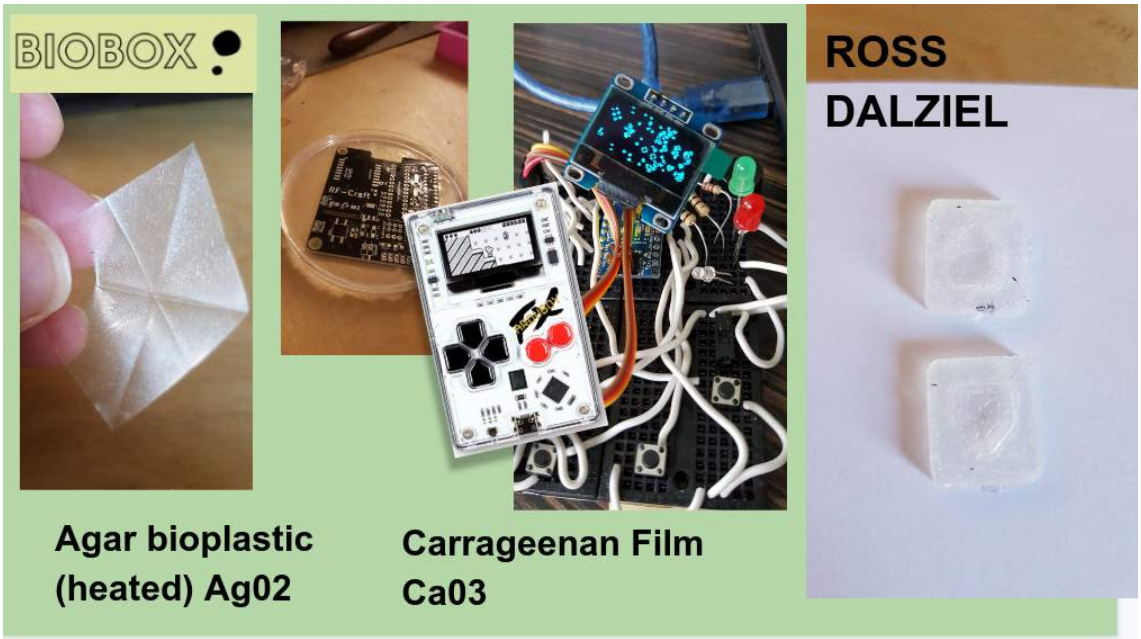

Figure 66: Presentation slide of Biomaterial experiments using the BioBox kit at home for an online STEAMhouse workshop

flourishing.

In my research making with biomaterials productively revealed the interleaved care and maintenance required to realise them. By extension it also reveals how all technoscientific materials are not only valuable because of their inherent material properties and qualities but because of the dense networks of practices; of care and labour, of standardisation and collective discipline, of creative experiment and speculation. This network was what I wanted to reveal, to access and develop capacities for. Materiom wanted to use this network to foster sustainable materials production, to intervene in the proplematics of making sustainable alternatives to extractive production. My Critical Kits and Materiom's, the *BioBox* (Figure 65) to a degree, shared the articulation of the state of the network - the density of care and labour in order to make something happen. Critical kit making is a set of strategic encounters with materials to *fold-in*, orientated to reveal and *un-fold* social interactions and produce new capacities, rather than 'artistic' outcomes or art production.

What was unfolded was how the DoES Liverpool community and its 'culture', run almost completely on different forms and categories of care, interleaving the maintainence of complex collective infrastructure and the freedom of access to individuals seemingly at the same time. Just like in the NMC, by caring for materials and infrastructure, the community care for each other. Interleaving is about developing sensitivities to actually existing practice instead of focussing on developing completed artistic art-science works. It's worth noting however this latter approach, making fully realised products and kits is also what the culture of DoESLiverpool desires.

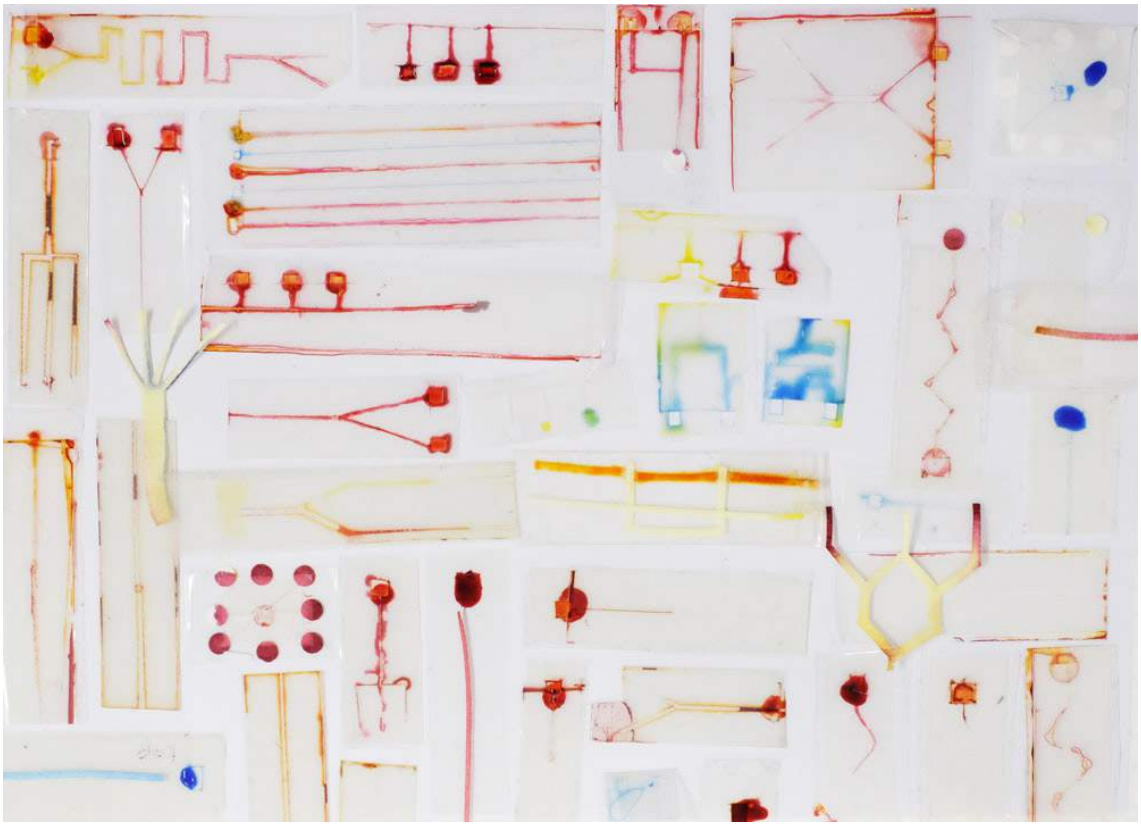

Figure 67: Image of microfluidic chips made in the Science Practice studio from the blogpost *Low-Tech microfluidics* (van Schaik, 2015) Image Credit: Science Practice Studio and van Schaik

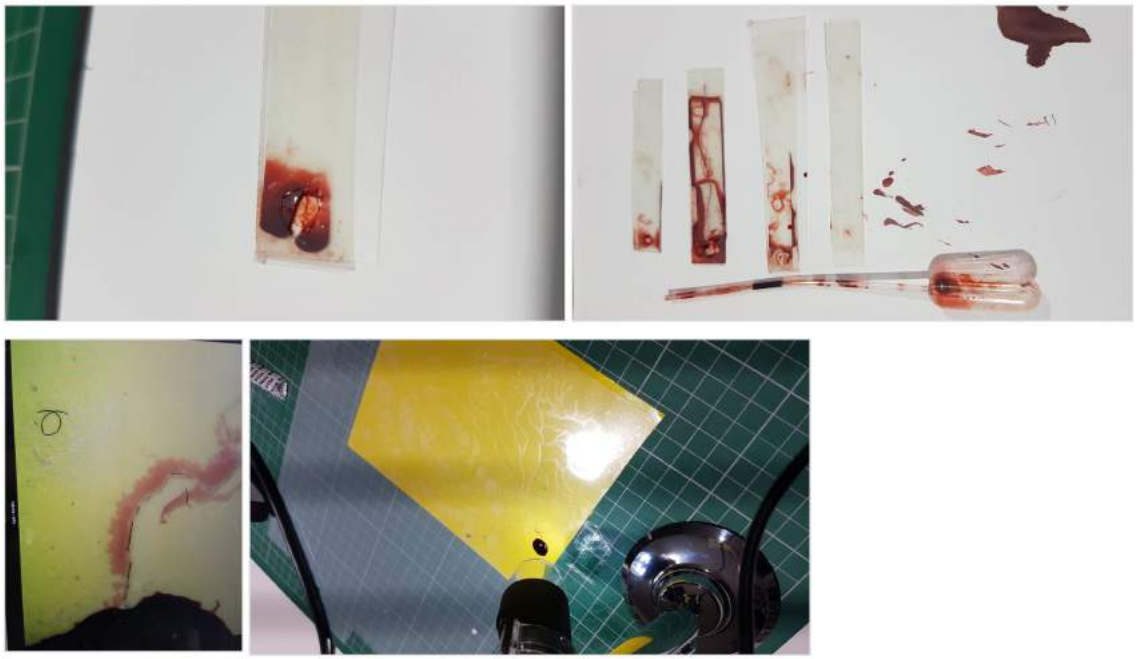

Figure 68: Image of DIY microfluidic experiments at DoES in response to van Schaik's work

Figure 69: Social media post of online paperfluics discussion

Wearable Tech Badge Workshop

Alongside the biomaterial work the group and I developed a Wearable Technology starter kit in the form of a wearable badge (Figure 70-71) and associated workshop (Dalziel, Pullig and Pease, 2020) for beginners inside and outside the community to learn how to build simple cost effective and easy to use platforms for wearable projects that interfaced with e-textiles and alternative sensors, embedded LEDs and actuators. It attempted to interleave the specific knowledge of many in the community in the use of ESP32 and ESP8266 circuit boards, minimal 'boards' cheaper and smaller than the Arduino and Raspberry Pi's popular in maker culture. These resilient little boards have the ability to run the Python programming language, a modern language popular in code clubs and science.

The kit and associated workshop was far less 'open' than the *LabFromAChip*, a far more conventional maker instructional designed to build up newcomers knowledge in electronics and interactive sensors. Arduinos and Raspberry Pis, the usual platform for makers interactive work can be cumbersome, too general purpose, with high energy demands and taking up valuable space. Wearable Arduino's and Pi Zeros exist but are expensive. ESP8266 chips and development boards solve these problems, small, lower power yet still able to run a minimal version of Python for various applications. They are available cheaply from manufacturers in China but require slightly more intermediate knowledge to use. The tactic was to make the path to that knowledge easier and better travelled. Many maker projects are pieced together from face to face interaction gleaned from makerspaces or maker events, online

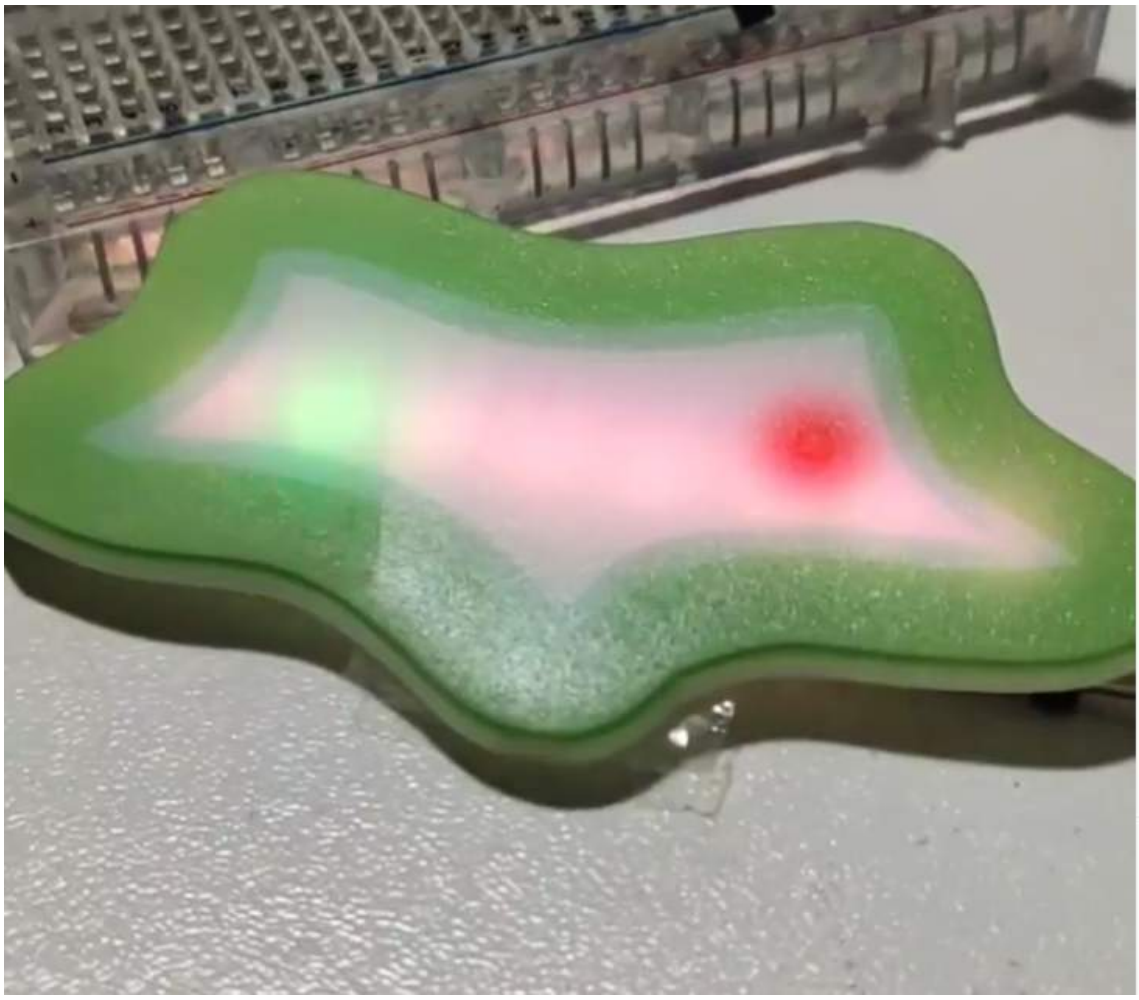

Figure 70: Wearable lasercut badge made to look like *Euglena gracilis* and embedded with programmable multicolour LEDs

tutorials of various approaches and difficulty and lead to wrong turns and failed experiments, buying the wrong component, misunderstanding a material. The kit (Figure 71-72), much like the STEAMhouse Bio Box (Figure 65) was designed as a linear comprehensive instructional so that conversations could take place easily around the workshop.

Figure 71: Simple wearable technology kit featuring fabric stretch sensor and breadboard components

The Workshop attempts to provide a stepping stone into more complex Internet of Things and interactive practices. The 'badge' element again responds to the tech conference badge making practices described above while being the most basic kind of wearable device. The design for the badge is based on an illustration of the *Euglena gracilis* algae, a prompt to discuss the idea of living sensors and biomaterials. Fabric and conductive thread help fabricate an analog stretch sensor that causes an LED or LED array to pulse or change colour (Figure 71). I tried to prompt, within a conventional maker how-to workshop, the indeterminancy of hand made analogue sensors and DIY e-textiles. I wanted to understand what different approaches one must take when making technology that is wearable, making people aware of the dense networks of systems that make technology work, by releasing them from desk based and mains powered convention.

Despite this strategic critical intent, Interleaving breaks down in the workshop. There are no Haraway inspired implosions describing the density of technoscience. Unexpected problems and questions arise despite meticulous planning. A room is double booked requiring sudden reorganisation of workspace delaying a paid workshop for 15 minutes. This critical 15 minutes and change of location is combined with 1 participant computer simply refusing to release the required serial port. Suddenly the group are too busy trying get their projects to work or their software installed to fold in reflections on the carbon cost of lithium batteries, or how anode elements can be produced from synthetic graphite made from oil processing by-products in the North east, shifting maker markets and what future materials can do computation. Here

necessity of robust fool proof guidance trumps reflections on technoscientific nooks and crannys. This relatively simple kit nevertheless involves teaching interleaved skill sets of textile knowledge, sewing, soldering, electronic theory, prototyping, procedural logic, math. There is simply no time to follow the Euglena algae prompt.

In practice in the my-first-pcb and Wearable Tech Badge Workshops, it is hard to pause and look at the vast vistas of supply chains microscopic landscapes of reconfigured exotic materials, to reflect on the multitudes of sedimentary knowledge. The workshop deadline pragmatism advances relentlessly. One aspect of the circuit due to be completed one evening that seemed stable and well documented starts to play up. What is the theory of the voltage divider that this analog soft circuit is capitalising on? Have we got it wrong, misunderstood? Re-arranging the tables for the workshop has to wait while two advanced PCB designers explain the circuit from first principles.

The development of tutorials and shopping lists for DIY microfluidics and microbiology, mapping of supply chains, and the path to manufacturing printed circuit boards are a learning assemblage. It is in the slow careful ad-hoc interleaved material experimentation and process of *assemblaging with others* in a makerspace where critical reflection happened. The *process* of making kits was more of a space for critical thinking than the kit in actual use. This focus on development over utility feels strategic in nature.

The kit is not nearly as 'successful' as the *LabFromAChip* kit which has now been distributed and used in multiple settings and workshops, but a useful distraction in understanding how kits can work in practice. What do we want to pass on and how do we do that? What kinds of knowledge and learning do people want and do makers understand that?

Developing the kit reiterates and complicates the tensions and contradictions in the 'open' and 'democratic' structures of feeling of identity in maker culture, originally discussed at the Critical Kits symposium in 2017. On the one hand, makers make friendly kits 'for anyone', helping reduce barriers to using and benefitting from technology, an affective feeling of empowerment by passing on power. On the other hand, kit making 'for anyone' reinforces the affective importance of the maker's individual and collective accomplishment of complex, difficult knowledge, care and expertise 'for us'. Making is a strange double empowerment for makers despite their committment to radical democracy.

Critical Distractions

Distractions are a critical feature of the culture of DoESLivepool. Hot desking or visiting with a particular task in mind, it is easy to get in a situation where one can overhear a conversation about a problem that invites comment or helpful suggestion. Sometimes these distractions lead to helping other members out with something or introducing one member to another's knowledge. There is a culture of being generous with time. They can be deeply frustrating if under time constraints, but ultimately empowering for the community, helper and member needing help. These can be maintenance related, or to do with some kind of engineering problem or an offhand conversation that leads to a technical 'rabbit hole', often followed up immediately in

relentless verbose detail. A Wearables session can get lost in considering technical alternatives to conductive thread techniques slowing down 'progress' to the end goal of completing a kit. But this distracting knowledge becomes useful days, weeks, months or even years later. Following distractions is an unwritten rule of the organisation in contrast to a playful sign by the lasercutter regarding rule zero, 'Do Not Be On Fire'.

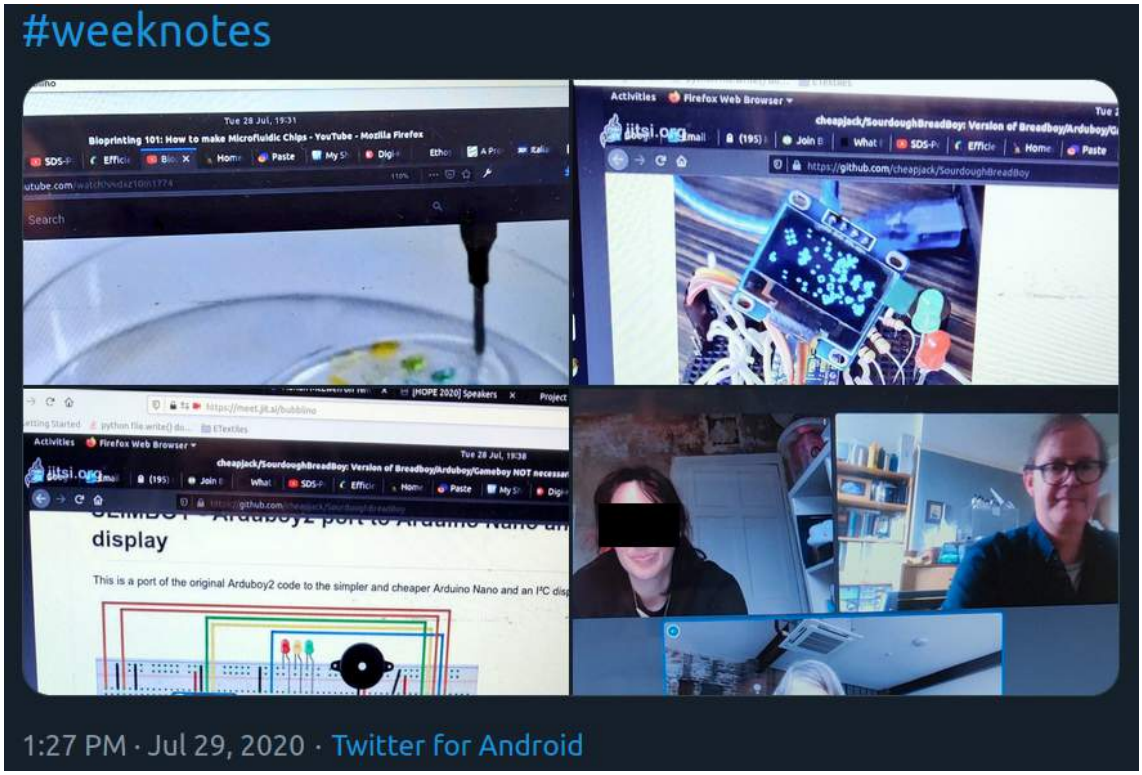

Figure 72: Discussing microfluidics at wearables night

In discussion Jackie reflected on how encounters with biomaterials follow unexpected diversions depending on who came into the space that evening requiring support but then pick up on knowledge developed from previous diversions (Figure 72-74). For an art science practice, 'diversion following' feels strategic, or at least a tactic. In the 3D Print Club I try to introduce and reproduce DoES practices as a strategy to reproduce the agency and engagement I observed as empowering in the makerspace as a stable social base for art-science to build on. Part of that strategy is following the unpredictable interests of the participants, often deferring my need to complete relevant art-science prototypes, instead committing to participant's desires, following the actors. In some Wearables meetings algae is left drying catastrophically under the microscope when newcomers want to know how to control addressable LEDs, or require an induction to using a lasercutter. In the 3D Print Club microfluidics experiments failed to gain much traction amongst the group, while interacting with bigger living organisms like *Drosophila melanogaster* using the *FlyFarm* kits, did. It remains unpredictable, and limits Interleaving Practices as a method. Problematically the benefits of Interleaving as an approach often became visible only after the fact. In that sense diversions are not strategic, with a clear goal on the horizon that is followed by determination and discipline. There are troubling but productive trade-offs.

Jackie commits a good deal of her free time to the space although sceptical as to

Figure 73: Wearable Technology Group experiments with natural dyes at home and in the space, like this turmeric tie-Dye. Image Credit: Jackie

Figure 74: Experiments with onion based alkanet dyed wool and fabric. Image Credit: Jackie

whether diversions are a strategy. However together we acknowledged that our distractions around Biomaterials often eventually prove productive. These tactics are not necessarily driven by forward planning but an underlying desire to do inclusive making. Following distractions mean newcomers with unexpected demands can find support and help. Some newcomers are visibly surprised by oldtimers taking a speculative question seriously and trying it out in the space there and then, encouraging them to take part and come back and do it better.

Futuregazing

There are many different members of DoES and their engagement in the wider community varies. However there is a general commonality with people who become regular users - the oldtimers - in that they share an interest in fostering an open democratic creative supportive and local technical culture as part of an understanding of the idea of 'Doing your best work'. This phrase emerged through collective reflections that lead to a shared values document ('DoES Liverpool Values', 2019) partly prompted by a 'Futuregazing' workshop, which I developed with organisers to understand a collective vision for the organisations future (Figure 75). This workshop could be seen as another distraction, but from my perspective see it as an opportunity to contribute to the communities support of my research project. It builds on a makerspace mapping kit (Figure 76) developed by Hannah Stewart and her colleagues at the RSA research project *Future Makespaces in Redistributed Manufacturing* (Stewart *et al.*, 2018) I have previously contributed to. The workshop turns out to provide interesting observations while being an example of another kind of kit from design practice, the civic development 'toolkit' for thinking or organisational development.

The workshop activity arranging and modifying a modified version of Stewart's tool, reveals members interests and understandings of what they do collectively (Figure 75). Many members of the community are interested in sustainable economies while entrepreneurs in the space and board of directors are passionate about avoiding 'business as usual' and 'gentrification as usual' sustaining an ecosystem of local business practice that sits alongside communal, aritisic and progressive socio-political activity. One member describes themselves as 'corporate refugees'. 'Come for the equipment and stay for the people' is a phrase often repeated by one director's observation in describing how the community grows. It is a phrase periodically invoked internally and in outside advocacy for the organisation.

In my observations here and elsewhere, what sets DoES apart from other spaces in the european hackerspaces tradition or in more professionalised co-working spaces is this collective self awareness of difference and specificity of the organisation's setup. DoES as a community prioritise *do*-ing over talking, part of a critique of other models of 'disruptive' innovation. They perceive many 'innovation hub' approaches as technological rhetoric and 'start-up' venture capitalist hyperbole, combined with a top-down managerialism, instead of real practical collective action to get things done, develop and ship new products. This awareness is realised in a set of core phrases that have emerged in their own descriptions of themselves and consolidated in the Futuregazing workshop. One common internal descriptive phrase is the cryptic 'DoES doesn't do anything' seemingly in opposition to the organisation's

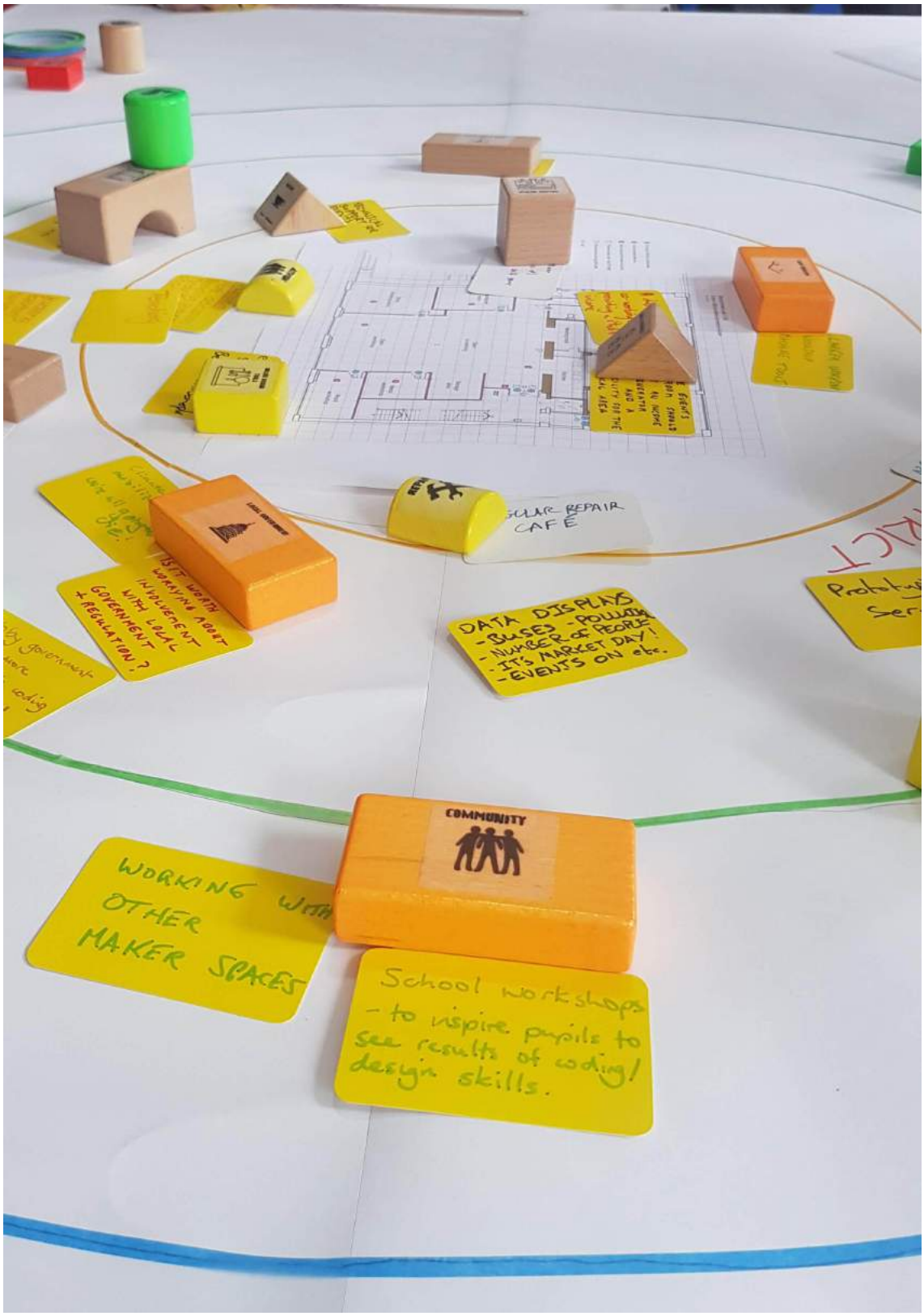

Figure 75: Futuregazing workshop using building blocks in progress

Figure 76: Futuregazing building blocks adapted from Hannah Stewart's discussion tool (2018)

equally cryptic acronym **D.o.E.S** which actually stands for 'Do Epic Shit'. This faux aggrandising in-joke is also self-consciously and most importantly the third-person present indicative form of the verb *to do*.

Unlike many organisations DoES has only one member of part-time staff to manage rent, bills and administrative tasks and no paid programme managers or strategic programme of events. The idea is to provide desk, co-working, fabrication workshop and event spaces and basic administrative support to the community who can then autonomously organise themselves in a 'horizontal' non-hierarchical fashion. Members encourage each other to use the space as they want but most importantly do it themselves, take on and pass on agency. So when somebody in the shared kitchen suggests an idea for what DoES should do they are encouraged to use the space and resources and run it themselves with others. This extends to the nature of the digital fabrication resources available. There are facilities, but no services despite what the website says. Individual members may offer services if they desire or can be persuaded but it is not the first response. If you want to use the lasercutter, 3D printer or CNC milling machines the first response is that you need to come in to the space and the community will help show you how to do it yourself. For machinery that could cause injuries or serious damage there are bookable induction sessions again run by helpful volunteers and with minimal fees.

Despite this 'horizontal' organisation and claim of 'not doing anything' letting the users of the space do what they desire, there is nevertheless a shared direction of travel. This became most visible in the organisations aforementioned value document, developed following the Futuregazing workshop, now framed on the wall as a poster (Figure 77), prior to this, a work in progress on an internal docrment.

> DoES Liverpool exists to support people to do their best work, grow into the lives they want to lead, and to explore and create ways of working and living for the modern day in a just society; spreading making, tech, and the new possibilities of digital tools throughout Liverpool and beyond. ('DoES Liverpool Values', 2019)

Interleaving Temporality In DoESLiverpool

In DoESLiverpool there is little financial exchange for labour. Almost everything; maintenance, moving buildings, cleaning, room booking, accountancy, organising is run by volunteers in the community. Rental of permanent desks for residents, hot-desking or lasercutter use and regular 'Friends of DoES Liverpool' supporters are the only income stream. The space does not receive any NGO or state support, and even tax relief on creative communal spaces in the city can be precarious. The organisation take a position that independence is more important than the 'strings' attached to a funding model.

To make this possible, tools and approaches from software development culture are employed complement the resilient pragmatism determinism of many of the individuals who make up the community. Most signficantly, GitHub issues are used to manage the maintenance and care of the space. They are designed to manage and maintain complex software and hardware technical projects and allows multiple

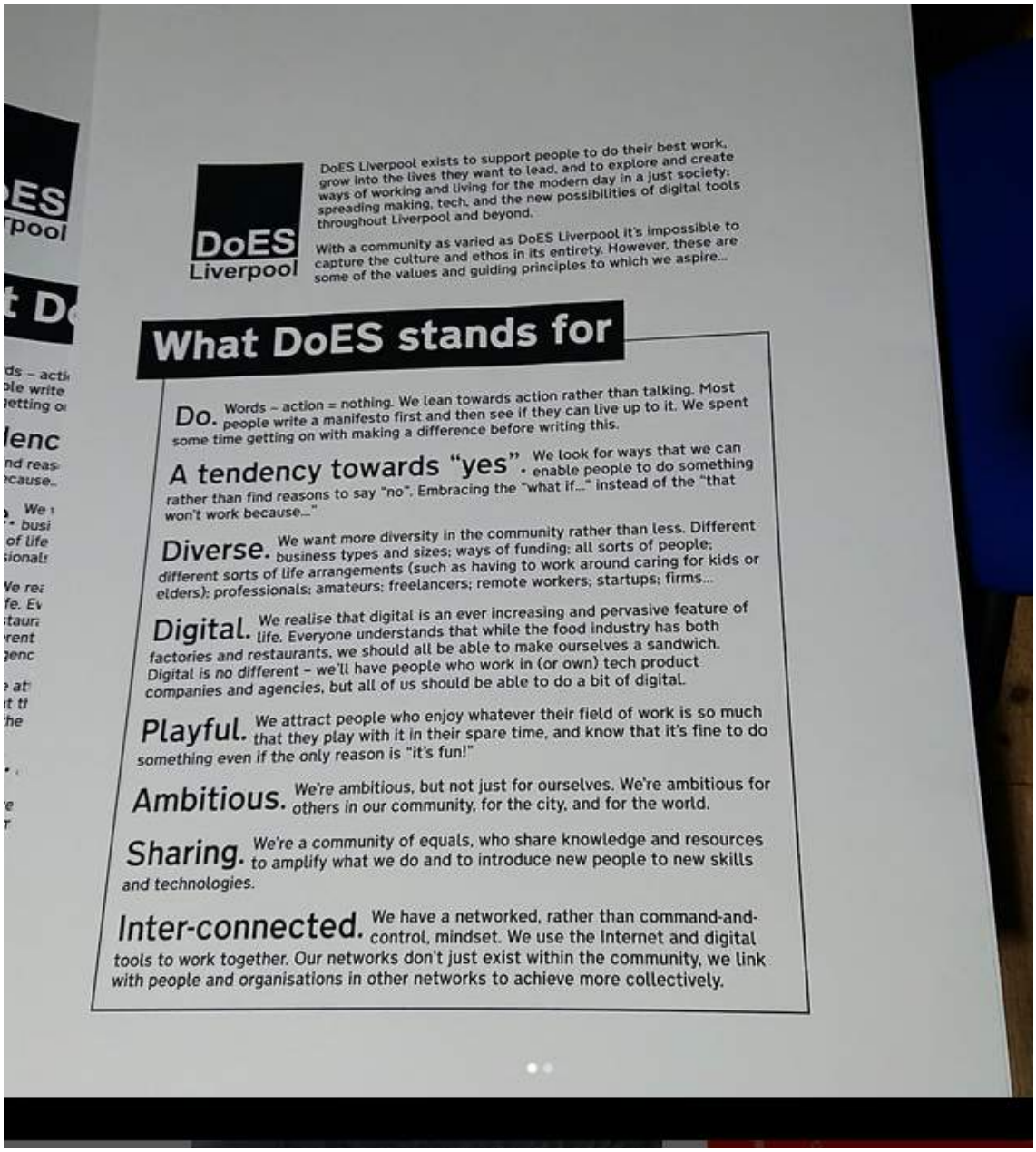

Figure 77: 'What DoES Stands For' poster in DoESLivepool. Image Credit: DoES-Liverpool 2022

features to be aynchronously tracked and where necessary revised discussed and differentiated by many interdisciplinary contributors.

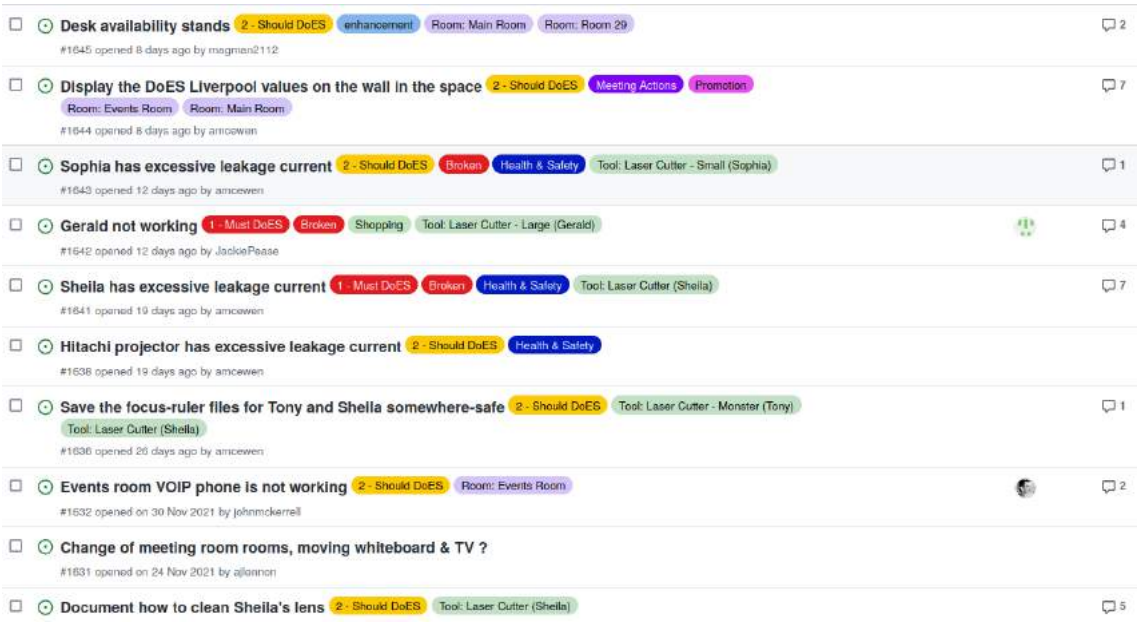

Figure 78: Example list of ongoing issues on the public GitHub page

Most significantly for DoES and something my own art and technical practice follows, re-empractising, GitHub issues (Figure 78) enables rich fine grained resilient detail of 'issues' that may be returned to and learnt from. Not every member is on GitHub and when newcomers have issues volunteer organisers and members of the co-directors group encourage them to join or post issues on their behalf. This limits the contributors to issues to speople usually deeply engaged in the community. However it is a fascinating publically accessible communal discursive space for careful and at times antagonistic argument on how best to maintain the community and its infrastructure. There is a remarkable absence of innovation or competitive rhetoric.

What is observed here and what could be a useful model for Interleaving Practitioners is how a diverse relatively unorganised group of volunteers and constituents with varying commmitments and capacities can seemingly strategically deal with and sustain and develop complex caring practices across diverse materials, practice, expertise and most importantly different modes of *temporality*.

Triage

I began to map out activity through actor-network inspired diagrams based on GitHub categories, day to day observations of footfall and conversations in the space (Figure 79-80). Analysing and developing these diagrams, shapes and structures of the distribution of multiple interleaved practices emerged. This formed an understanding not just about the rich, diverse plurality and multiple nature of the organisation, the extent of the interleaved mix of disciplines and interests and capacities but how this complexity is shaped and prioritised not only in terms of types of practice but in terms of time.

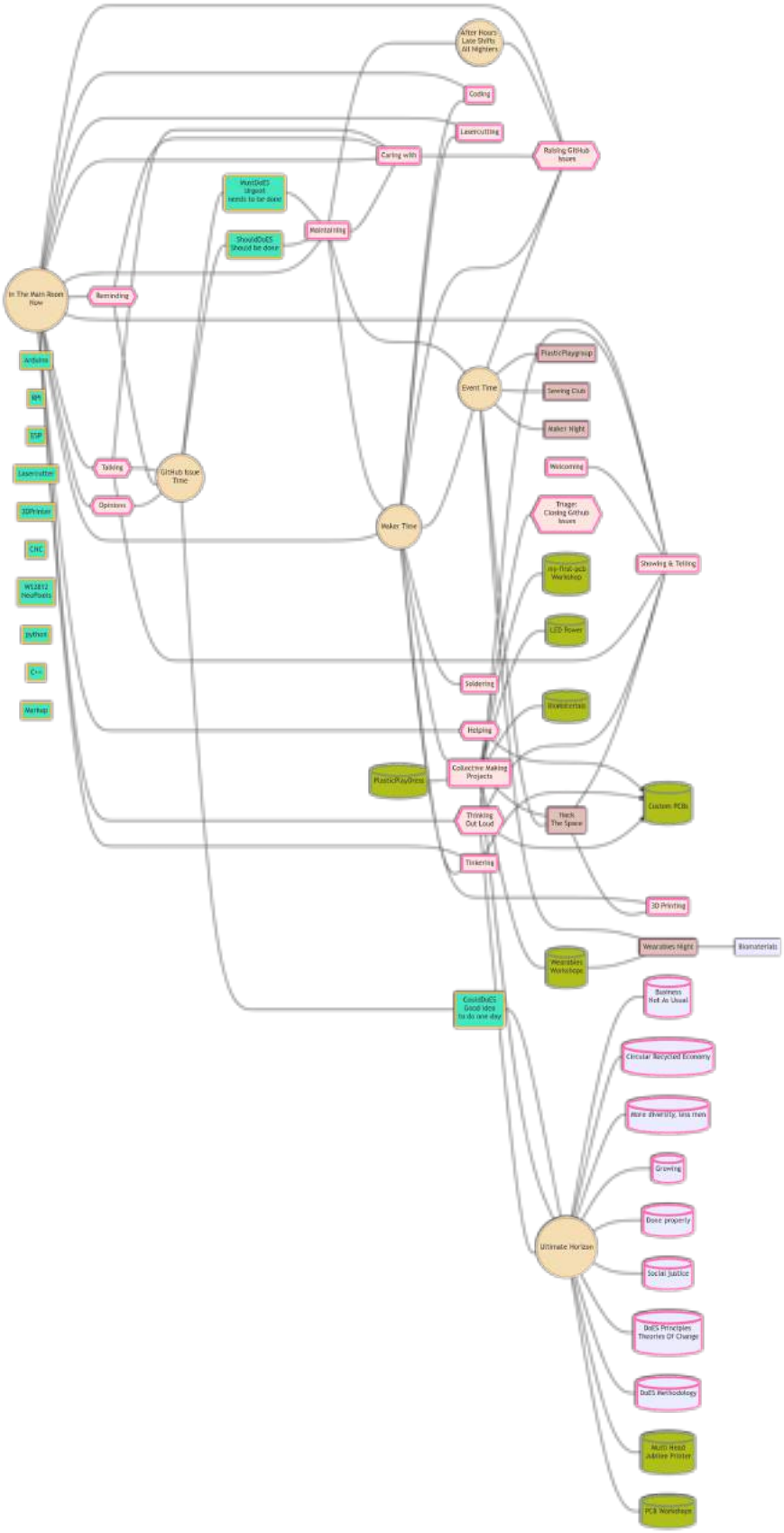

Figure 79: Rhizome diagram based on observation mapping out the interleaving of activity across time and space in DoESLiverpool

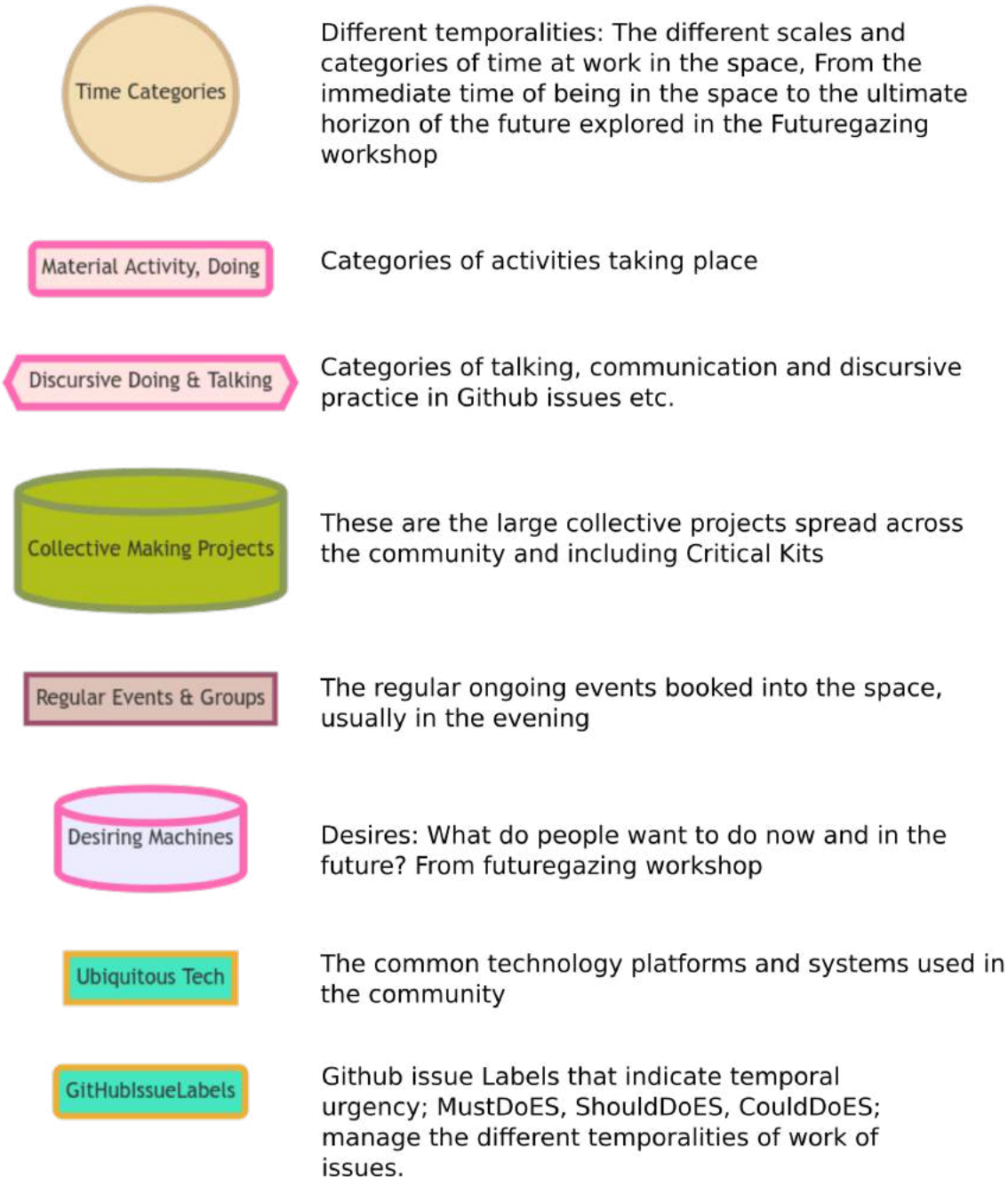

Figure 80: Key to rhizome diagram (Figure 79)

How do people cope with this complexity? How do they prioritise without programme managers? One process is known internally as a form of 'triage'. Triage is a practice that volunteers and organisers do periodically, flexibly and often asynchronously.

Figure 81: Triage using the GitHub issue labels *Must DoES*, *Should DoES* and *Could DoES*

A key feature of GitHub issues used by the collective is the ability to colour code, track, categorise and document progress over time with 'labels' (Figure 81), important requirements of high pressure complicated project management of hardware and software projects. Issues ongoing remain open, while resolved or no longer relevant issues are 'closed' or merged with others.

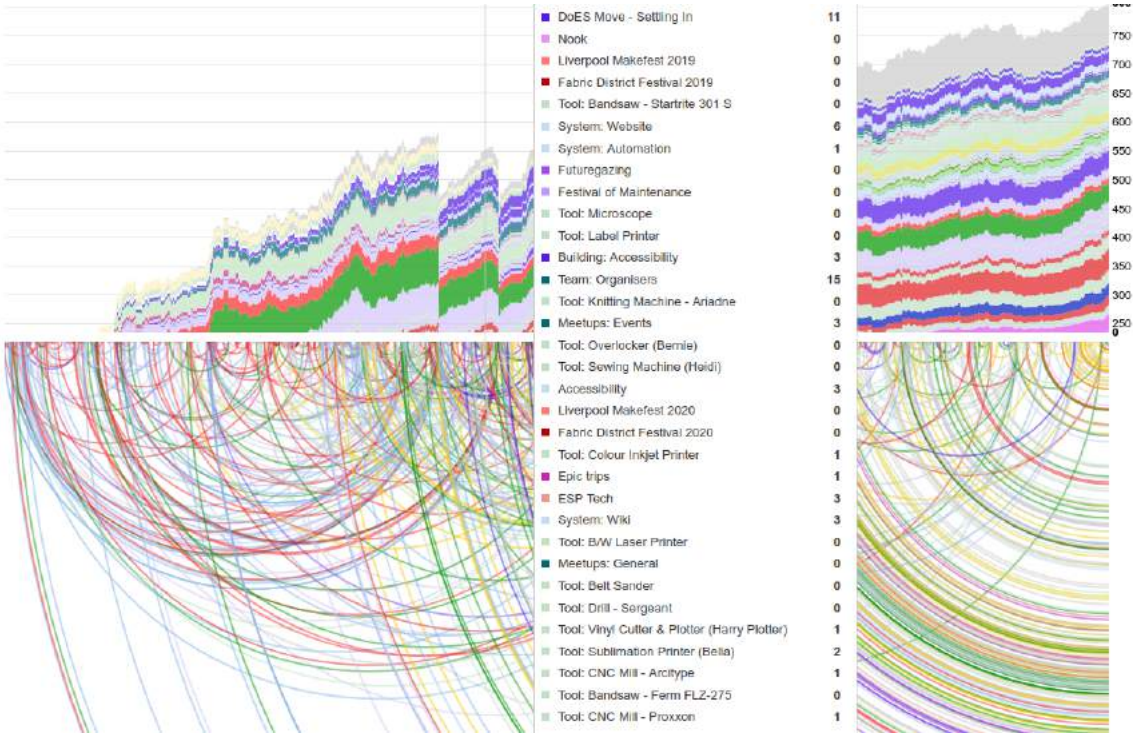

Figure 82: Visualisation of public DoESLiverpool GitHub issues since 2014: Made using BugLife

I analysed and visualised the complete history of the DoESLiverpool GitHub repository to discover large amount of issues that remain open for large periods of time. In the diagram (Figure 82), time moves from the beginning of the repository being setup, around 2014 in the first building, at the time of writing, gentrified further in the centre of Liverpool. Time proceeds to the present from left to right, with completed arcs showing issues 'closed' while incomplete arcs where their termination is hidden show that they remain 'open'. These open issues might mean incomplete tasks or deveopments being thought about or deliberated on. Red lines and areas tend to show more urgent labels, 'Must DoES' and 'Should DoES' when machines are broken and inaccessible. Green open arcs and areas are less urgent and to do

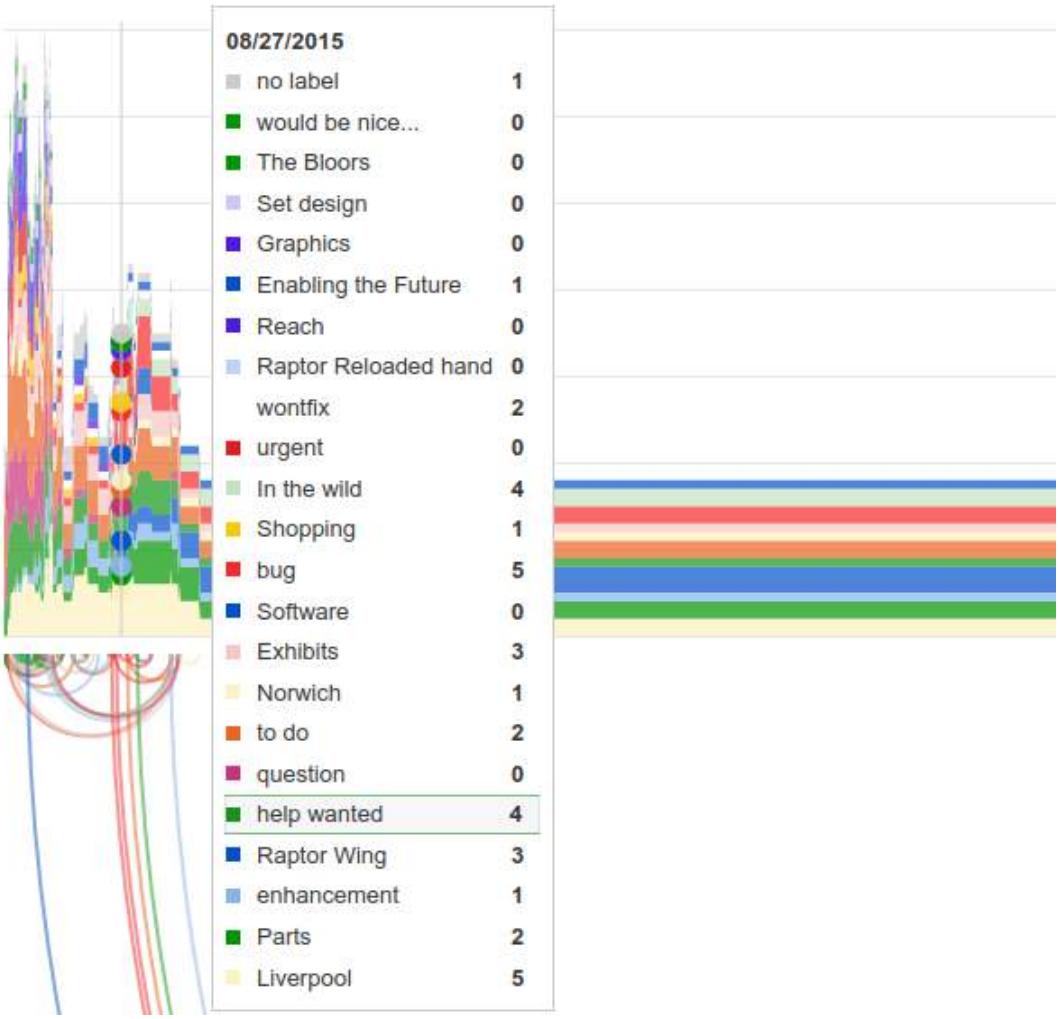

Figure 83: Comparison with public Desktop Prosthetics project from 2015, made using BugLife

with the future, 'Could DoES'. It's worth noting just how many issues are orientated to this future horizon. In some cases this represents either particularly difficult problems or a lack of consensus or materials to close an issue. More common is simply a general orientation and desire for a horizon of a 'better' future.

In other projects, the visualisation is very different. In (Figure 83) a complex participatory art project DesktopProsthetics I worked on with DoES, created, delivered and managed collaboratively by DoES community members volunteers and directors in 2015 with multiple partners like FACT, The Craft Council and REACH, a charity for families living with upper limb difference and disability. Despite the complexity of logistics for that project, which required contributors unfamiliar with GitHub issues to take on these practices in order to cope with the complex information flow, it is nevertheless starkly different, illustrating the richness of interleaved activity, collaboration and deliberation in the space.

How to cope with this kind of complexity? GitHub and the boundary work of Triage, categorising mapping and prioritising feels strategic and not just about doing what you want. The process of triage involves informal open group discussions with respect to this over most issues, which can be administrative, an announcement of something breaking or just an interesting idea, often while doing other things. Generally, following discussion these are then posted as issues and categorised with the labels 'Must DoES', 'Should DoES', 'Could DoES', in descending urgency (Figure 81). Temporality here is combined with both perceived need, 'Must' but also the *desire* to keep things in the right direction, 'Should' and the wider possibilities 'Could'.

Sometimes 'Hack the space' events are specially created partly for this purpose. Here people review issues that remain 'open' and contribute to the discourse and collective thinking prioritising and delineating certain practices over others while repairing and fixing them together or deferring for another time. Closing of issues is affectively satisfying for members, one feels happy to have contributed to the communal care of the community. Time and activity management is not just something to hit targets or a moral obligation but is full of affect and desire, essentially a form of *communal* mutual care, what Tronto called 'caring-with' (Tronto, 1993).

Bound up with care in the space is a general orientation to the future, a seemingly strategic orientation where collective making projects progress and things get fixed, or not. In the futuregazing workshop optimistic, pragmatic and utopian visions for the future emerged on equal footing with the anticipation of future maintenance problems and limitations. But there remains a general direction of travel to what emerges as a document collaboratively discussed at the end of the Futruegazing workshop, a set of shared values that one participant describes as a 'DoES methodology'.

In analysing this, I developed my own codes grounded in the issue data and observations in the space. There is a 'present-in-the-room-now' in the space of what people are doing or talking about currently but also a constant awareness and care for other times and other tasks, 'Maker Time', 'Event Time' 'Github Issues Time'. Mapping these codes as network diagrams leads back to the spatial, landscapes of practice and a landscape of temporality, and lead to overlayed complex diagramitic studies, in response to the sedimented social activity observed. Made up from sketches, photographs, GitHub analysis and coding, what emerges is a landscape

of practice assembled, a complex *assemblage* worthy of Edward's and Ruskin's vast machine, Haraway's and Dumit's implosions, Law's mess and Deleuze, Guattari and Buchanan's *assemblaging*.

Despite this topology of futures and temporalities there is generally very little organised systematic planning of reaching a set goal. Instead people are prepared to slowly care for and maintain existing and emergent cultural practice. Nevertheless critical moments can prompt sudden unexpected mobilisations to respond to a crisis or deadline, a strategic approach seems to emerge from nowhere.

Culture and Strategy

Strategic encounters with materials and tactical advantages of following diversions is consolidated when the Wearables Meetings are interrupted by the first lockdowns of 2020. The lockdown shifted all meetings and observations online both in the makerspace and in this study. At the same time the DoES community responded to the PPE crisis ('DoES Liverpool Visors', 2020), mobilising the community's collective practices, labour and equipment to spin up a face visor manufacturing process that between March and July 2020 manufactured almost 30,000 lasercut face visors for supportive care settings across the North West, part of the global maker community response to the crisis. The 3D print club also contributed making 3D printed visors and mask strap supports to support NMC staff in their slow re-opening toward the end of 2020.

To claim that maker practices; and those peculiar to DoES; are strategically building resilience for potential civic disasters and crises would be overblown. However the resilience of the community is evident in the PPE response and is the origin of a powerful imaginary in maker culture identity and practice. Makers in DoES and the NMC had powerful desires to help their own community and others and in the pandemic, this was easily visible, though possibly catalysed by other examples of mutual aid across the world and of course a response from makers all over the world. In the comparatively fledgling maker group at the NMC, the resilience imaginary consolidated relationships and made 3D Printing a way of supporting similarly vulnerable people, when their normal therapeutic visits to the therapeutic centre had to be suspended.

Online, the Wearable group, like the 3D Print Club became confined to domestic spaces, although some core DoES organisers would run video sessions in the space with well organised distancing and hygiene to share experiments safely. This opened up a set of rich biomaterial experiments using domestic food and natural based dyes, and led to new participants experimenting at home and then sharing at evening meetings. Plotting experiments were carried out in the space alongside textile making and at my home studio, coordinated online and interleaved with interactions with participants at BLS. Understanding strategic encounters with materials as a form or preperation for new possibilities and capacties was useful in this crisis, which closed down so many capacities but opened up new possibilities for communal care and mutual aid. This offers a strategic model for not just art-science experiment but for the inventive social science Noortje Marres and her colleagues describe, exploring how specific technoscience is made and configured through transformative ethnographic

encounters.

Both McEwen and Jackie, in interview and co-analysis, however are resistant to the idea of strategy. Strategy from McEwen's perspective is symptomatic of governmental innovation programmes that professionalise managerial approaches to creativity in technology and growth in business without doing anything substantial. They setup strategic partnerships, core objectives and outcomes and build incredible landmark buildings before 'doing' anything. He recalls his time in a start up where they developed a complex strategic disciplinary framework for development with intricate Gantt diagrams and timelines. However almost immediately other more experienced third parties ignore that doing 'just enough' planning to get the job done, the strategy became 'to deliver'.

Jackie, when discussing how makers in the space facilitate learning, following distractions or needs of visitors or community members often at significant cost to progress of their own projects, was doubtful if this can be understood as an intentional strategy. Other participants are also reluctant to define how they work in that way. What *is* important is the slow development of what they see as a *culture*, a way of doing things. Perhaps this is the 'DoES methodology'. It is the *maintenance* of a culture of collective *doing* and *caring-with* that is important. The microbiological meaning of the word culture is metaphorically productive here as much as the cultures of cultural studies. Microbiologists grow *cultures* on plates of agar as part of testing procedures to understand and model complex microbial interactions, a standard microbiological practice. *Culturing* means providing the conditions for microbial communities to thrive and multiply - it is also a way of 'seeing' the invisible work of microbes when they flourish enough to be visible to the human macro scale. It concentrates and intensifies microbial populations which are then counted using technologies such as the Hemocytometer, part of the so called 'gold' standard of disease diagnosis I explore in case study 5. Strategy perhaps seems too organised and restrictive, less about pluralism, going against the internal claim by many in the organisation, that DoES does not *do* anything. Instead the community picks up on culturing practices, sharing information, helping each other out.

Both strategic and cultural approaches however, share a *desire* and orientation toward the future through an approach to practice, doing not just talking. In my practice embedding can be understood similarly. In my work with Domestic Science we described our approach as 'not to use science and technology as a subject for our practice but to critically take part in it as a culture'. It is a political project sensitive to how things are *done*. At times it is much more about tactical and ethical means over strategic ends. Strategy implies following a direction one may not fully endorse in order to reach an intermediate gain toward an ultimate goal or 'end'. Developing a certain kind of 'culture' however is more flexible and open ended, and perhaps it is more like a set of productive tactics to work in a certain way that can then come together in a sudden critical moment or slowly build and aggregate. In DoESLiverpool the ultimate goal seems to be to have a healthy culture of diverse interests, materials, equipment, sensibilities and skills to do 'your best work'.

The Agonistic Maker

What might be called the maker community at DoESLiverpool is by no means a monolithic identity. It is diverse in the disciplines it gathers together. Computer scientists, creative technologists, entrepreneurs, TV and music producers, hobbyists, coders, programmers and software developers (devs), textile designers, biologists, geographers, game developers, music producers, shopkeepers, craftspeople, wedding designers, artists, guitar makers, mould makers, illustrators and makers of all kinds. DoESLiverpool is disciplinary agnostic and encourages all kinds of communities of practice to co-exist and form alliances.

DoESLiverpool provides a culture of pluralistic modes of care, complex spaces for learning, innovation and resilience. Above all it is a culture made up of unacknowledged coalitions of the collective and entrepreneurial. There is a resistance to the hegemony of disruptive innovation models and endless growth in favour of sustainable circular, doughnut like economies. However it is firmly liberal and neo-liberal, explicitly pro-business and work orientated but in a democratic alter-capitalist mode with an eye on social justice. Reflecting on Mouffe's idea of hegemony means the maker community are positioned in such a way to play potentially important roles in counter hegemonic practice in the way technology is made and maintained.

Mackenzie Wark (2019) speculated recently on new class formations, like the 'vectoralist class' who own the means of production of the 'big data' or technology platforms. Makers who work amongst the looms of these data infrastructures, in software development and maintenance are technoscientific workers who could make significant counter hegemonic interventions in the technical world. Adams' Energy Toxicity Matrix is a prime example of this, an intervention in a wider project, to 'green' the internet and technical making (Adams, 2019).

Somehow DoESLiverpool stays with the trouble and thrives on an opposition to perceived business as usual while encouraging a culture of bootstrapping and scaling up ethical and technical business ideas and products. Their independence is central to their identity and their ability to innovate on their own terms. They embrace the entrepreneurial neo-liberal self yet the organisation evokes all the critical possibilities for molecular resistance to capital accumulation. It is a collective endeavour full of contradictory coalitions.

Interleaving 4: Assemblage, Affect and Desire

The mapping of temporality in DoES adds complexity to the relational landscape of practice that has so far been a compelling spatial analogy of how people work together (Figure 84). But there is also a landscape of discourse, activity and care and complex shifts in time. Landscape analogies can quickly break down once you realise there are interleaved stacks and strata across multiple asynchronous temporalities: things don't always become sedimented into the stable surfaces of a hillside that can be easily walked upon. The assemblages discussed earlier, in Law's explorations of mess became more descriptive. Assemblages can include materials and practices but also affect and feeling, akin to what Raymond Williams called, usually for much larger *political* affective assemblages, the 'structures of feeling' (Williams, 1975).

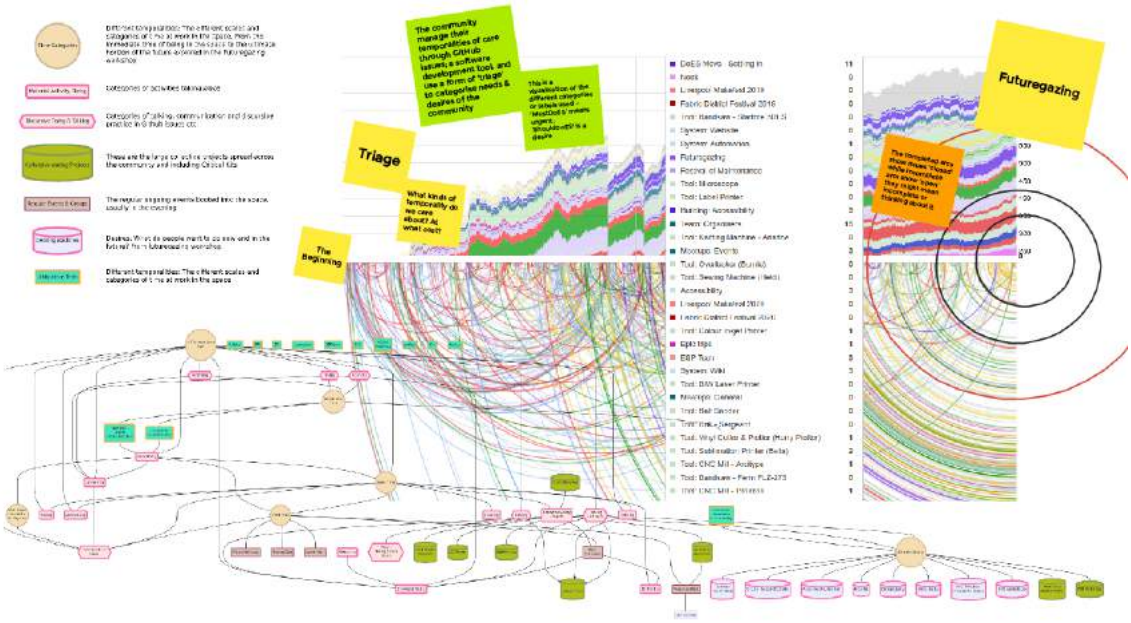

Figure 84: Overlaying GitHub issues and a mindmap of temporal categories 'In The Main Room Now', 'Maker Time, 'Event Time', 'Futuregazing'

In thinking of DoES as an assemblage with complex multiplicities of time and care, it is easy to get lost in ANT-like networks of human and non-human actors. Desks, GitHub issues, leaking sinks, dirty laser cutter lenses, universities, soldering irons and landlords all form complex relations.

In (Figure 85) I revisited my observations of networks of relations, and different senses of temporality developed through the 'triage' practices, everyday footfall and directions of conversations into drawings and sketches to get a sense of the assemblage and structures of feeling of DoES. Fascinating relations of humans and non-humans are revealed but there is also a structure in the way the network 'clumps' together, how relations are lumpy. The Interleaved sensitivity reveals how they are not smooth and homogeneous yet connected and interacting.

Understanding how different social ontologies and epistemologies deal with lumpy structure became important here. This is where other iterations of Assemblage theory became useful. Multiple assemblages of time and care generated interesting ANT style diagrams (Figure 84). But where is an account for the *intentionality* of all this heterogeneous activity? Where is the joy, frustration and desire of making together? What is doing the assemblaging? In The Assemblagists section, I described Buchanan's critique of ANT and similar 'assemblage-as-system-of-things approach' (Buchanan, 2021) which ignore Deleuze's 'productive desire' and 'desiring machines' essential to his conception of assemblage and his entire project. Including *desire* makes the topology of DoES come alive. As I learnt observing the study of how insects are vectors for disease in BLS, these relational vectors - the lines between objects on a network diagram - are complex living relations.

In DoESLiverpool, BLS and the NMC what drives and holds the assemblage together is *desire* and *joy in making*. Makers and scientists are rarely not enthusiastic in these sites. This affective enthusiasm is *productive* desire. It drove the sudden mobilisation

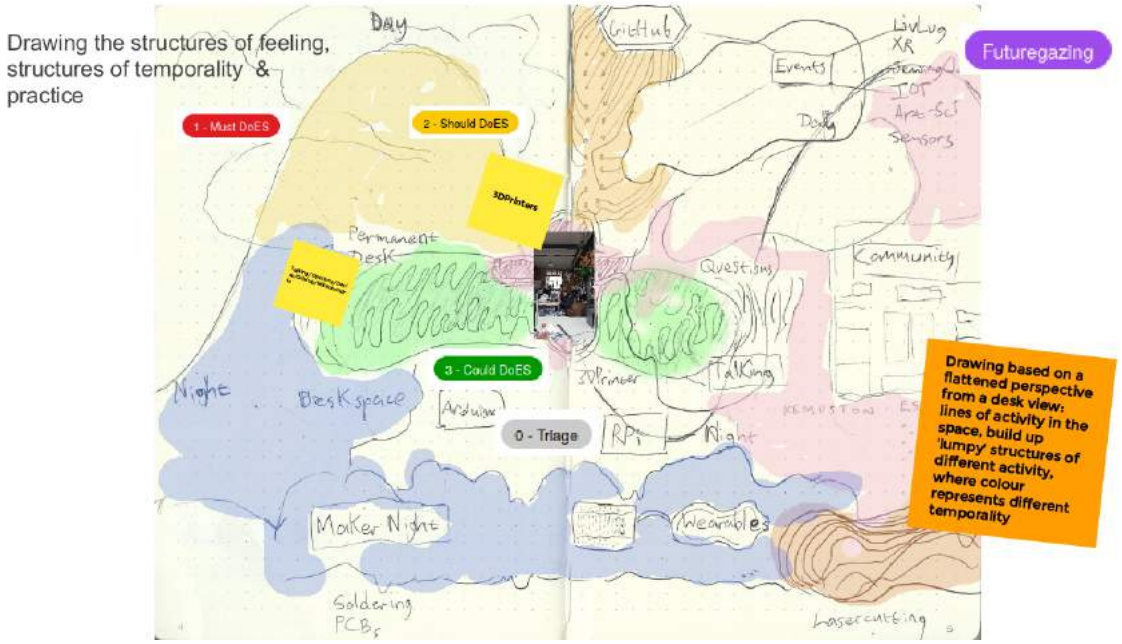

Figure 85: Sketches of the lumpy structures of temporality and activity painted over a flattened perspective view of the DoES office plan view. The central green object refers to the shape of the mitochondria, the energy generating organelle in all eukaryotic organisms, representing the energy of the space, the communal talking and doing

of the maker community to care for each other and fight the COVID-19 PPE crisis but it also produces larger scale 'techno-fixing' mythologies, what Deleuze might describe as at a molar scale, and at the microscale, more subtle behavioural issues, like mansplaining; an issue acknowledged by the DoES community.

Critical Kits originally responded to uncritical tendancies or 'techno-fixing' hyperbole in maker culture that can seem to dominate when looking at the culture from a distance. However by making-with and caring-with makers and reflecting on long form interactions with them in this study, it revealed nuanced sensitive and collective caring practices. Making and experimenting are full of desires for something. In DoES it's 'doing your best work' (Conversations with the Futuregazing workshops at DoESLiverpool 2019). In the NMC joy, desire, and frustration of 3D printing built the capacities for care that project produced. In DoES, where organisational heirarchy is kept to a horizontal minimum, people are 'free to do their best work' an affective 'structure of feeling'. *Desire* in DoES is not the desire to be the best but a desire for something better: better innovation, better tech, better ecosystems for the Internet of Things, a better sustainable world.

In the next section I reflect on my interactions in low cost open-source biomedical diagnosis and how interleaving and understanding maker practices as part of techno-scientific assemblages can lead to informative critical making, exploring problematic outcomes of maker desires to help.

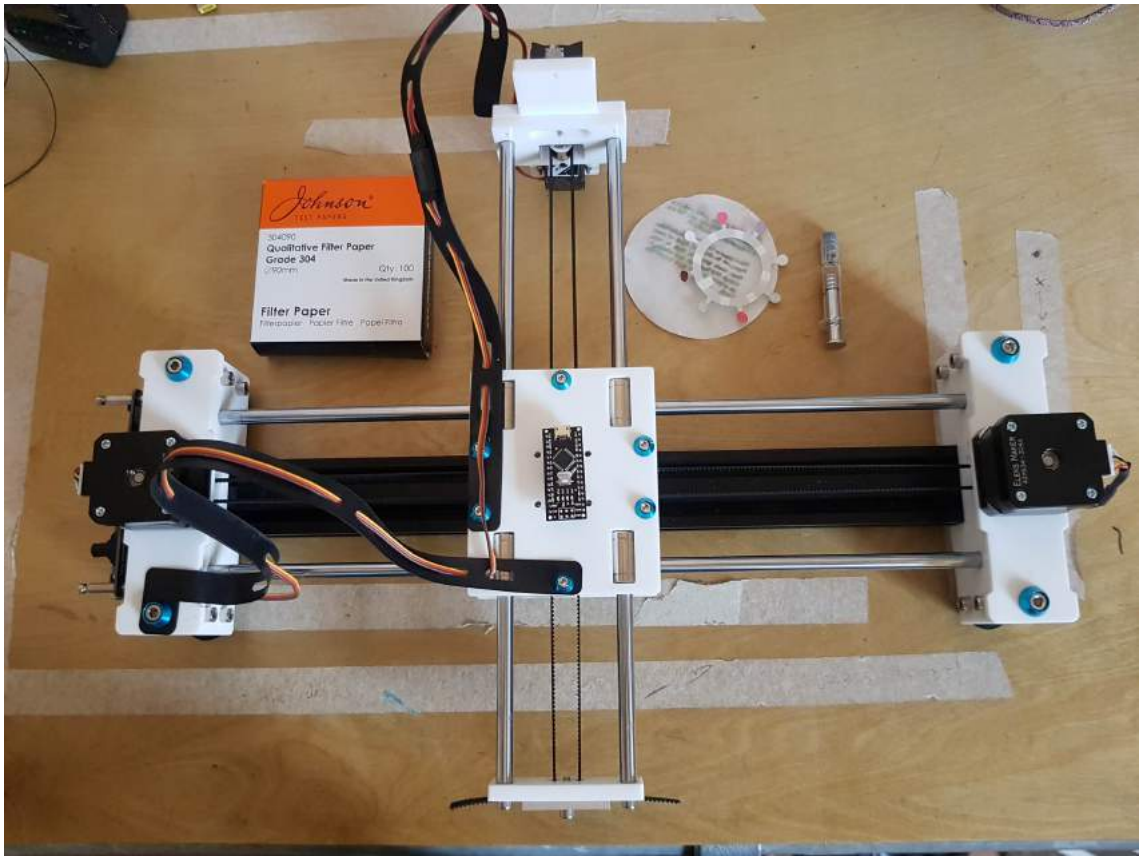

Figure 86: Open source CNC plotter and extruder for prototyping paper based microfluidics and textile CNC batik based on a popular low cost Eleskdraw plotter kit run on an Arduino Nano clone and the CNC grbl library

Case Study 5: Printing and Plotting Diagnostics

This case study explores the idea of *productive failure* which I observed as a commonality between making and scientific experimentation. Finished projects at makerspaces, scientific papers and art exhibitions elide all the wrong turns and scrapped approaches that led to and ultimately are part of their completion. Well intentioned maker hyberbole, elides failure in lieu of a success story of the democratisation of science and technology. This can lead to overconfidence that maker culture can solve every problem.

Let me return to my collaborative work with the research participant, Diana, making low cost and open-source diagnostics referred to in my first case study. She tested an early *LabFromAChip* kit and contributed to a series of meetings led by Dillon and later conducted a follow up interview with me online. As part of her study I prototyped key examples of low cost diagnostic projects that had been developed by makers and biomedical engineers (Coelho *et al.*, 2017; dnhkng, 2020; Seok *et al.*, 2017; Velders *et al.*, 2018) and provided feedback and discussion. This led to the *WaxPlotters* critical kit (Dalziel, 2022b) (Figure 86). Diana's study into the field of low cost approaches to diagnosis as part of the mitigation and control of so-called 'Neglected Tropical Disease' (NTDs) explored thousands of biomedical papers on the efficacy of human and animal based diagnostics for a range of endemic diseases. Her study featured a meta-analysis of this literature to understand the potential for low-cost maker approaches to molecular diagnostics, a core practice for disease control. One aspect of the research was the importance of 'Point of care' testing, that is being able to complete a diagnostic successfully in the field using existing infrastructure.

What Diana discovered in the literature, was that the use of open-sourced maker approaches to technology initially showed potential in being able to deliver molecular testing in cost effective ways. This involves developing a test for the presence of complex molecules proven as indicators of a particular condition. Conditions range from a novel disease like COVID-19 or diseases like dengue fever and Leishmaniasis in Low Income Countries (LICs) of the global south. The molecular standard for diagnosis, the 'PCR test', now a household phrase post-COVID-19, capitalises on the Polymerase Chain Reaction (PCR), the ability of certain thermally resistant enzymes to drive and support acccurate DNA replication through thermal cycling. Such a test essentially replicates tiny fragments of DNA from a sample, exponentially in such a way to make them easily detectable. In the COVID-19 context a variant of PCR technique RT-PCR (Reverse Transcription Polymerase Chain Reaction) is used to detect the RNA of the SARS-CoV-2 virus, a single stranded nucleic acid that like DNA (Deoxyribonucleic Acid) carries genetic information essential to all life. Conventional PCR testing requires a certain configuration and assemblage of lab equipment for these controlled temperature reactions at scale. Sociotechnical infrastructures in a region or nation state must be developed enough to include not only a temperature controlled supply chain known as a cold chain, access to buffers and chemicals, but trained field clinicians and technicians. This is often unavailable at scale in the LIC areas thought of as 'endemic' for many of the NTDs looked at in Diana's study. One project innovates by avoiding the PCR process altogether and instead using a comparable, in terms of accuracy, process called

Loop-mediated isothermal amplification (LAMP) that has much simpler temperature and infrastructure requirements to amplify DNA or RNA fragments essential to diagnosis.

However a number of problems, presented themselves through my process of critically making key diagnostic projects like GitHub user dnhkng's *POCKET-LAMP* (dnhkng, 2020). Despite my access to electronics, 3D printers and maker knowledge, I was only able to build the simplest of prototypes and struggled to source the required chemical buffers to make a diagnostic. This prototype would need the labour of a team of makers to scale up a robust 'one button' testing kit that the project desires. Here I found commonalities between makers and art-science practitioners in the limitations of their speculative prototyping. On a website or academic paper with clear circuit diagrams, they look ready to radically democratise 'point of care' diagnostics in the wild, an attractive techno-fix for a difficult problem. However much of the project documentation I followed lacked nuanced information and guidance especially with respect to the sourcing of crucial chemical buffers.

The Interleaving of practices of maker culture and microbiological technique enabled Diana to understand and critically evaluate these diagnostics in a way that her meta-analysis of literature alone could not. Returning to STS, these black boxes can be opened up, invisible work re-empractised, a viable molecular test re-enacted. Through Critical Kit making we learnt together that molecular diagnostics depend on complex assemblages of technoscientific making and globalised supply chains.

This is what the embedded and participatory art practices of Interleaving offer art-science collaboration. Together we understood the boundaries between our disciplines, what they make possible and what they do not. Our interactions led to what Diana called in interview the 'other side of the equation'; the considerations of complex social relations and practices, not just the microbiological or molecular facts of the matter.

Productive Failure

The *productive failure* of the diagnostic kit prototypes made important embodied knowledge. I went on to develop a critical kit that intentionally interleaved the practices, components and requirements these messy unfinished diagnostic prototypes are contingent on. This kit would be an intentional boundary object, generating capacities for Star and Griesemer's boundary work. This would also be an *assemblage object* revealing the complexity of the complex socio-technical relations and desires assembled and interleaved in such a way for diagnostic kits to do their work. The *WaxPlotters* (Dalziel, 2022b) project (Figure 86-87) made with participants in DoES and the NMC would fold-in and enable the prototyping of diagnostic tests using Computer Numerical Control (CNC) approaches to making that had emerged in the Wearable Technology Interest group at DoES. These included pen plotting, using pens to draw layers of paths to make up an image; batik, the formation of patterns using heated wax to isolate and discriminate between dyes and paint and 3D printing with exotic biomaterials developed from the Materiom recipe book (Corbin and Garmulewicz, 2018).

This hybrid plotter kit used existing accessible low cost components, and existing

desktop 2 axis plotting machines to draw, heat and extrude materials accurately by Computer Numerical Control (CNC). I used the approach to low cost temperature control from the *LAMPShield* (Velders, Schoen and Saggiomo, 2018) project that facilitated the LAMP reaction, to heat and extrude wax and custom biomaterials (Figure 87). The extrusion of heated wax could be used to make millifluidic channels to prototype diagnostics. This technique was based on my re-empractising of microfluidic techniques in the literature: Tempest van Schaik an alumni of the biomedical start up Science Practice, in her article *Low Tech microfludics* (van Schaik, 2015) and the paper *Rapid prototyping of paper-based microfluidics with wax for low-cost, portable bioassay* by Yao Lu et al (Lu *et al.*, 2009). An Arduino controlled 3D printed heated syringe assembly plotted heated wax on filter paper forming wax hydrophobic 'walls' that fused into paper fibres allowing liquid samples to flow in desired directions, to interact with biochemical agents used in diagnostics. Free and open-source software popular with makers, *Inkscape* generated 'gcode' a standardised format for CNC technology based on designs generated in software tools designed for microfluidics by the CIDAR research group at the Biological Design Center at Boston University (Densmore and Oliveira, 2021).

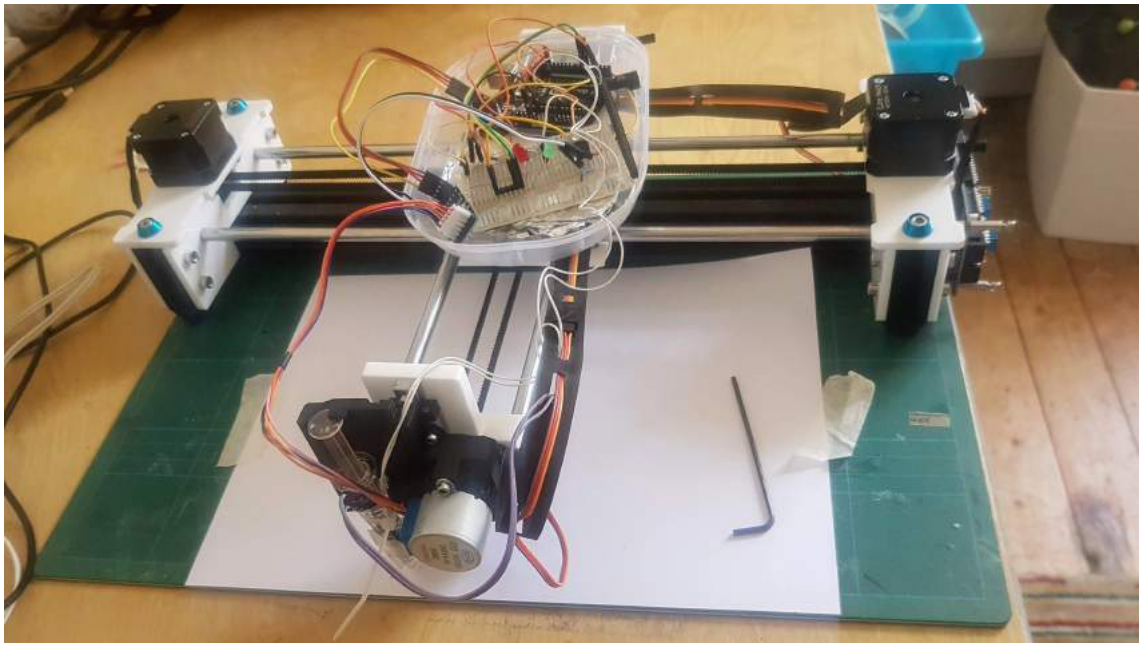

Figure 87: WaxPlotter with prototype heated wax syringe extrusion assembly

However I soon reached the boundary of my maker skillset and time, unable to overcome software issues on the plotter control board, and difficulty making the heating system robust enough and callibrated sufficiently well to extrude wax consistently enough to form microfluidic channels. The project remains incomplete and failed to result in a robust microfludic system. However this failure generated important knowledge. As a by-product the plotter could be used as a form of digital batik for textile makers and two participants significantly developed the plotting system with a pen to generate beautiful plotted images and designs for sewing and making kits. This was partially prompted by the activity (Figure 88). This kit revealed rich complex layers of practices within the makerspace and formed new capacities for developing more even if a Digital batik/microfluidic/biomaterial extrusion system

Figure 88: Example of Jackie's plotting images. Image credit: Jackie

has so far failed to be fully realised.

By pursuing this interleaved project, intentionally developing a boundary object to Interleave and fold-in mulitple practices and material constraints, it in turn *un-folds* issues and boundaries around the idea of 'innovation' and 'low cost', materialising the limits of maker approaches. What became apparent was that there is an exciting story in maker culture of radically democratising knowledge making and technoscience, a core maker desire, a well meant attempt to change the world. It is part of the desires of the Foldscope, fostering 'Curiosity worldwide' opening up field diagnostics to 'anyone'. There is another counter story that Interleaving reveals however, the story of slow, emergent, careful diligence, maintenance, strategic patience and productive failure. It is through failing, falsifying and testing that produces social learning. Makers and life scientists in this study seem most concerned with a culture of the anticipation of failure manifesting as ongoing care and maintainance of experiments and equipment. In my wider research documented in the Critical Kit Library (Dalziel, 2019b) the simple story of innovation largely persists, where exotic equipment can be dropped into a community and radically transform them, uninintentionally eliding the slow careful work and capacity that makers, scientists and carers for people affected by disease and genetic history require.

Slow Emergence, Coloniality and Care

This slower story is important. What many of the maker projects reviewed in Diana's research lacked was fine grained documentation that might consider social, technical and bodily difference. This understanding of difference was explored through the idea of coloniality by critical clinicians in the field like Eugene Richardson (Richardson, 2019, 2020), academics such as Allotey et al in their article *The Ongoing Neglect in the Neglected Tropical Diseases* (2010) , that refer to post-colonial scholars in the tradition of Edward Said and others (Sandoval, 2000; Shahvisi, 2019; Spivak, 2010). *Orientalism* is Said's foundational contribution to understanding how the Western imaginary constructs 'the Other' through an hegemonic lens that reproduces power structures otherwise understood to be part of the past. There are problematic orientalist assumptions that European makers can 'help' countries endemic with disease who are otherwise neglected, by sending them Arduino projects. A material and above all, *participatory* interdisciplinary knowledge of human practices are required to control disease and its debilitating effects. Extractive political economies that linger in post-colonial states and sustained by reactionary responses to struggles for sovereignty must also be considered (Fanon, 2004; Rodney, 2012). Interleaving Practices and critical kit making could contribute to methods for making this knowledge. It would of course require a whole new sedimented social history of embedding, developed by different bodies with different histories, different shapes of interleaving practices.

Let us return for a moment to Mattern's point in her article with respect to how some local knowledge made up of 'lessons in the landscape' resist 'kittification' (Mattern, 2021, sec. 4) which my observations here seem to back up. Failures to adequately represent and mobilise the complex assemblages required for diagnostics to work in the field and for makers to be effective prevent desires from being actualised, failing to mitigate the spread of disease. The failure of my prototype *WaxPlotters*

project and attempts to reproduce the diagnostic kits in the *BREADBOARD-LAMP* describe a critical shape of limitation. In the microfluidic literature, according to (Longwell and Fordyce, 2019) these limitations 'renders a "lab-on-a-chip" more of a "chip-in-a-lab" '. What Longwell and Fordyce, 2019 call the 'world-to-chip barrier' is analogous to the 'world-to-kit' barrier Mattern observes. The shape of this boundary reveals how 'indigenous' knowledge and other local epistemological standpoints are part of deep, rich assemblages of knowledge and care. Critical kits that delineate world-to-kit boundaries is a space for a radical pedagogy that acknowledge different ways of knowing and what can and cannot be included.

Critical Kits can be seen as experimental tactics in learning about the assemblages and biopolitics of biomedical diagnostics. It revealed problematic assumptions and lack of knowledge when attempting to innovate within important large scale technoscientific interventions in endemic disease that resonate with ongoing assemblages of COVID-19 mitigation. It problematized the idea that a test alone can mitigate endemic debilitating disease - making a diagnostic test is just one part of 'the equation', a complex assemblage of sedimented knowing, caring and doing.

> Disease, ... occurs within a context of lives fraught with complexity. For any given infectious disease, who gets it, when, why, the duration, the severity, the outcome, the sequelae, are bound by a complex interplay of factors related as much to the individual as it is to the physical, social, cultural, political and economic environments. Furthermore each of these factors is in a dynamic state of change, evolving over time as they interact with each other. Simple solutions to infectious diseases are therefore rarely sustainable solutions... Without significant efforts to address health and poverty, along with the myriad marginalising factors in the social, cultural, economic, political and physical environments in which affected populations live, there will continue to be neglected people and neglected contexts. (Allotey, Reidpath and Pokhrel, 2010, pp. 1, 5)

Endless Deferral, missed opportunities

> It's not this sort of, I would like to say this almost macho way of thinking about... I mean 'you're a real problem solver you know I tinker it through' it's not about that.. It's about the joy of never finishing anything of knowing that whatever you do actually you have to put a stop to it - because it's never finished! (The Tinkering Studio, 2014, from 2:20)

Folding in CNC practices in the makerspace, microfluidics, point of care diagnostics, DIY Biomaterials and domestic experimentation our capacities grew but to date no complete kit 'ready for shipping' has been actualized. What it has led to is an ongoing project 'PlotterParty' to develop a version of a Jubilee printer ('Jubilee 10cc Syringe Tool', 2021), an open-source desktop 3D printer with interchangeable printing heads that include a syringe based extruder for semi-liquid DIY biomaterials, a computer controllable felting and batik for textiles and 2 Dimensional plotting and cutting. It is another embodied artefact but full of deferred interleaved possibilities (Figure 89-90).

This is the risk for embedded practice like this, the value and richness of embedding

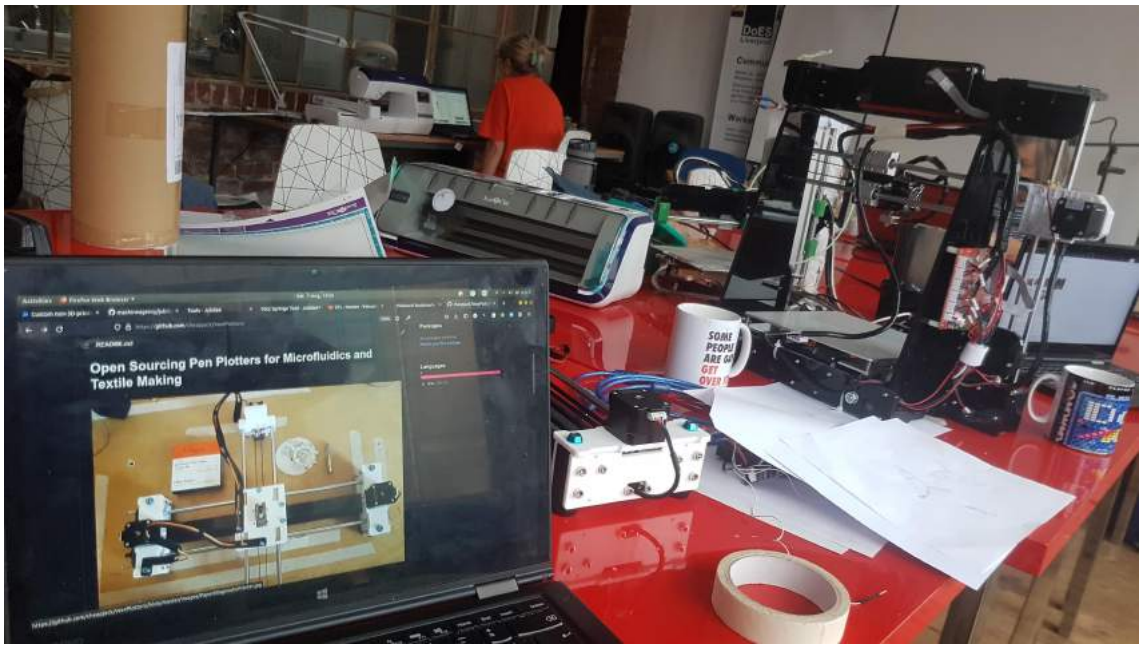

Figure 89: PlotterParty event at DoES Liverpool, where participants experiment with CNC plotting, digital embroidery and hack 3D printers

Figure 90: Jubilee Printer head prototype

can be lost in unfinished projects that fail to intervene at any kind of scale. In DoESLiverpool 2 years of activity developed an artist Mar Canet's prototype open-source knitting machine, the *Knitic* (Canet, 2013) which became a key feature of maker events. This boundary object generated social activity in the community and contributed to later interests and knowledge in textiles. In 2022 it remains in a corner of the makerspace alongside storage of hackable knitting machines. It is not discarded, but the social activity has moved on and momentum has been lost. Makerspaces, like artist studios and life science lab benches, can become storage for historical projects that are no longer active, unfinished projects unrealised. What is unique to many makerspaces, and not entirely by design but more by necessity due to lack of space is that these 'inactive' projects often remain visible in the space. This visibility is driven by shortage of rental space but unfinished projects like the *Knitic* and the unfinished Jubilee printer now in the fledgling NMC makerspace described in my conclusions, have an ongoing affective role on newcomers to the space even if the active social life of the project has faded away.

Early on in my research, an after hours workshop member at DoESLiverpool by startling coincidence, came into the space to prototype a microfluidics device which coincided with my discovery of microfluidics at BLS so quite quickly we had something in common. However despite working alongside each other and developing prototypes no critical kit emerged, other directions were followed. The *LabFromAChip* and *FlyFarm* kits became stable finished kits but with different mobilities. The *LabFromAChip* kit is ready for shipping and use in my ongoing practice, easily built into a workshop. The *FlyFarm* however requires more investment, more desire to develop over time. Like many projects in an embedded art practice and in DoES Liverpool it is hard to predict the outcome.

Interleaving 5: Assemblage Theory and Practice

This rich discussion and analysis of the interactions at DoESLiverpool puts forward Interleaving Practices and Critical kits as a method for exploring and understanding complex assemblages of discipline, ways of knowing, practices, materials, care and temporality.

What was interleaved? It was the interleaving of intimate long form encounters with technoscientific practices that supported and prompted rich ethnographies and led to understandings of the research sites. This method is not so much a specific pattern of behaviour or research design but rather a strategic intent, considering extended time periods of embedding in the 'culture' and 'distraction following' in order to develop deeper understandings and capacities on the utlimate horizon. The strategy is to keep possibilities for productive encounters open through almost endless deferral, slowly building capacity, but responding quickly to opportunities or needs. These encounters made it clear how kits, and by extension wider technoscientific practice, require and are always partially in relations with, complex assemblages of practice and temporality.

Pooya Ghoddousi and Sam Page, in their recent paper *Using ethnography and assemblage theory in political geography* (2020), argue for thinking of assemblages as part of an ethnographic method, resonating with the Interleaving approach.

> An assemblage approach also blurs the boundary between the researcher and the researched–as the research is co-produced through said relations – opening potentials for participant sensation, empathy and solidarity thereby enabling a Participatory Action Research. ... it can help the research move away from producing generalisations of phenomena and focus on generating concepts that explain patterns of relations and processes of becoming (Ghoddousi and Page, 2020, pp. 8-9)

When Marres and her colleagues call for *inventive* social methods that intervene, 'Participatory Action' becomes central. For me assemblage theory, particularly the Deleuzian concepts of *productive desire* and *strata*, provides a set of compelling tools for understanding the sometimes bewildering implosions of relations and configuration that STS and other forms of relational mapping generate. A fully realised assemblage approach to specific aspects of biomedical science, interleaved with inventive embodied participatory kit making could follow from this study. My approach is to use critical making to 'feel for the organisms' to build capacity for empathy and solidarity and co-produce important assemblages of feeling and understanding.

In the workshop organised by the conscare group from Lancaster Centre for Science Studies, *Temporalities of Care in Conservation Environments* working together with researchers Mariana Cruz and Edda Starck these assemblages became 'lumpy coalitions', interdisciplinary alliances. (Boschen *et al.*, 2022). Previously siloed and seperated individual perspectives can clump together into productive and affective visions of care, an intentional collective *demos* that actor-network theory can fail to grasp, otherwise just so many webs of relations relating. Observing the participant's productive and joyful desire to use new materials together in ways that are actively connected to diverse 'goods' is transformative. Maker culture and its technical economies are partially connected to larger technoscientific assemblages which means there is a potential for makers to become effective radical educators and material activists. In DoES the culture is to provide an accessible safe space, a capacity to experiment together.

I do not fully commit to, nor understand, Deleuze and Guattari's schizophrenic analysis. That is beyond the scope of the study. Likewise, I have only touched on the deep complexities of technoscience and microbiological life sciences and how they are brought together in the sites of the study. However Critical Kit Making and Interleaving could increase the capacity for a radical pedagogy of the technical arts and humanities. My research through practice and the practices of others has led to another playful prototype which I present in the next chapter. This is not another kit for the manual but a prototype *practice*, a radical practitioner *interleaved* with others, itself some kind of assemblage. This virtual prototype I attempt to actualise, configures and facilitates a method for working alongside and across different ways of knowing as a collective.

Chapter 5: The Interleaving Practitioner

the urgency of the present demands that our scholarly responses not be limited by the confines of imagination. (Sandoval, 2000, p. 19)

What is an Interleaving practice? It is something like an art-science practice, like being interdisciplinary. In thinking about the observations of activity every practice in the study can be seen as interleaved to some degree. It is inevitable that people in their complex variegated landscapes of practice switched modalities and registers, daydreamed, filled in a spreadsheet, put plaster on a wall, implement a theory, looked at a tweet, designed a box, organised a shelf, leafed through a book, bought a sandwich, delivered a workshop, searched on eBay.

The Interleaving Practitioner is part cartographer, part curator, a playful facilitator and gatherer of this normal activity. Such a practitioner has a careful sensitivity and orientation to the interleavings of their own and others practice and materials across time and space, the collective labour of making technoscientific assemblages. Such a practitioner looks for the 'settings' on the system as Marres (Marres, Guggenheim and Wilkie, 2018) describes it, the critical points and contradictions but also the distractions and granular assumptions perhaps lost in grander narratives and then carefully tweaks the settings or prompts them to change in appropriate ways. Like leafing through several books at once while making notes for a new one.

Making kits ensures one is not overly dependent on a literary leafing of books analogy. Interleaving like critical making is a practice, like the messy leavening and folding of sourdough bread. It includes some indeterminancy and improvisation. There is a recipe from a book, but then there is the feeling of the dough. Different mixes and types of flour and water and salt make variegated doughy landscapes, yet they hold together; they are lumpy and recognisable as dough and with work, can become nourishing bread. Individual components of flour and dough and air can still be visible, nothing is completely smooth and homogeneous. There is clumping and lumpiness that is not entirely predictable, is unique and heterogeneous but from a distance still recognisable as bread. Most significantly it is *intimate* hands-on labour with non-human actors, yeasty collaborators working at a different scale and strata, incommensurable with ours yet still interacting, present. Bread is one of the oldest technologies, pre-capitalism, pre feudalism. Yeast and humans have a long collaborative history together for over 6000 years when evidence of wine fermentation was discovered (McGovern *et al.*, 2017).

The Interleaving Practitioner folds-in material intimacy by jumping from literature to practice from art to science with a sensitivity to social relations and affective productive desires. The Interleaving Practitioner learns to expect and respond to what and who gets folded in, making intervening decisions along the way.

The Dialectical Biologist

> The role of art in contemporary techno-scientific worlds... lies in being a generator and facilitator of new grammars of collective action to face the economical, political and bioethical issues that emerge from the intersection of venture capitalism, mass media and bioscientific accounts of the world. (Andrés Barragán, 2009, p. 329)

One of my first employments as a 19 year old was for Centre for Overseas Pest Research (COPR). This lab was located in the most secure contained

> research area in the UK. It was housed in the highest level inner 'sanctum' security area within Porton Down, the Government's chemical warfare research centre. The only reason it was there was because modern insecticides were based on nerve toxins. Here we see a complex intertwining of chemical warfare linked to the colonial relics of support for overseas aid to control 'pests'. (Thesis Commentary by Supervisor Rod Dillon, 2021)

The Interleaving Practitioner prototype has the most to learn from one final perhaps most important Practitioner that I have hitherto made invisible. In some ways I have left the best till last. I have lent heavily on STS and feminist technoscientific scholars. However their theoretical approach only emerges from an *a posteri* position, observing and analysing practices after they have happened. Clinician Eugene Richardson, before his online presentation at the annual 4S meeting in 2002, playfully called social scientists 'curators of facts' making a strong epistemological distinction between the natural sciences and the critical post-humanities, while making a compelling argument for these two positions to inform each other in his presentation of his paper *On The Coloniality Of Global Public Health* (Richardson, 2019). Bridging this curatorial distance is what critical making, embedded and participatory art practice has to offer answering my first research question. The Interleaving Practitioner interleaves the gap between theory and practice, art and the real. Perhaps some STS scholars already do that. In Haraway's case her training as a zoologist and PhD study in Developmental Biology is interleaved with her scholarship.

The final practitioner to learn from is the *Dialetical Biologist* named after the book by Marxist biologists Richard Levins and Richard Lewontin. For me the dialectic is once more related to Williams' 'active and complex relations' (1988). Dialectical relationships like complex commensalism in the biological world are not binary either-ors, they are mutually related to each other, a relational union of opposites. Human and Non-Human, inclusions and exclusions, tactics and strategy, art and science. Dillon is no stranger to complex human and non-human dialectical relationships in his scientific and artistic research into Leishmaniasis. In his own and his fellow scientific travellers teaching practice I observed at BLS, there was a constant focus on the relationships between micro and macro organisms, shifts of registers, scales material and immaterial care in understanding biological assemblages. Molecular objects, model organisms, the impact of war on sewage services and a tidy backyard are all part of the assemblage of the Leishmaniasis parasite Dillon and his colleagues study. The human social world is mutually related with the non-human and at diverse scales microbiology shows that these alleged opposites become fuzzily interrelated, another interleaving.

During the study in co-analysis and shared interactions at BLS he told fascinating stories of insect borne disease. He described how the interleaved social lives of insect and human accelerates the spread and virulence of debilitating diseases by human practices like the sale and distribution of used car tyres which can be full of mosquito eggs. In his colleagues modules, one lecture uses the playful format of a Latin American telenovella to explain the serious soap opera of human and non-human relations. In another lecture Dillon explains how the impact of war and inequality on human infrastructure and practices particularly accelerates endemicity and human suffering. Much of microbiology particularly in the study of disease requires the understanding of a vast range of components and scales across the molecular domains

of human and non human biology, and the molar domains of ecology and human social formations and practices what Deleuze would differentiate as relationships between the Biological and the Techno-semiotic *Strata*. Microbiologists in BLS appear to be deeply engaged in complex assemblages of strata that cannot be conveniently or easily differentiated. Unorganised plots of land, water logged plotted plants and protective fly netting to protect sleeping humans sold as fishing nets, driven by economic precarity is always part of the assemblage of disease alongside the microbiota of the gut of a sandfly. Ongoing underdevelopment, de-regulation and practices of coloniality in regions deemed tropical and 'endemic' with disease are as important as molecular phylogenetics and taxonomy of arthropod-pathogen systems. This is science that seems open to critique not just because of personal values or morality, but through empirical necessity. Dillon shares with me the literature critiquing his own field (Shahvisi, 2019) and he passionately explains to students how tropical disease was constructed by the transatlantic slave trade, a key period of his research career spent in the Liverpool School of Tropical Medicine. He points out how it is no accident that this centre of study is based in Liverpool, a historically vital port in the trade of human beings as commodities. In an offhand comment he warns students they may be marked down if they simplify lower income countries in the global south with an heirarchical 'Third World' label.

The intersection of lab practices and maker culture of this study began with visits to his lab for his annual bio-art intervention in the training of microbiologists, *MicroMart* (Dillon and Jackie Parry, 2014). He showed me how microbiologists often have to make their own equipment much like the makers in DoES in the design and practice of their experiments (Figure 56). Microbiologist, social scientist and artist and maker interleavings are norms for a dialectical biologist. The nature of the objects of their field's study, its debilitating effect and affect on the human body and complexity of 'disease vectors', the relations that allow a disease to spread in populations, necessarily means they must understand complex human practices at the same time as cellular and molecular processes. Microbiology when implemented in epidemiology requires interleaving complex scales and temporalities driven by a desire to mitigate the spread of disease and understand microbial worlds. Based on the teaching and practice I observed, they seem constantly aware of complexity and how an endemic disease is a dense assemblage of human and non-human actors and that multiple shifting variables must be considered.

From my perspective it is the sensitivity to social and microbial assemblages that underpins Dillon's art-science practice. His most recent work with Southern on the *Para-Site Seeing* project (Dillon and Southern, 2019) radically gives Dillon's non-human collaborators who he painstakingly cares for and nurtures in his labspace, social media platforms. There Dillon and Southern speak as if they were the insects or gut parasites, imagining their non-human identities. The work is full of tactics to help other humans understand how 'disease' is a complex social assemblage that cannot be isolated into simple diagnostic one button tests and solutions. Instagram and Twitter post are assembled to represent the journey of parasites through the sandfly gut and the contemporary humna world. An exhibition allows audiences to imagine parasite's travelling around the world by receiving 'parasite passports' and experiencing an airport waiting lounge designed to playfully emobdy the social nature of parasites relationships with human needs, desires, and inequalities of *mobilities*, an

area of social science research Southern explores. Yet this is not just playful science communication, not just an innovation logic. Dillon develops rich careful relationship to his virtual parasite collaborators and there are fascinating configuration shifts between subject and object when his twitter alter-ego *LDBob* became more popular than his own at a parasitology conference.

Figure 91: Rod and Viv Dillon as *Ophiocordyceps unilateralis* with art direction by artist and performer Conway McDermott

Over the course of the study a collaboration emerged lead by Hwa Young Jung, Domestic Science, and postgraduate student Yasmine Kumordzi, Rod Dillon and his partner and fellow microbiologist Viv Dillon, with a network of queer artists, scientists and performers. The group published the *Endosymbiotic Love Calendar* a printed wall calendar (Figure 9) distributed and sold to queer-friendly spaces and organisations where each month represents a microorganism through photographic documentation of performers in a kind of interspecies cosplay and drag. Dillon himself, with his partner scientist Viv Dillon, performs, encouraged by Liverpool artist Conway McDermott, to embody the *Ophiocordyceps unilateralis* parasitic

Figure 92: Image of the Endosymbiotic Love Calendar open at the month of May featuring Rod Dillon as the fungus *Ophiocordyceps unilateralis* on the Wall of *Root 69* a non-gender hairdressers in Liverpool, next to proprietor Steven Graham

fungus that changes the behaviour of ants (Figure 91-92). This project, influenced by my literature review, evolved away from the critical kit approach. Instead my colleague Jung's 'found format' approach to design became more appropriate as the project evolved over 2 years. In collaboration with Rod and Viv Dillon, the project won the Microbiology in Society Award 2020 from the UK Microbiology Society, the largest membership organisation for microbiology in Europe. The project is relevant with respect to how it interleaves, following Barry and Born's ontological logics, reconfiguring the subjects and objects of art and science. It also works in a kind of radical pedagogy mode, in the everyday 'domestic' settings of a kitchen, office, airport or hairdressers, complex interleavings of art, science and the social. The calendar represents an expanded life science practitioner that goes beyond the public imaginary of the biologist in a white lab coat.

Lost in the MicroMart

Dillon and his colleague Dr Jackie Parry run the *MicroMart* workshop, an intervention in the art-science dialectic and the core Microbiological technique modules essential to the careers of many biomedical and microbiology undergraduates, initiated by Dillon. Here microbiology undergraduates culminate their microbiological technique training with a challenge to make an artwork implementing their learning of microbial behaviour and the materials practice and protocols of the microbiologist. They are invited to represent an important and meaningful aspect of microbiology from across their theoretical and practical training by making a piece of bioart with the material practices of the laboratory. This is radical pedagogy, introducing another way of knowing, art practice, as a method alongside microbiological protocol to connect their technical knowledge to the radically different but no less important *techno-semiotic strata* of the social. It is no Frayling like 'bolt-on' but serious play that pre-empts and frames their independent research projects that form their final dissertations. Dillon then invites art-science practitioners like myself to playfully 'judge' the results like an art competition. I have attended 3 of these events with different artists and it is part of the origin story of this study.

MicroMart seems strategic, it allows artists to engage with students and students are able to explain their practice to artists. It introduces the artist to microbiological practice, potentially recruiting them to Dillon's vision of laboratory as artist studio. Like in DoES this is part of a desire to develop a culture - in this case an inter-disciplinary culture in his department. By embedding art-science in the Faculty of Health and Medicince curriculum in this way he goes beyond the traditional temporal boundary of an artist residency and tries to embed dialectical relations between art and science.

Attempts to reduce the MicroMart to a kit format fail due to health and safety concerns: there are some forms of knowing that require seclusion. Not everything should be placed in the wild, practitioners need to take care and some care requires very specific forms of seclusion and discipline. Dillon's and his colleagues seclusion however, remained open and sensitive to the social. It seemed driven by desire to fully understand the microbial world in its full relational complexity with the human. How the human is made up of multitudes of relations; mutualisms, parasitic, commensal, symbiotic, is also part of a keen sense of social justice mixed up in the

playful interleavings of art and science students make in the Micromart. Another approach to interleaving is attempted setting up a club for the faculty, *ClubBioMed*, a counterpart to the 3D Print Club. The club fails to gain momentum partly as I shifted focus to the 3D Print Club's and unfortunate timing. It's another casualty of the Interleaving approach where not all cultures grow, not all tactics pay off strategically. Dillon's direct intervention to a specific module is much more effective, it sticks and grows. In this way, it is a powerful example of how Interleaving Practice could be implemented in the radical pedagogy mode of Barry and Born. Art-science is interleaved into a technical module and is part of the assessment of their training. In other modules related to epidemiology, geographical, political analysis and theory could be interleaved in the same way. One interaction with another masters student suggests geopolitics and ongoing underdevelopment of certain nation states in Africa are as much a part of endemicity as the life cycle of insects. The life sciences are full of spaces for interleaving other disciplines and this should be studied further. Observing the teaching and learning of microbiology in my research shows, like maker culture, a potential critical assemblage for radical intervention to expand the scope of what there it to learn in the biomedical life sciences. It is radical as it is situated on the most productive of all boundaries, the boundary between human and non-human, suffering and flourishing. With the humanities arguably under attack by popular authoritarians, Interleaving the critical humanities with life science degrees perceived as 'high value' in the job market, could be a strategy worth pursuing to keep critical theory alive and relevant.

From the Interleaving Practitioner perspective, Dillon's vision for the laboratory at BLS to be an artist's studio sets up strategic encounters between the practices of artists, makers, biologists and social scientists. By emphasising studio *practice* rather than a project, he encouraged artists such as Andy Gracie and Gina Czarnecki discussed earlier to interleave scientific and artistic practice technique and method. The artist embodied and embedded in the lab builds capacity for understanding more than if they just make work 'about science' from afar. My encounters with Dillon's colleague Alexandre Benedetto in the lab between tasks, the 'spacing' of interleaving in social learning theory were essential to the development of the *LabFromAChip* kit. The curatorial sensibility of Dillon's, depends on sensitive understandings of commensal opportunities for art and science and a sense of patience to allow interleavings to occur.

Observing the culture in BLS made me understand the potential of art-science practice as a space for radical social learning. It also made me understand boundaries and difference, and the blurring of boundaries of human and non-human, subjects and objects that takes place when understanding holobionts and the behaviour of disease vectors. It complicates any kind of simplistic structure or essentialist understanding of the world. Complex interleaved approaches to learning, critique and care could be setup to make further interventions in the assemblages of biomedical technoscience in other institutions.

Contingency

Let's return to another dialectical biologist, Stephen Jay Gould and his critique of the popular imaginary of evolutionary progression in the Burgess shale a rich fossil record in the Canadian mountains of British Colombia (Gould, 1990).

The Interleaving method brushes dangerously up against a tautology of the interpretation of that fossil record that Gould critiques, where all the remains seem to fit the idea of evolutionary progress and represent a rich set of experimental ancestors for the life we see today. Gould instead suggests that the vast diversity does not necesarily lead to a chain of ancestry leading to 'higher' complex organism but is characterised by millions of evolutionary experiments that become extinct, what he calls 'decimation'. In my study, retrospectively, events proceed from strategic encounters with materials to a fully interleaved, rich, commensal art-science project. From this perspective, a workshop introducing 3D printing as a way to hack reality beginning with a 3D printed desktop identity kit *Thoughts On The Desktop* (Dalziel, 2018) and evolving into the *FlyFarm* (Dalziel, 2021b) kit at the NMC had 'enough' and the 'right kind' of ancestral prompts and assemblages of material to gather together a group of people in such a way as to lead to complex explorations of technoscientific flourishing that continues to grow at the time of writing. Critical kits look like they *fold-in* all the components for complex implosions and detournements to *un-fold* complex assemblages and intervene productively later. Interleaving seems to provide a method for intervening in complex assemblages to generate new emergent flourishing. The 3D Print Club are now developing a fully realised makerspace that gathers together the practices of care and making across their whole community. Interleaving seems to cause this through fortunate and well thought through strategy - after the fact.

What is elided are the similar tactics, initiatives, interest groups and activity in my research that failed to form a significant assemblage like *ClubBioMed* (Dalziel and Dillon, 2020). The *Critical Kits Manual*, provides documentation and 'proof of work' of the flourishing *LabFromAChip* kit and *NMC3DPrintClub*, but also stalled and incomplete prototype kits made in the study. It points to a rich online fossil record of the critical making in this study that did not become a stable easily distributable or useable kit. Almost as rich, for me as an Interleaving Practitioner and assemblagist, as the Burgess shale Gould explores. The *WaxPlotters* described in the final case study, the *SourdoughBreadBoy* and *BREADBOARD-LAMP* kit are unfinished, problematic, not quite working well enough and half made. The *Endosymbiotic Love Calendar* began setting up interdisciplinary meetings across art and science characteristic of Jung and my practice, guided by Rod and Viv Dillon. Yet it took a turn away from critical making, the situation requiring a different format from the 'kit' and a different form of collaboration. It is a 'wrong turn' for the case studies chosen in my thesis, but flourished beyond the study, *un-folds* elsewhere.

This is the Gould like *decimation* which he posits as the true character of reality of the history of life on earth and the actual nature of art, science and art-science practice. Most organisms, art projects or scientific experiments die before becoming anyone, anything or any theory's antecedent or ancestor. In my study, GitHub is littered with unfinsihed software and hardware vastly outnumbering popular fully maintained and documented software projects used across the technoscientific world.

And a further decimation before that, are the 'failures' and incomplete git repositories on maker's own machines, not 'good' enough to warrant publishing and documenting on a public repositories. There is an 'infinity of traces' (Gramsci, 1992) beyond the inventorised fossil record of GitHub commits, outside the exhibition catalogue, or the pre-print life science scientific paper. These are the *productive failures* that Gould puts forward as the real nature of history, and not the inevitable progression of higher forms of life and organisation.

Figure 93: Image of the fail better plot

A series of contingencies and capacities must be arranged to make organisms possible, clubs flourish, makerspaces sustainable or a microfluidic diagnostics mitigate disease. Again the key question of any theory-method hoping to unfold cause and effect: *How did it come to this?*. Interleaving offers no comforting analysis just an approach to reflexive discovery and experimentation. Interleaving Practitioners and Dialectical Biologists must start things up and anticipate failure, and then fail better, a quote attributed to Samuel Beckett plotted on a poster on the wall of DoESLiverpool from its earliest beginnings when a group of technologists assembled their first 3D printer kit and donated their first soldering iron and then experimented with CNC motors to move a pen on a wall (Figure 93). There are no guarantees or proofs for this method and way of knowing. Perhaps any researcher could spend time watching people in the same field sites with a different method and describe what those people were doing in their 'full complexity' with similar results. This method, although not predictive, generated knowledge through sensitivity to how it intervened, how it actively prompted and prodded inventively, how it made, or did not make, a difference. A sensitivity grounded in material bodily experience not simply discursive review and analysis.

As material 'prompts', the kits, sound simple. In fact my research shows how they are contingent on a collective material intimacy and social history of learning and boundary work that indicate rich sedimented complex assemblages of labour and care. They prompt what was eventually discovered but they do not make predictable

or falsifiable laws of interdisciplinarity or art-science practice. At any point the assemblage can be decimated, wiped out, become as extinct as a redundant python software library in maker culture, whose dependencies are no longer maintained.

Looking back over case studies prompts the question - What worked? I have thought about the exploring, facilitating and curating of boundaries and tactic of practicing alongside things to exploit opportunities. I have answered my research question, how I contribute to method in art, science and STS and knowledge production, through making and observing and intervening and asking further questions, 'How it came to this?', 'What was assembled and what was interleaved?' and 'What materials, methods, labour and sensitivities were gathered together? What strategies were followed?

Gould might ask for the anatomical features of the Critical Kits that were contingent on what played out productively, what I was able to discover. But the kits' features visible in the *Critical Kits Manual* and their online repositories, are only meaningful when entangled with the situations of their use. My contribution to method through Interleaving Practices is the understanding of how method is an *assemblaging* practice. It tries to be critical and experiment with what kind of assemblages make new coalitions and capacities possible, to expect and anticipate failure and extinction, like the *WaxPlotters*, and to exploit opportunities when they arrive and flourish like the 3D Print Club. Setting up a culture of biology labs as artist studio, of a place with prototyping and making tools lying around making it easy and safe to experiment is ultimately strategic. By building capacities but expecting tactical failures we can make it productive and re-articulate desires.

> we are a thing, an item of history, not an embodiment of general principles.. We are the offspring of history, and must establish our own paths in this most diverse and interesting of conceivable universes (Gould, 1990)

The Shape of Interleaving

> we do have to be for some worlds and against others. (Haraway in conversation in Fabrizio Terranova's film *Donna Haraway: Story Telling for Earthly Survival* (Terranova, 2016)

> The encounter between two disciplines doesn't happen when one of them sets about reflecting on the other, but when one realizes that it must resolve for itself and with its own means a problem which is similar to that which is also posed in another. (Bergala *et al.*, 1998, p. 49)

The Assemblage social ontology and biological research and what participant Diana called the 'social side of the equation' implies that everything is already always embedded and interleaved. The embedded Interleaving practitioner might imply

some sort of disconnected not-embedded, not interleaved place which is quite simply, not possible. Considering that, what is *not* an Interleaving Practice in this study?

The difference would be to not actively develop deep long form embedded sensitivity, to do no re-empractising, ignore difference and complexity, focus on one project and not be distracted, all of which is sometimes strategically necessary. Sometimes a one button test or paper diagnostic must just discriminate simply and quickly and get shipped. In the Wearable Technology Badge Workshop considerations of human and non-human boundaries defer to the easiest way to programme an LED with Micropython when the workshop room is double booked. A puncture must be repaired, an antibiotic administered at scale, possibly reducing global immunity. There are sometimes urgent immediate horizons that must be placed in the 'Must DoES' category and other desires deferred to another round of Futuregazing.

Interleaving and critical kit making can be followed in some situations but entirely inappropriate in others. In DoES responding to the PPE crisis, delivery and expediency was more important than the deferrals of critical making and culture making. A similar PPE face visor kit made differently and more slowly in the 3D Print club, instead of urgently filling a need it let the group care and understand their collective practice and contexts, more than it provided a desperately needed resource. Interleaving suited that context: The Neuromuscular Centre, as it turned out had to close completely and so PPE was only needed when cleaning the centre for its slow re-opening. There are, of course, trade offs with any method. The *WaxPlotters* project had all the components folded in but it remains parked and deferred awaiting a new development push. There is no project ready to be deployed for field workers to prototype new diagnostics with their own cost effective means of production and the group are yet to make a successful CNC batik method.

What I found amongst the decimations and trade offs, in the slow emergent fine grained collective interdisciplinary work of the study, was that explicitly starting with a strategic expectation of both slow interleaving and decimation, to commit to inventive interventions, generated a difference in my practice. It developed a sensitivity, orientated to possible futures, a way of feeling for the assemblage of things and what capacities could be built and nurtured. It is a bit like becoming the dilettante artist Mark Dion sees himself as, or the amateur of reality that Anne Marie Mol described. The Interleaving Practioner unlike the dilettante, must be explicit in how they intentionally intervene, to be more committed and accountable than the outside interloper Dion frankly describes. In the 3D Print Club interactions, I experienced unexpected transformative encounters with my participants. As practitioner and researcher I was changed by the interactions and I *became interleaved*; increasing my own capacities to care for my participants. Feeling for and expecting messy lumpy coalitions to emerge from Interleaving means you can see opportunities and imagine new possibilities, but you must put in the labour and time to build up bodily capacities to care. You must leave the safety boundary of the amateur and commit, at least partially, to a discipline. You see what becomes lumpy and follow the structures in the interleaving, the traces in the actor-network. As it takes shape, you can follow some shapes and not others. Assemblages are not smooth and continuous they are messy and have shape that changes over temporal and bodily context. Participating shifts their shape again and deforms their capacities and their directions of travel. Anticipating that lumpiness and being able to recognise

particular shapes and respond with appropriate tactics can be productive.

> *Assemblages are not collections of things.* In many cases the physical things assemblages draw into themselves are completely incidental, just so many props needed to actualize a particular *arrangement of desire*... It is the underpinning *organization of desire* that matters, not the bits and bobs, and this is true for all varieties of the assemblage. (Buchanan, 2021, pp. 65–66, their emphasis)

Chapter 6: Conclusions

They require promiscuous knowledge; they seem to accuse one of not having done enough homework. Anxieties arise, some look for an exit. Even worse, the connections may threaten the well-made world one lives in. One senses a potentially dangerous demand in them. The dormant activist stirs, "If I find out that T- shirts contribute to environmental degradation or coffee to poverty, how am I going to get out of bed at all?" How to live, how to know, how to be comfortable. How did comfort get wired in anyway? (Dumit, 2014, p. 345)

there is no development, no social struggle, no social contradictions which proceed exclusively according to the will of men and women. We come into struggles, to forms of life, which operate on a given terrain. . . . to be both a scientist and to be involved in the struggle (Hall, 1983, pp. 38–43)

Figure 94: Image of completed *LabFromAChip* kit

Many of the kits in my research prompted new experiences with inventive social objects (Figure 94). Novel diagnostics, tools for the curious, kits for making and doing microbiology 'in the wild', growing new materials. Kits used widely by makers also have a strong history in art practice, which I explored in the original Critical Kits Symposium card game (Dalziel, Jung and Winterburn, 2017) (Figure 1). They are part of a genealogy of instructionals approaches to art object making in the early modernist and Dada works of Max Ernst, Picasso, Kurt Schwitters, Man Ray and Claude Cahun. How are critical kits different, how are they critical? For the artist and participants making and using these kits helped explore the 'active and complex relations' of technoscience by thinking through gathering and manipulating materials. Critical Kits are like the ingredients of sourdough bread, protocols of microbial culturing, maker biomaterials, or algae shaped wearable sensors: they help prompt and make messy interleavings at work in technoscientific assemblages. They *un-fold* and *fold-in*, they are like the yeasty sourdough starters in bread making, made from the landscapes of practice in which they are embedded and are fashioned by, and then fashion that landscape in turn in an ongoing process.

By making Critical Kits we *fold-in* diverse things, prompt new possibilities and build new capacities. Using them and at times *failing with them* helps to *un-fold*

and understand the full complexity of their context in their landscapes of lumpy practice. I have described how kits in their arrangements of bundles of materials can reveal technoscientific assemblages, configurations, boundary labour, invisible work and care. The kits where shaped by the interleaving of shared interests, folding-in antagonism, irrelevance, frustration, joy and struggling with other ways of knowing: the difficult work across difference. As *intentional* boundary objects, they also shaped the capacities for this kind of work. Critical Kits are the *tactical* elements of Interleaving, in that they have specific utility for future interactions. They help run workshops, or embed deeper into a culture and also allow people to 'do' something; the ability to take images of algae and yeast with maker counterparts to lab equipment, let the 3DPrintClub help their community to return from lockdown or interact with microorganisms with games and stream the results online. They *fold-in* materials, methods and practices grounded in observations and encounters in my research assemblage.

Critical making in a specfic time and place and with specific bodies with specific affective capacities and specific materials gives the inexhaustible implosions of STS and complexities of technoscientific objects a shape and direction of travel. They seem to beg questions on social ontology beyond their humble helping role as tool, and became useful in thinking of technoscience and technoscientific development. Critical kits carefully make assemblages of materials and practices that prompt actors, like the cultural probes of design, into a certain kind of experience convivial to a certain way of knowing. They try to assemble materials in such a way as to prompt questions and not just boundary work but *assemblage* work - they are *assemblage* objects.

This makes Critical Kits more than tools for the 'cartographer of relations' or convenient knowledge mobilising packets. Kits made in this way act as some kind of diagnostic or compass. Making and prototyping in a place and critically reflecting on the process, on the interleaving of practices, builds a capacity and sensitivity to the landscapes of practice in which researchers as cartographers must become intimate with. Assemblage objects convivial to analysing the work of assemblage, implosions and configurations, but also sourdough starters with self organising elements.

Kit Dependency

Kits organised and gathered materials and scales, helped reveal what they might try to make mobile. They were tactics for Interleaving not just by-products of being there. Despite this organisation, packaging and mobility, kits don't work on their own. They depend on, to lesser or greater extents the desire, intention and labour of the social, requring engaged actors. They need to be interleaved. This dependency is perhaps why they have revealed so much and yet can risk doing nothing. In many of my interactions with Critical Kits I must also intentionally prompt and perform reflections on 'material history' in conversation. Despite my rejection of the spectacular transgression, there is a kind of performance necessary when using the kits with participants alongside the prompts in the materials and their documentation. Without the presence of me performing the role of workshop leader, these prompts may not be taken up by kit users at a distance. A *LabFromAChip*

workshop with NHS staff gives time to reflect on what kind of practices their jobs are made up of, sharing nuanced histories of social learning. But this was dependent on my framing of the workshop in that way and my performance while making alongside the participants over weeks online. I had not designed this kit to act as a cultural probe or therapeutic tool for NHS workers alienated by stress in the workplace but in retrospect interleaving in biomedical training at BLS meant I had the capacity to see that opportunity and follow it. The kit contained prompts for this unintentionally, in how it allowed some NHS staff to re-empractice and re-connect with elements of their original biomedical training and reflect on their working conditions now. The kits did not do this on their own. The Interleaving practitioner had to intervene.

Critical Kits include a set of prompts that are prescriptive enough for people to follow something and progress, yet open enough to allow unexpected use in the future. One tactic is to develop the 'richness' of documentation in a kit, to fold in more. For the PCB element of the *LabFromAChip* kit, there are deep levels of documentation and tutorials for making PCBs that can be re-used to teach PCB design for manufacturing in (McEwen, 2020) and guides for making electronics responsibly. PCBs in maker kits are often presented as opaque products which some makers object to - they are presented as black boxed commodities with little opportunity for makers to learn anything, the kits 'just work'. Critical kits try to form a contradictory balance of working well enough to help but without doing everything for you. Many participants comment on their frustration with the kits and then the joy of getting them to work.

One set of *LabFromAChip* kits are passed onto two research participants, Claire Weetman and her collaborator. There are no opportunities for me to perform, they are fully embedded in Callon's wild and only tiny prompts and tactics in the materials and documentation can possibly have any agency. What happens is they became interleaved with the specificities of the artist's own practices. They add and remove things from the kit and then distribute it out to their participants, they perform and enact it in their way in their contexts with their sensitivity. They don't desire the complicated art-science practices, they take the prompts they desire shaped by who they work with. What is returned is radically different from my intent. No art-science takes place, instead a 'digital blanket' was made out of Foldscope images, alongside phone images taken using a special cardboard frame to make images at the human scale mimic the Foldscope style, a circular image framed blurrily by the nature of the ball lens, all made at home by the artists and local families. These blankets are then used in group picnics outside to socialise safely in bubbles in covid surges and to bring people seperated by the pandemic together. What were the anatomical features of the kits that were contingent and what capacities were produced? It was not just the components but the intention and desire of the artists and families who used them.

Other interactions at MakeFest, *LabFromAChip* workshops, *FlyFarm* kits, PCB design and Wearable Technology badge making workshops and the ongoing *WaxPlotters* project all featured a range of different prompts for engagement, in different settings and registers and ranges of intimacy from hands on face to face workshops to online workshops across time zones. Each project and prototype, finished or not aims to prompt and *interleave* sensivity to the who, how, why and where of making and maintaining technoscientific projects. They attempted political and pedagogical cuts in the world, space and time for future coalitions and alliances. Over lockdown the

approach became less about kits to mobilise knowledge and materials effectively, than about gently increasing a collective capacity for intimate encounters with materials. What kind of temporary makerspace and lab can be made in your lockdown kitchen? My work with Domestic Science, explores what ways of knowing constitute science and the domestic. This became relevant in how the concept of biomaterials were explored by the Wearable group experimenting with organic dyes made at home and in the makerspace. When STS scholars at online conference sessions received their kits they commented on how, post COVID-19 the art-science kits resonate with how many of us are 'doing domestic science now'.

Kits and many other analogous complicated technoscientific objects from silicon chips to cars do not work on their own. The world must be changed radically over complex landscapes and temporalities to make them work, petrol must be processed, land enclosed, developed, taken back into the commons, abandoned again, materials extracted, wars started, roads built across the surface of a planet. This 'cost' of technoscientific capacity is often elided. Kits are always entangled in complicated structures of more than components; the social side of the equation. This idea of cost makes *assemblage* important, what capacities were contingent in order for something to become possible? Why are LEDs so cheap?

The answer is often made invisible. Labour costs of care and maintenance which feminist struggles continue to make demands for, most vitally in everyday gendered social reproduction and domestic care, are also elided in maker culture and technoscience. Vast infrastructures full of exploitation of human and non human resources must be built to make enough LEDs to sell them for a few pennies to makers in the global north. Care for the makerspace and the pedagogy that takes place in DoESLiverpool and at the NMC are built on these troubling contingencies. However from my observations and interactions thay can become critical spaces for acknowledging this and gazing toward future more egalitarian and ethical forms of technoscientific making.

Caring-with the Organisms

> The point is not only to expose or reveal invisible labours of care, but also to generate care. (de la Bellacasa, 2011, p. 94)

I want to answer my research question further, what I see as the study's contributions to art, science and STS and interdisciplinary knowledge production by reflecting on some specific literature in those domains and how I see these contributions in terms of care at this point. STS scholars Calvert and Szymanski's describe intimate relationships and structures of feeling between bioengineers designing 'whole genomes' and the 'yeastiness' of the yeast they work with in *A feeling for the (micro)organism? Yeastiness, organism agnosticism and whole genome synthesis* (2020). They study engineers involved in whole genome synthesis, a substantial qualitative jump in bioengineering from genome *sequencing*; the study of how genetic material is ordered in the whole organism, to *synthesise* the 'design' of whole genomes. They are encouraged to abstract away the specificity of an organism and treat it like a 'chassis' to build on. However the researchers perceive that engineers have built up intimate affective relationships with the organisms they work with, they care about their 'Yeastiness'.

They argue that as humans get closer to making new organisms a wide range of humans must be involved in the process as values and ideologies play a part in the decisions made in biological engineering. Despite an assumption engineers must use *Saccharomyces cerevisiae* as a kit to engineer organisms, they still develop a capacity for care through refusing to lose the sense of the organisms' identity, its 'yeastiness' (Ibid.). This felt similar to the capacity for care required in BLS characteristic of Dillon's and his colleagues scientific practice that depends on *caring-with* the model organisms they work with, minimising the stress of sandflys and *Drosophila melanogaster*. Care was observed in the participants that played with algae, SCOBY communities, fruit flys and bioplastics but also the care for machines, 3D printers, plotters and microscopes, caring for each other through them. Interleaving Practices and critical kit making built bodily *capacities* for intimate, sensitive and affective relationships that lead to complex assemblages of care.

Perhaps it is problematic to introduce care, an often gendered, marginalised, classed and racialised experience of uncompensated everyday caring, to the care in a makerspace full of relatively privileged hobbyists, software and hardware developers or the care of well paid but precarious biomedical researchers and their fly colonies. Clearly this care is not the same as the caring labour of the marginalised. These are relatively privileged spaces that already have enough social and economic capital to care, so of course this limits the scope of the study and the speculations I make for their methodological and political value. Nevertheless the method attempts to build on and maintain a *surplus* of care.

Once again De la Bellacasa's privileging of care over an 'assemblage of things' or network of relations and concerns in technoscientific making was important in understanding the value of this slow method. Care is an intentional committment something that is *enacted* and *done* it is accountable in that you must care for some things, and not others. Care is not just a neutral network. Care is an affective, political act full of desire, invisible labour and time. This critique of care could be applied to how one uses the idea of boundary objects. A boundary is not a thing in itself, it is a productive difference full of social labour and care. My kits show the boundaries of science and art, of DIY lab practice, of expertise, of human and non-human. But as *intentional* boundary objects they also generate new capacities for care; they do not just agnostically delineate or negotiate different concerns or interests. Critical Kits, interleaving and folding-in, generate more than just an understanding of the already existing care already present. The *FlyFarm* kit unexpectedly generates care in newcomers initially disgusted by insects close up. With the *LabFromAChip*, a new relationship with the green scum in a bottle of water emerges. By making with the non-humans, machines, algae and invertebrates the participants care for each other. The engineers in Calvert and Szymanski's study develop a capacity for care for the 'yeastiness' of the microorganisms they are supposed to be agnostic about. Their yeastiness should be less important than their instrumentalisation as a chassis for building whole organisms 'from scratch'. Critical Kits make you realise nothing can be really made from scratch, there is always an existing assemblage to deal with. To answer my research questions we need to also ask, how could the idea of increasing capacities for care be harnessed through critical making and Interleaving and applied in biomedical technoscience? A Critical kit approach to Calvert and Szymanski's world would make a critical kit interleaving contradictory desires for

being accountable to yeasty difference and organisms as development platform.

HCI researchers Austin Toombs, Shaowen and Jeffrey Bardzell make ethnographic studies of an American makerspace in *The Proper Care and Feeding of Hackerspaces: Care Ethics and Cultures of Making* (2017) use making, and hacking as boundary objects to understand what is going on there. They use the theory of ethics of care to find a complex social interdependency of maintenance and a form of what they describe as, 'covert' and 'hacker-care' (Ibid.) that seems to contradict the popular neo-liberal imaginary of makers and hackers developing individual freedom, self-empowerment and resilience. Critical Kits and Interleaving Practices could be employed to extend ethnographic research like this into maker culture and explore how it is sustained, why some maker communities flourish and others fade away and what kind of political and caring capacities can be brought into being, what desires they can actualize.

Let us return, one last time to Ratto's critical making project: to think through materials, which my research contributes to. In my observations and method, I invite critical makers to *care* through materials, and more specifically and explicitly to make caring-with constituitive of thinking through materials. Moreover this thinking must also be done *collectively*: Caring and thinking, much like the forms of power the social sciences and critical humanities aim to reveal, do not exist in and of themselves, they are always in relations with other things, other humans and non-humans in an emergent assemblage. It must be noted however, that making even the most dangerous and corrosive technoscience like the weapons platforms built at BAE systems in Barrow in Furness, where the *BlackBoxGolf* project is deployed, require care. Care is not always benign and it can become dangerously mundane aswell as invisible. In the case of military technoscience some care is necessary, while other forms of care and temporality must be actively and ferociously repressed. They are not simply neutral technoscientific networks of actors interacting. In DoESLiverpool it takes some confidence to begin to take care of the space. Often some people caring prevents others from taking part and building their own capacities for care.

Critical kits prompt capacities for care, but they don't make things easy packaging and bundling conveniently, rather they gather problems together by interleaving. In this way they powerfully contribute to technoscientific critique. Unlike a purely discursive approach to critique they prove somebody has spent time, labour and care over them, made material commitments, not just made them mere concerns in the abstract. The *WaxPlotters* fails to democratise digital batik or microfluidics - so far. But the failure is all the more convincing and productive than a discursive review or meta-analysis. The *WaxPlotters* respond to researcher J M Pearce and colleagues work 'Open-source Wax RepRap 3-D Printer for Rapid Prototyping Paper-Based Microfluidics' from the *Journal of Laboratory Automation* in 2016. This ambitious project's desire, to make the cost of paper based microfluidics for electrochemical detection close to zero, was interleaved with the desire for new ways of using CNC technology as a kind of digital batik in DoESLiverpool and the desires of the 3D Print Club to be able to print exotic home made materials. I ordered components and spent precious community time attempting to make something similar. But despite extensive documentation of materials, 3D models, a detailed wiki and open-source tool chain, our version of this device remains unfinished. The 'cost' is not even close to zero. The project shows what kinds of costs are really involved in such a project in

terms of communal care and labour an important question that cannot be answered discursively, they must be asked through making, critically. Critical kits are not packages of solutions but rather packages of problems. How can we care and be critical of the way we make things without impeding 'progress' and improvement that leads to flourishing ethical technoscience? What are the biopolitical implications of the trade-off between making with more or less care? Critical making like this could help answer these kinds of question in fine grained detail.

> This involves not only detecting what is there, what is given in the thing we are studying, but also to think about what is not included in it and about what this thing could become — for instance if other participants were gathered by/ in it. In that sense, standpoints are not fixed, as they depend on material configurations and on our participation in (re)making them. A feminist ethos of representing care is not reduced to the application of an established theory but it has to be constantly rethought, contested and enriched. (de la Bellacasa, 2011, p. 96)

Assemblage Objects

Critical kits extends the boundary object approach by considering the idea of *assemblage* objects. Like boundary objects they are a playful way of thinking with something, 'a methodological category' (Griesemer, 2016) or representation, aswell as real things to discover and intervene with. *Assemblage* objects are a way of thinking about and intervening with assemblages across different communities and scales, assemblages of care, desire, material and time. GitHub in this study is an assemblage object - a technoscientific assemblage to think through many of the making practices observed. The Critical kits are *intentional* assemblage objects; the projects published on their GitHub repositories summarised in the *Critical Kits Manual*, show the traces of this richness and point to possibilities for using tools like GitHub as a form of assemblage mapping for technoscience in the making. Assemblage objects help a practitioner be aware of boundary making, representation and the materials gathered together and made, but also the deeper complex *infrastructures* they are embedded in, a big part of Star's sadly unfinished research work. Critical kits fold in GitHub because it is a part of the rich ecology of practices, a significant assemblage to think through that then un-folds how makers do things. Other places and practice to study will have different assemblages of course. The DoES analysis recalls, although on a much smaller scale Star's and Ruhleder's research in the 1990s in Chapter 24 of *Boundary Objects and Beyond: Working with Leigh Star* (p. 377-415) on early computer 'community systems' and an ethnographic approach to 'an ecology of infrastructure'. I imagine an alternative timeline a different future, where Star continues to pursues her unfinished work on infrastructure as an active contributor on large GitHub projects raising and opening all kinds of issues that are not easily closed but open to new possibilities and new priorities.

I see Interleaving and Critical Kits as contributing to STS methods for understanding and intervening in complex technoscientific assemblages or infrastructures, the big complex objects of our conjuncture. You develop understanding by critically making technoscientific objects, folding in materials, desires and methods as you find them,

changing settings here and there gathering new coalitions along the way, then letting them un-fold into new understanding and failures, or new capacities, the result of research intervening in the world. A kit-making method for STS and art-science.

Futuregazing

Making, experimenting, critically or otherwise is always orientated to complex infrastructure, care and temporality, some timeframe that is not now, a form of socially acceptable utopia. When we see scientists and makers focussed and caring on the task at hand, it is easy to think they just methodically approach things by comparing situations to previously banked knowledge - like following a 'how-to' manual, or cashing in on an investment. However, a how-to must also hide the complex wrong turns and other possibilities otherwise it could become confusing and useless. In fact, when making the participants, scientists and makers, were always thinking about other possibilities and temporalities, constantly comparing to previous mistakes and anticipating new ones or following new opportunities. In this sense making, especially with kits, is always strategic and driven by desire to mobilise something elsewhere in time and space. Critical making intensifies and draws out critical points in that process, it defers completing things. Although the DoES GitHub repository impressively futuregazes at the horizon it also obsessively and verbosely trys to capture and learn from the past. There is no mistake that goes untracked. At times git users can add the option '-v' to add verbosity - reveal more invisible work or use the command 'git blame' to track the origin of a software commit or a saved incorrect change to a wiki page.

In BLS the workbenches hold undergraduate, graduate and research that takes years to complete; in addition to the complex temporalities of keeping model organisms alive and stress free. Looking at how complex temporality and practice work in DoES and BLS it is easy to abstract it as innovative project management, what can get forgotten is desire. It is the desire of makers and scientists that really drive things not obsessions with project management infrastructure.

Interleaving and Critical kits as Assemblage Objects, is a method that needs much further study in the context of Deleuzian assemblage theory and infrastructure, ethics of care, STS method, and science pedagogy and inventive social science. STS practitioners and other assemblagists, attempt to not only map the full structural complexity of technoscience but include the importance of understanding how method and observation intervene and partly produce the reality it attempts to access and unfold. STS and the feminist technoscience project, is a crucial ethical critique of knowledge production and all the more crucial for research in the oncoming wilds of future and present crises. Critical Kits, Assemblage Objects and Interleaving offers the opportunity to be intimately part of the working relations of technoscientific production 'on the ground' caring-with the things that you are trying to understand. Different bodies and histories to my own and my participants could explore this differently with different kinds of materials not necessarily kits. Different affective kinds of care temporality and desire.

I now understand Critical Kits and Interleaving as contributions to understanding technoscience for both curators and constructors of facts, STS studies and techno-

scientific practitioners and makers. They include theory, method and materials but also care, feelings, affect, ideology, big messy assemblages. Gathered together they contribute to inventive and interventionist Art and STS approaches to social research and aim for transformative enounters. They started from a critique of technoscientific making but have become strategies and tactics for increasing positive capacities for care in the Deleuzian sense of more not less.

Seclusions and Enclosures

> ... the different disciplines are not all in the same boat. (Callon, 2009)

Kits in the case studies and the wider research can be seen as tiny molecular historical conjunctures. Their affordances, what they can do how they were made are highly contingent. They can be seen as complex assemblages of a particular set of historical circumstances; globalised supply chains, ubiquitous computing power, prototyping and the availability of the large scale manufacturing of advanced capitalism leading to a surplus of democratised knowledge. I put forward that making such technoscientific objects slowly, collectively with care and an awareness of them as assemblages, full of interleaved labour and desire, with an eye on social justice is not only productive and educational but transformative and strategic when attempting to make better worlds.

The Interleaving method that emerges is not immediately political. It not only follows the actors, but acts alongside them, beginning with embedding and the possibilities of doing what they do there. A strategic flexibility in time is required, making space and meaning that allows discontinuous, emergent - at times irreconcilable - ways of making, thinking and speaking to fold-in productively. Reflecting again on Chantal Mouffe's agonistics, Interleaving Practice could be articulated as strategic counter hegemonic practice to foster more complex political capacities. (Mouffe, 2013). Developing sensitivities to the political and material trade-offs in kit making and so wider technoscience, can helpfully reveal ideological and hegemonic formations. In my research at DoES and BLS - and this should be studied further - makers, scientists and artists, other than planning for success or diligently ensuring efficiency, experiment and efficacy, rarely articulate or ask questions of their practice in fundamentally strategic terms.

Equally, makers and teachers involved with STEM and STEAM approaches in mainstream secondary education, which I have so far kept outside the scope of the research and literature could also benefit from a strategic orientation to care and maintenance in how they organise and deliver educational material. For people in DoES, developing a sensitive and caring culture is more important than some kind of strategy for innovation. However that cultural commitment to care, maintenance and distraction following is nevertheless ultimately strategic. This could be an important approach to complement STEM approaches and increase the capacity for critical thinking in primary and secondary education in the UK when financial and ideological pressure seeks to only deliver skills for a job market that is in any case poorly defined and in crisis. This needs further study if educators are to influence new generations of technoscientific makers, artists, science studies scholars and young Interleaving Practitioners.

In the Futuregazing workshop and the ongoing responses to it, the culture, what DoES stands for, desires to live up to shared values are strategic in reaching the goal or making a better world for the elusive and problematic 'everyone' that makers artists and scientists attempt to include. What is the ultimate horizon of the interventions they want and how should they get there?

Organizing through Interleaving

> The problem with most 'relational art' is that it absolutely exemplifies the tendency within both cultural and political radicalism to engage in 'tactical' interventions which simply have no social or political effect, to the extent that they become isolated enclaves within which a certain set of ideas or experiences can be preserved and reproduced, while having no discernible impact on anything outside of themselves. Experiential laboratories they may be; but an experiential laboratory with no ability to publicise its results, with no 'strategic orientation' to the outside and to the future, remains nothing but an enclosed territory and a depoliticised space (Gilbert, 2014, p. 191)

Attempting to understand the shape of Interleaving in DoES leads to considering some basic theorizing of political organisation that activist and philosopher Rodrigez Nunes discusses in his book *Neither Vertical nor Horizontal A Theory of Political Organization* (Nunes, 2021), reflecting on the dissipation of critical moments in the global occupy alter-capitalist movements in Brazil, US and the UK.

One is *horizontal*; that is, emergent organisation, tactics and orientations of care without top-down leadership. The other is *vertical*, disciplined and committed to a specific direction of travel. Nunes argues for strategic flexibility in interleaving these two modes. Interleaving and making in DoES, the horizontal is dominant and attractive, providing affective senses of freedom. There are also however sudden verticalist moments, in the lead up to a national or local maker event, or in a communal crisis when having to move building. The sudden crises of COVID-19 revealed that the horizontalist culture of asynchronous care could become vertical very quickly, a complete emergency set of new practices were put in place with a very clear goal ; use all resources to mass produce as many face visors as possible.

The current historical conjuncture features complex assemblages of biomedicine and governmentality combined with an ongoing crisis of democracy, representation and expertise. Anti-vax sentiment has become a growing disturbing structure of feeling. This is perhaps unsurprising considering the inability for non-scientists to feel any sense of agency in the technology of vaccination or the multiple crises of the social orders they are part of. When the representation of both politics and expertise breaks down, new interleavings of embodied experience could be a productive strategy to repair the capacities of the body politic. In the ongoing crises of democracy simply representing and then intervening on the behalf of other subjects, effectively silencing them, won't make the cut, in both disease mitigation and other biopolitical challenges in future precarious worlds. Critical Kits as assemblage objects and Interleaving Practices offer verticalist tactics and horizontalist strategies that might be productive here.

It must be said however, that these case studies and the wider PhD study are only small tactics in terms of scale, what Deleuze and Guattari would think of as *molecular politics*, compared to larger, what they would call *molar* formations such as social movements or organisations. So in response to Gilbert's provocation above, their strategic value is easily overstated. Nevertheless, when the Foldscope kit ships over 1.5 million units, and maker culture generates myriad eBay markets of kits or set development challenges that radically democratise biomedical technology and equipment, then these have the potential for significant assemblages toward a positive biopolitics. Reconfigured through counter hegemonic interventions, building capacities, following distractions, they have political potential to cause significant qualitative shifts. Makers and scientists, from a distance, can seem ideologically depoliticised but are actually quietly engaged with struggle, a latent activism, gazing at the future. Life science students and scientists, even at the scale of this study, are situated near important seats of power, and can be disproportionately influential in institutional biopolitical conjunctures. Witness the recent sudden visibility of epidemiologists on mainstream news when the COVID crisis sets up the barricades to business as usual. My research revealed how maker entrepreneurs have particular sensitivities to supply chains from an eBay shop to a PCB factory, sensing nuanced opportunities in the forces of technoscientific production. The deep networks of social care in charitable organisations like the NMC, have quite extraordinary capacities for collective care and mutual aid. These are molecular yet critical fields of practice for making new radical democratic spaces for technoscientific making full of critique and care.

My research questions ask what are the implications and opportunities for knowledge production. Primarily Interleaving orientate practices to political and interdisciplinary horizons beyond the immediate, letting in other ways of knowing as a culture and ultimately, a strategy. Embedding, feeling and caring for the organisms it defers production when possible, instead slowly building capacities horizontally. Yet it can seize stactical opportunities to intervene vertically when necessary. Interleaving is part of the many processes of any assemblage. Assemblages are complex and heterogeneous in their full critical complexity. Interleaving understands how assemblages are not unfeeling systems, they are full of affect, desires, hopes, joy and despair. The means and ends logics of Interleaving Practices approach to strategy are also subject to collective care and invisible work, common to all micro and molar politics. It reminds practitioners that method necessarily requires a political committment and responsibility to intervene in a particular way. There is always an assemblage and wider landscape or ideology that you work within, never fully secluded. Following Mouffe and Gilbert, Interleaving anticipates how what practitioners do is part of an 'ecology of material relations' in 'a general field of complex interdependence' (Gilbert, 2014), an ongoing antagonistic affective hegemonic struggle for human and non-human flourishing. One of the implications and opportunities of this research is an understanding of the roles and methods of knowledge production in these wider struggles and committing to where one intervenes.

This study is limited; the participants are small in number, and in their own little enclaves and enclosures. But they are enclaves for doing both inventive social science and experimental politics. Making experimental practitioners, experimental coalitions of artists, engineers, biologists, physicians, activists and social scientists.

We need experimentation and 'research in the wild' when crises arise that will require new coalitions of critique and care now and for the wilds to come. There is much to explore further in Interleaving a critical social science that could be engaged in an experimental care-full politics, a latent assemblage of struggle in a historical conjuncture where scientists are placing their bodies in the way of state actors (Johnson, 2022) and makerspaces like DoES host Extinction Rebellion protestors planning their next confrontation with fossil capital.

Unfolding

Interleaving Practices is as much a way of finding out what is happening, what an assemblage is, as it is a method for interdisciplinary art practice and inventive research, making and participating in new assemblages. To answer my first research question, embedded and participatory art practices in art and biomedical collaboartion offered a way to think of an Interleaving practitioner who becomes slowly more sensitised to their world through collective critical making, feeling for the organisms and molecular forces of assemblage and production. This sensitivity is full of care but is also strategic and opportunist, noticing and encouraging affective material interests, building new capacities.

Critical kits make boundary objects into assemblage objects; they are inventive, intervene and draw attention to all the already existing desires and infrastructures in an assemblage. Interleaving Practitioners use Critical Kits to both understand assemblages and intervene with care in the process of assemblaging. What gets made is another key feature, *care-full*. Critical Kits are *full* of care, a nuance captured in the hyphenation of *care-full*, not just the care taken to avoid mistakes.

So what contributions do Interleaving Practices make to theory and method in art, science and STS? Ultimately my research contributes to the inventive social science that Marres and her contributors call for (2018). The research through practice; embedded, participatory, shows how interdisciplinary invention and intervention require care-full, experimental, affective, tactical and strategic politics. What is the ultimate horizon of desire for social scientists, biologists, makers and artists in making methods and theory? The research is a starting point for imagining what new coalitions can be made with those practitioners and what capacities they will need to intervene in technoscientific assemblages and worlds in crisis.

One horizon for STS is to '...combine representation and intervention in social research.' (Marres, Guggenheim and Wilkie, 2018, p. 27). What the projects in that book share with my horizon for Interleaving Practitioners, across the case studies, is an understanding of the 'experimentality of social life and social situations themselves' (p. 33). It is a strategic affective *desire* to increase the capacities of the liveliness of the actually existing experimentalism of the social, for both researcher and research participant, together. Let us return to the metaphor of the leavening of sourdough bread, which I keep interleaving through the thesis: a lumpy coalition of human and non-human labour that needs time and labour and care ready for baking. Interleaving Practices increase the capacity for complex creativity and political subjectivities, exploiting the dialectic of inquiry and intervention.

Figure 95: Garden path to the NMC 'Retreat' inhabited by the 3D Print Club at The Neuromuscular Centre. Image credit: The Neuromuscular Centre

As i write in the summer of 2022, the 3D Print Club are no longer a club on a video stream, but a real built environment based in a heated wooden shed known as 'The Retreat' (Figure 96). You find this fledgling makerspace by following an accessible wooden deck (Figure 95) in a beautiful garden that has massively developed and grown over lockdown, with wild planting overgrown zones cut grass paths, pond and a semi permanent marquee. But this is not a place to fall back, retreat and hide, rather a space for lumpy coalitions to develop new capacities. The club has flourished in the assemblage of crises just as the garden has. Humans vulnerable to COVID-19 due to particular genetic bodily histories that societal structures make disabled have returned to the real at the NMC charity. There is a troubling backlog of hundreds of people living with neuromuscular conditions returning for physical therapy, solidarity and mental well being. This is a space to flourish in the trouble.

My research has also influenced the charity's Social Enterprise company, *NMC Design + Print* to buy a new lasercutter with donated funds, building on the new capacities. I am employed part-time in this new makerspace (Figure 98), to setup and integrate the lasercutter facilities with the design enterprise, the clinical teams and the Shed Club (an existing group of makers based in a wood workshop in the NMC car park), who partly inspired the format of the 3D Print Club. With my research in mind, I now see myself as an Interleaving Practitioner and my work as part of a life project to increase the capacity for care and survival with others in precarious worlds.

Assemblage objects are still being made. An open-sourced 3D Printed enclosure made with wooden frame, made by the shed club, 3D printed modular connectors printed in

Figure 96: The NMC Retreat, the new home for the 3D Print Club at The Neuromuscular Centre

the makerspace and laser cut acrylic cut at DoESLiverpool, something the NMC will soon be able to do themselves becoming future lasercutting oldtimers. The enclosure protects the print bed from fluctuations in air temperature (Figure 97), designed together, it interleaved all our communal practices. As part of the ongoing flourishing, I have begun a project to make 3D scans of the forearms of physiotherapists in the NMC clinical team. Then we can 3D print custom supportive materials and frames for therapists' bodies, to build their physical capacity to develop experimental and necessary clinical interventions that support the community's therapeutic needs. Meanwhile Domestic Science are putting together a residency programme to embed artists with disabilities of all kinds to work to collaborate with the NMC maker space supported by the network of practitioners my research has helped to articulate and form. It is a space for further research into care-full assemblages and inventive art and social science.

My research has directly built these capacities and new assemblages. However the real impact of my research is that in building in the way described in the study, being care-full, with a strategic view, Futuregazing, leads to the productive anticipation of the impossibility of any singular actor causing transformative intervention. No 'individual' - which from biology and social science we understand as convenient abstractions like body, class, race, gender or kit - can be credited on its own. The Interleaving Practitioner expects to be only an intentional part of an assemblage of desires, of an *organised* ecology of practices.

Figure 97: Another *Assemblage Object*, the 3D Printer enclosure at the NMC Retreat made together by the 3D Print Club and Shed Club at The Neuromuscular Centre lasercut at DoESLiverpool

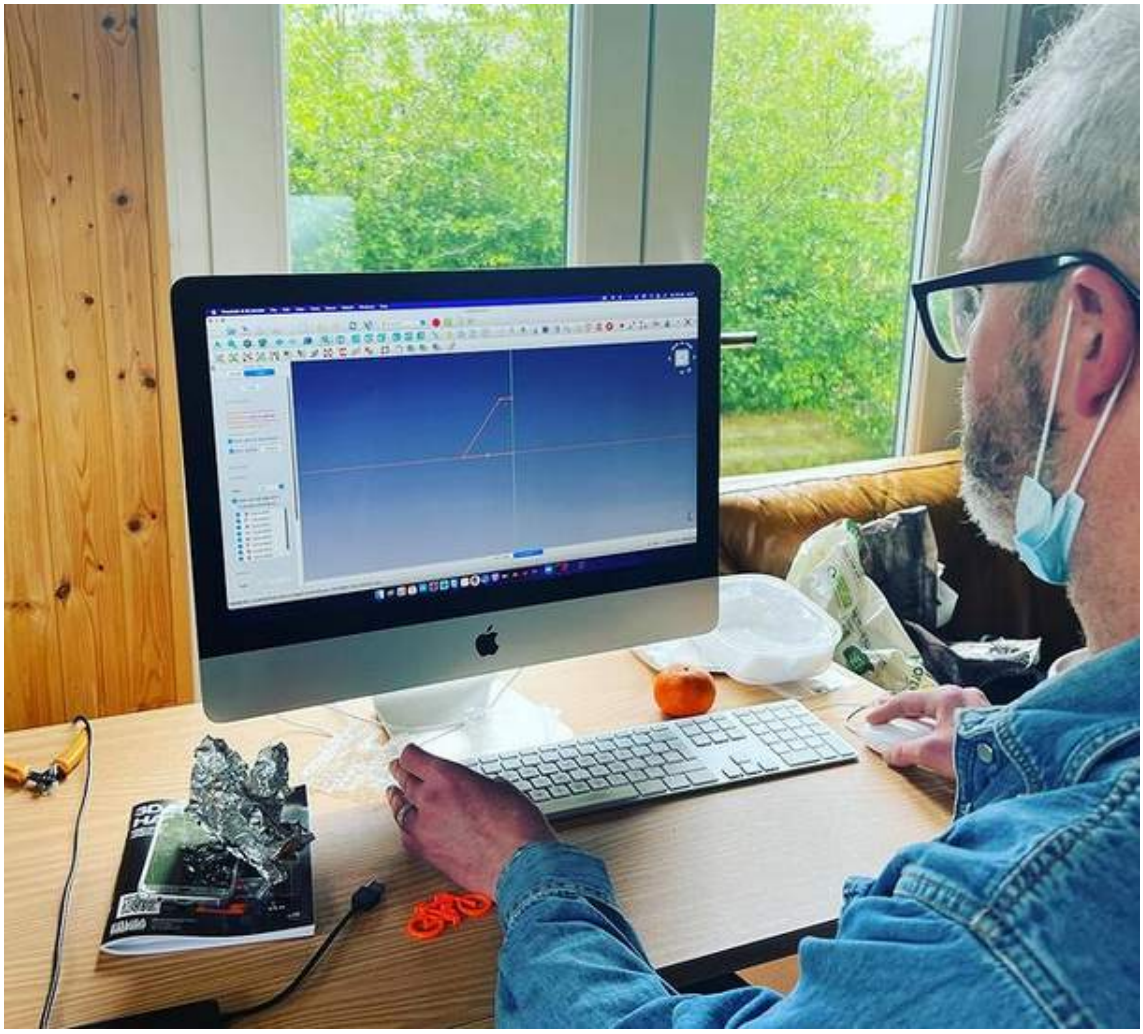

Figure 98: The researcher designing PCB enclosures in the retreat while waiting for visitors and 3D Prints to complete

Interleaving Practices are the opposite of a one sided positional approach to politics that Nunes critiques:

> It takes the work of others for granted, failing to acknowledge the ways in which they create conditions and opportunities for us... even those who claim a position of radical autonomy are never really outside these relations of interdependence (Nunes, 2021, secs 5, p.353).

Interleaving Practitioners understand that both intervening and maintaining new capacities to act is fundamentally a collective project across shared desires: they follow the dialectical biologist's holobiont point of view. We have never been individuals, we are always a commensal interleaved assemblage, coalitions of solidarity and struggle, feeling, making and knowing through art, science, critique, labour, desire and care.

Figure 99: Image of the *PrecariCat*, The Critical Kit logo, a remix of the GitHub 'Octocat' logo and the hammer and sickle symbol for workers solidarity

The Critical Kit logo combines GitHub's 'Octocat' logo with the hammer and sickle motif that represents the tradition of coalitions of worker organisation and revolutionary communism combined with the vector and fork motif that represents technoscientific workers in the 21st century. Traditionally the hammer represents industrial workers while the sickle represents agriculture, and together they symbolise solidarity across classes of working people. The vector and fork represents a coalition of technoscientific workers, the makers, using the GitHub fork symbol from software version control, and a 'vector' symbol, representing social science's mapping of relations, the disease vectors studied by biologists and Wark's speculation on the 'vectoralist' class. It represents the coalitions of microscopic, macroscopic and biopolitical life in my research while referring to Donna Haraway in the tentacles of the original Octocat.

Appendices

Appendix 1: Participant Information Sheet and Informed Consent Form

Contact Persons at Lancaster University Ross Dalziel, Principal Investigator & PhD Candidate, Lancaster Institute for Contemporary Art (LICA) Email: r.dalziel@lancaster.ac.uk Dr. Jen Southern (Supervisory Team), Lancaster Institute for Contemporary Art (LICA) Email: j.a.southern@lancaster.ac.uk	Prof. Paul Coulton (Supervisory Team), Lancaster Institute for Contemporary Art (LICA) Email: p.coulton@lancaster.ac.uk Dr. Rod Dillon (Supervisory Team), Faculty of Health and Medicine Lancaster University Email: r.dillon@lancaster.ac.uk Judith Mottram (Director of LICA) Lancaster Institute for the Contemporary Arts (LICA), Lancaster University Lancaster LA1 4YW Email: judith.mottram@lancaster.ac.uk Phone: +44 (0)1524 594395

On behalf of the Lancaster Institute for Contemporary Art (LICA) we would like to invite you to take part in this research. Before you decide, it is important that you understand the aim of the research, what it will involve, and your rights as a participant. Please feel free to ask questions at any time.

The main aim of the project is to understand how people including artists, makers, engineers, educators, technologists, students, workshop participants, enthusiasts, audiences, passers by, hobbyists and scientists understand and interact with the biological world. In particular we are looking at how people use 'kits' to do this. By kits we refer to a diverse range of examples, everything from a bicycle repair kit, an educational kit, a kit to discover genetic information or a tool kit to aid understanding a subject, procedure or policy. We want to make better kits and understand both their limits and their opportunities.

Who is carrying out the research?

Artist, maker and PhD Candidate Ross Dalziel is the Principal Investigator (PI) supervised by Prof. Paul Coulton, Dr Rod Dillon and Dr Jen Southern at LICA.

What does the research involve?

The research may involve collecting one or more of the following kinds of data to study and analyse, focussing on how participants make, design, discuss and use kits and biological knowledge.

1. Hand-written notes

2. HD video recordings, in some cases 360 degree video, with audio recordings of participants working individually and/or as a group
3. Individual audio interviews

We may also use these methods to record the situation and context of your participation or other details that may not seem relevant, but could be to the study. You are welcome to ask questions about any of this at any time.

How will the data be used?

We (the principal investigator and supervisory team) will only use the data (the video and/or audio recordings, handwritten or digital notes or transcripts of your participation) for analysis to help us understand how people interact with kit making activity and biological knowledge. Our findings based on the analysis will be used in a final thesis and may be published in academic journals, papers, books in print or online. We may also make artworks, exhibitions, further academic research, online journals, talks or blogs and other kits based on what we discover. These kits may be shared online or distributed for others to use. These kits will not contain or publish any identifiable or anonymous data we collect, but embody the result of what the research team discovers based on the analysis.

Should any *descriptions* of the activity in the data (not the video or audio data itself) be used in support of the presentations or publication of findings it will be anonymised or participants may choose to be identifiable through a pseudonym.

How will my privacy be maintained?

We will ensure your anonymity to the best of our abilities. All collected data will be treated confidentially in accordance with the General Data Protection Regulation (GDPR) and the UK Data Protection Act 2018.

Where you are recorded in hand-written and digital note-taking, the data will be kept in private notebooks kept in secure locked storage or on the Principal Investigator encrypted devices, anonymised after transcription and only be used for analysis, by the PI and only accessible to him and the supervisory team. You may choose to be identifiable through the use of a pseudonym.

Where you are recorded and identifiable in audio material, for example in an individual interview this will be kept securely on encrypted devices, then anonymised after transcription into text and used only for analysis by the researcher and the supervisory team. You may choose to be identifiable through the use of a pseudonym.

Where you are recorded and identifiable in video material this will be kept securely on encrypted devices and used only for analysis accessible only to the researcher and the supervisory team.

Should any *descriptions* of activity in the video data (not the video data itself) be referred to in the final thesis or in any public form, such as publication, journals etc. this will be anonymised.

Should any *transcriptions* of the written or audio data be used or quoted (not the audio data itself) or referred to in the final thesis or in any public form, such as

publication, journals etc. this will be anonymised. You may choose to be identifiable through the use of a pseudonym.

Data will be treated confidentially and stored securely on the principal investigators private encrypted laptop, encrypted external hard drive or the secure Lancaster University OneDrive with restricted access to supervisory team only.

Sensitive Information - If you disclose any information that may be sensitive, you should also be aware that our research is subject to the Freedom of Information Act. This means that external agencies can request the original data held by the researchers. If anything you reveal in the interview (or other data collection method) suggests that you or somebody else might be at risk of harm, I will be obliged to share this information with the study's supervisory team in the first instance. If possible I will inform you of this breach of confidentiality.

Group Work – You may participate alongside and in direct context with others. In this case your fellow participants will be asked not to disclose information outside of the group and with anyone not involved in the group without the relevant person's express permission.

Project Timeframe – The project starts **July 2019** and is ongoing until **October 2021**.

Data Storage - Handwritten and digital notes will be kept in private notebooks kept in secure locked storage or on encrypted devices, maintained and accessible only to the Principal Investigator and supervisory team for up to 10 years to allow for further possible study.

All audio & video data will be kept securely on encrypted devices, maintained and accessible only to the Principal Investigator and supervisory team for up to 10 years. *De-personalized data, such as transcribed audio interviews and analysis, will be kept securely for a minimum of 10 years after the date of collection. This is to allow further analysis and follow on research.*

Your Participation is *voluntary.* You have the right to withdraw from the study without providing any reason for your withdrawal at the time of participation or during data collection. You can request that audio recording stops or content is erased (but only content that you as a participant, are part of). You may also withdraw up to 2 weeks after your participation and if you do, your data will be destroyed and not used or analysed; after this point you will be unable to withdraw & the data will remain in the study due to the need for analysis to begin.

Please note if you participate in group activity recorded by video you are welcome to withdraw at the time of participation or up to 2 weeks after the recording. If you withdraw your contribution will be digitally removed from the study by digitally editing, blurring or obscuring the video frames in which you appear . Please do consider this carefully when agreeing to participate in group work and ask the research team any questions or concerns you might have. The research team will inform you before recording begins.

Please keep a copy of this form so you can contact us.

Risks – The risks involved in participating are low. It is possible that ethical

subjects around the use of animal material in biological science may arise in the course of the study that as a participant you may find uncomfortable or provoke strong feelings. The supervisory team will endeavour to provide support should this become a problem for you. It is unlikely that we will record such a debate, as it is not the focus of the study. Again you may choose to withdraw from the study without reason and your contributions will be removed as described above

What are the benefits of participating? A deeper understanding of how scientists, artists, technologists, makers and others use things like kits is important not only in the context of academic research, but for the pubic understanding and support of biological science, education, policy, maker education, design and everyday life. By participating in this research you enable important insights and methodological innovations.

What if I want to make a complaint? Please get in touch with our independent contact **Judith Mottram,** Professor of Visual Art & Director, Lancaster Institute for the Contemporary Arts (LICA) judith.mottram@lancaster.ac.uk

For further information about how Lancaster University processes personal data for research purposes and your data rights please visit our webpage: www.lancaster.ac.uk/research/data-protection

Thank you for taking the time to read this information sheet! Please don't hesitate to contact us if you have any questions. If you are happy to participate, please read and sign the Informed Consent Form overleaf.

Informed Consent Form

By filling out the form below, you confirm you have read and understood the 'Critical Kits' participant information sheet overleaf, understand the issues and your rights and have had the opportunity to consider the information, ask questions and have had these answered satisfactorily and wish to participate in the study.

Name (in capital letters):

Email: _____

I provide information with the expectation of confidentiality.
I consent to being observed by the researcher and recorded through **hand written and digital text based notes** used ***only for analysis*** by the researcher and his supervisory team.
I consent to be **interviewed** by the researcher using **audio recordings** and the content of the interview be used ***only for analysis*** by him and his supervisory team.

I consent to appear in **audio recordings of group conversations** made with audio-visual devices of the researcher used ***only for analysis*** by him and his

supervisory team.
I consent to be identifiable in **video recordings** made with audio-visual devices of the researcher used ***only for analysis*** by him and his supervisory team.
I understand that with respect to video recordings of groups of people if I withdraw I will be digitally blurred or obscured in the video frames in which I appear and so consent to only take part in video recorded group work in this study on that basis.

I understand that my participation is voluntary and that **I am free to withdraw at any time during my participation and up to 2 weeks from the date below**, without giving any reason. **After this point** I understand that I **cannot** withdraw from the study as analysis will have begun
I understand that if I disclose anything that may be sensitive or reveal someone is at risk of harm, I understand that the research is subject to the Freedom of Information Act. This means that external agencies can request the original data held by researchers.
I confirm I would like to participate in the study.
I would like to give additional consent to being identifiable in photographs or quotations for illustrative and documentation purposes of activities. This is distinct from my consent to the above, and ticking this box confirms you wish to be identifiable in this material. This does not affect your consent to the other data collected in the study

Signature: _____
Date: _____

Pseudonym (optional)*: _____

I choose a pseudonym to track my contribution where appropriate to the research thesis, research outcomes, publications, presentations or further studies.
I would like to also use this pseudonym to attribute my contribution to any kits developed as a result of the study.
* *If you do not choose a pseudonym, we will choose one for you; the selected pseudonym will be available on request.*

Appendix 2: List of Other Works

In this section I briefly describe a list of other works, projects and activity that took place in the research, but not included in The Critical Kits Manual. These works are referred to in the thesis.

- ClubBioMed Attempt to setup a bio art club for participants at BLS
- DigitalMigrations A series of workshops on maker and digital literacy for contemporary arts students, with additional care informed by my research
- DisruptEncodeConsolidate Symposium Survey of art-science situated in my professional practice and networks
- Endosymbiotic Love calendar Collaborative project of Domestic Science, the art-science collective I co-founded, and supervisor Dr Rod Dillon and Dr Viv Dillon and artist Hwa Young Jung and a collective of queer performers and biomedical scientists
- InterspeciesGaming Fledgling set of projects and resources for developing games with microorganisms
- PaperJam Paper based projects with environmental scientists
- ThoughtsOnTheDesktop Version of artist Neil Winterburn's Flunstellas project to introduce people to maker culture at the NMC
- Wearable Technology Interest Group Blog And Wiki Resources and website of the Wearable Technology Interest Group at DoESLiverpool.

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Critical Kits

Manual

CHEAPJACK

Ross Dalziel

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Illustration : Re-drawing of a diagram of *Euglena gracilis* in Mackay, S. (2022) 'Identification of the genes encoding enzymes involved in the synthesis of the biopolymer paramylon from *Euglena gracilis*'.

‘It’s a task of giving history some shape and sense, for a particular reason, … to understand my history in terms of other people’s history, in other words to try to understand, to move beyond, to generalize one’s own individual experience to the experience of others. And I think the great goal is in fact to become someone else. To transform itself from a unitary identity to an identity that includes the other without suppressing the difference.’

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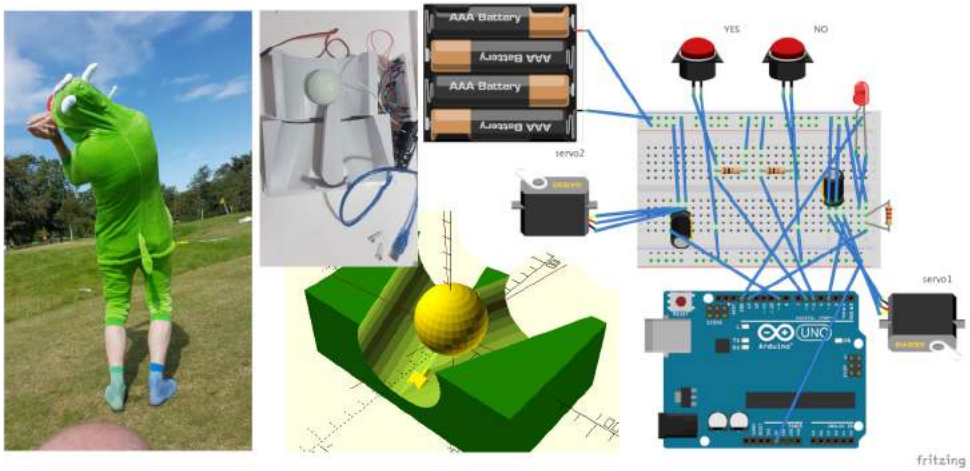
README.md

A Science & Technology Studies influenced Golf Hole

Make files, instructions and details of a Science & Technology Studies Crazy Golf hole for Domestic Science & Full Of Noises 2019 in Barrow Park, Barrow-in-Furness.



A Black Box is a way of thinking about technology; like a computer, as hiding, obscuring or ignoring how it really works. This is often necessary but sometimes it can cause problems and assumptions. All we know as black box' users is we put something in and expect something to come out. Most of the things we use every day can be seen like this. This rechargeable kit interprets a black box on a golf course. When you successfully 'putt' your golf ball 2 buttons can be pressed and the ball is released conveniently to progress onto the next golf hole, or less conveniently, toward an origami microscope workshop with the opportunity to view the freshwater algae Euglena gracilis swimming in the grooves of an old 7" vinyl record, and dress up like this fascinating model organism used in 'biotic gaming' and freshwater biology. We ask participants to think about how we see with microscopes and feel for other organisms.

cheapjack/**BREADBOARD-LAMP** Public

Code Issues Pull requests Actions Projects Wiki Security Insights

master 1 branch 0 tags Go to file Code

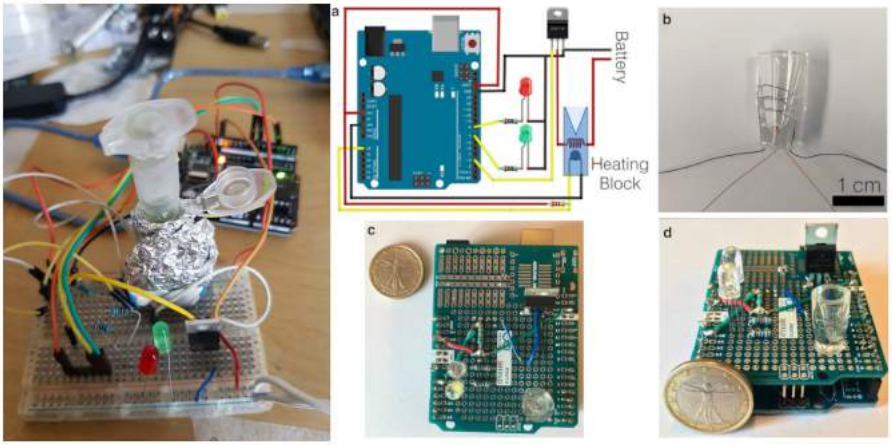
cheapjack images 2 days ago 2 commits

images images 2 years ago

README.md

BareBones Breadboarded Version of a LAMP DNA Amplification System

BareBones Breadboarded Version of a LAMP DNA Amplification System (Velders et al., 2018) Field Point of Care Diagnostics Shrimping.It style Low cost DIY temperature control by Nickel Cadmium wire from the LAMPShield project facilitates LAMP DNA/RNA amplification to heat and extrude wax and custom biomaterials. Can be combined with the WaxPlotter project for CNC control.



Breadboarding field diagnostics and biomaterials tells an exciting story of innovative material configurations that radically democratize knowledge making and technoscience, a core maker desire, a well meaning attempt to change the world. There is another counter story however of slow emergent, care-full diligence, maintenance, strategic patience and productive failure. The key feature of both maker prototyping and scientific practice is failure: it is intimacy, failing, falsifying and testing that produces social learning. Makers and life scientists are often concerned with ongoing care, maintenance and the anticipation of the creativity of failure.

cheapjack/**EthicalMicroscope** Public

Code | Issues 8 | Pull requests | Actions | Projects | Wiki | Security | Insights

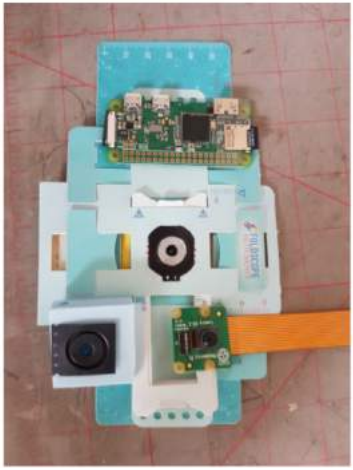
master | 1 branch | 0 tags | Go to file | Code

cheapjack streamlining text		14 March · 11 commits
builds	added pizero support cutfiles	2 years ago
images	more images	3 months ago
MET_Matrix.md	added a MET Matrix template in Markdown	3 years ago

README.md

DIY microscope stage that can be built with common makerspace tools

DIY remix of Public Labs version of the Simple Hackteria microscope following the Public Lab Build Guide while looking lovingly at the OpenFlexure Microscope project. Makes a pop-up microscopic Twitch stream using a Raspberry Pi and camera and github.comDynamicDevices/MakeSpaceLive by Alex Lennon and Matt Croughan at DoES Liverpool to share live video and 3Dprinter progress across a federation of makerspaces. Designs also includes a Raspberry Pi Zero camera with 3D printed case compatible with a Foldscope



Why ethical? It's open source and freely available and is meant to help people, especially makers, access basic microscopy using laser cut acrylic, standard microscope optics available on eBay and 3D printed PLA. Numerous open source designs for microscopy exist but here a barebones, minimum effort and low cost approach brings together the Hackteria and Publiclab designs and makes it compatible with a foldscope, a lasercut arcade cabinet for DomesticScience and affordable for classroom use.
It was also designed as part of a microfluidic aquarium add-on to the stage so that microorganisms don't have to dehydrate and die on the slide. This is a prompt to provoke thinking about how we work with and learn from microorganisms when we observe them, and what that might mean in terms of ethics and waste.

cheapjack/**FlyFarms** Public

Code | Issues | Pull requests | Actions | Projects | Wiki | Security | Insights

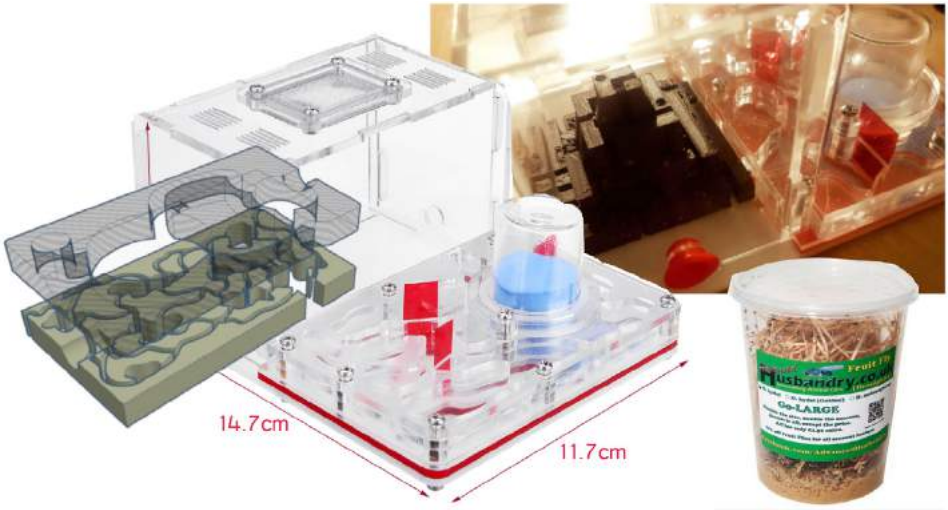
master | 1 branch | 0 tags | Go to file | Code

cheapjack streamlining text		14 March · 6 commits
images	streamlining text and images	3 months ago
models	first commit	9 months ago
openscad	first commit	9 months ago

README.md

Non-humans can be farmers too

Kit for imaging and streaming environments of *Drosophila melanogaster* a form of Interspecies Gaming Watch model organisms, biomedicines non-human collaborators on the Critical Kits Twitch Stream



Kit that explores the craft practices of the genetic experimental science of neuromuscular conditions with actors who are both the subjects and objects of the condition. Here practices of using *Drosophila melanogaster* models of Muscular Dystrophy (MD) are reproduced with another model of similarly 'flightless' fruit fly. This let's makers follow the practices of experimental biologists some of whom use 3D printing. Designing and using the kit with makers who share the bodily history that expresses the MD neuromuscular condition makes interesting differences. Comparing and caring-with other organisms makes a difference.

Later versions of the kit include 3D printed moulds for producing fly environments from recycled paper, cardboard or a range of Biomaterials including algal bioplastics.

cheapjack/**LabFromAChip** Public

Code | Issues 8 | Pull requests | Actions | Projects | Wiki | Security | Insights

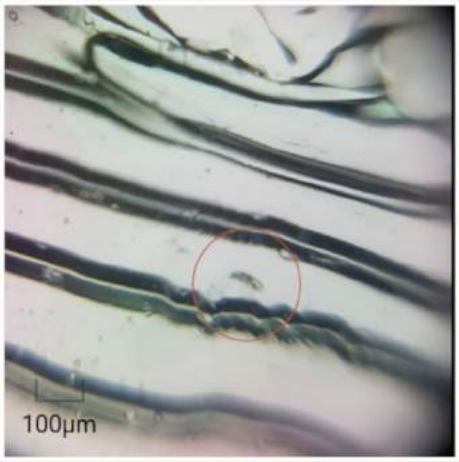
master | 1 branch | 0 tags | Go to file | Code

cheapjack Merge pull request #7 from amcewen/master ...	17 Dec	100 commits
LabChipPCB	Switch off power from the battery when there's...	2 years ago
builds	fixed weird shrinkin g of svgs	3 months ago
docs	temporarily add a workshop welcome	3 years ago

README.md

DIY intervention in Lab On A Chip Technology and Microfluidics

Lab-from-a-chip is a DIY intervention in Lab On A Chip technology using model organisms inspired by Science and Technology studies and scientific practice and part of Ross Dalziel's PhD research, Critical Kits at the Division for BioMedical Life Sciences at Lancaster University and makerspace DoESLiverpool https://cheapjack.github.io/LabFromAChip/



"A lab-on-a-chip is a device that integrates one or several laboratory functions on a single integrated circuit of only millimeters to a few square centimeters to achieve automation and high-throughput screening." (Wikipedia 2019)

"Microfluidic devices are an enabling technology for many labs, facilitating a wide range of applications spanning high-throughput encapsulation, molecular separations, and long-term cell culture. In many cases, however, their utility is limited by a 'world-to-chip' barrier that makes it difficult to serially interface samples with these devices."

(Longwell, Scott A, & Fordyce, Polly M. 2019)

cheapjack/**LatourScope** Public

Code | Issues | Pull requests | Actions | Projects | Wiki | Security | Insights

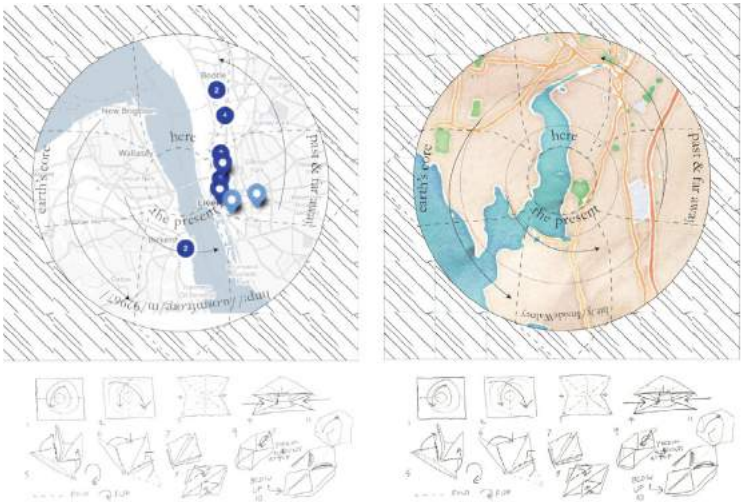
master | 1 branch | 0 tags | Go to file | Code

cheapjack Merge pull request #7 from amcewen/master ...	17 Dec	100 commits
LabChipPCB	Switch off power from the battery when there's...	2 years ago
builds	fixed weird shrinking of svgs	3 months ago
docs	temporarily add a workshop welcome	3 years ago

README.md

Origami folding maps based on Bruno Latour's 'Inside' performative lectures

The Latourscope is a folding origami map kit based on the work of Bruno Latour on critical zones from his Inside Lecture (Latour, 2017)



Latour thinks the idea that we live on the vast surface of the globe of spaceship earth is deceptive, especially when trying to conceive of our ever changing bio-social and bio-political relationships to our home. A soil scientists perspective is quite different to the mercantile globe maker; the critical zone for them is the tiny fragile vertical space that sustains human and non-human life; less than a kilometer above and below; which is more like a flat fragile veneer without which no life, no nature, no culture could exist.
My map takes a cartesian space from Open Street Maps and the Indie Manufacturing Project https://indie.mcqn.com/ and prints it inside an origami lantern shape. You have to carefully cut and fold your landscape and gently blow life into it. You then peer into the inner surface; try to get your bearings! Where are we really?

cheapjack/**MicroMart** Public

Code | Issues 8 | Pull requests | Actions | Projects | Wiki | Security | Insights

master | 1 branch | 0 tags | Go to file | Code

cheapjack Fixed bullet pointed list of materials — 4 days ago — 26 commits

images — Added a montage of results — 3 years ago

README.md

Rod Dillon and Jackie Parry's BioArt Module for Microbiological Technicians

Documentation of an iteration of the BioArt activity used as a teaching component at the Faculty of Health & Medicine at Lancaster University developed by Dr Rod Dillon and Dr Jackie Parry.

"As scientists, one of our roles is to be able to effectively communicate scientific concepts to the public. This takes a number of forms such as giving oral presentations, producing posters/ leaflets, all of which require some form of visual stimulus to keep the audience engaged e.g. pictures depicting the disease symptoms, a picture of the bug itself etc. One medium for communicating scientific concepts is BioArt.
A simple example is using live microorganisms on an agar plate instead of paints on a canvas. Microbial colonies vary in their pigmentation and their form (smooth, wrinkled, hairy, compact, spreading), providing a palette to work with. BioArt is not about making pretty pictures with pretty colonies, it's about conveying and interpreting scientific concepts which are demonstrated by the microorganisms behaviour on the agar which will make sense to an audience. You could use bacteria which communicate by Quorum Sensing through small diffusible molecules called Acyl Homoserine Lactone (AHLs); in our Bio Art this might be called a metaphor for words and conversations. The conversations have a positive impact on pathogenic bacteria by causing the up-regulation of virulence factors, making the cells 'nasty'. At low cell density, bacteria are essentially harmless because their conversations are too 'quiet', that is dilute) to 'hear' but at high cell density the conversations are 'louder', and the bacteria respond by becoming virulent and nasty."

mcqn/**my-first-pcb** Public

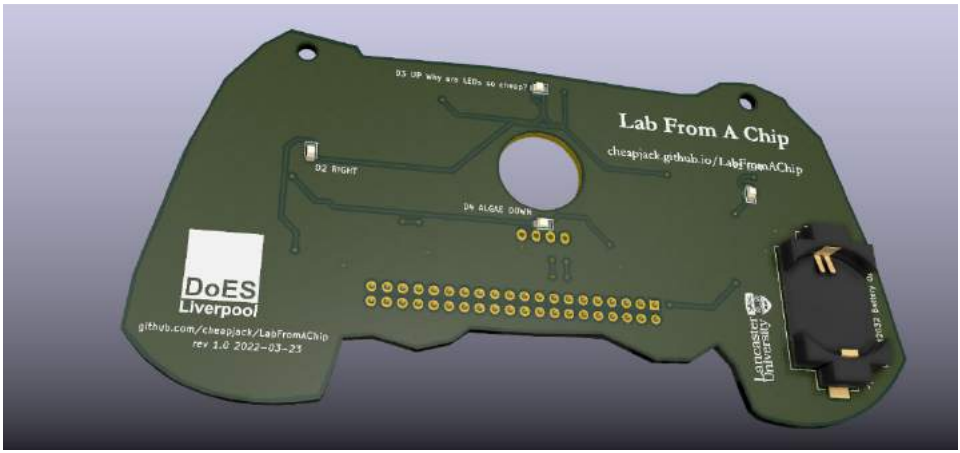
master 1 branch 0 tags Go to file Code

Adrian McEwen Updated Kicad website links to the new domain		8 Dec 48 commits
AddingArtwork	Add not on how to get the svg2schenzhen plug.	10 months ago
DesigningMyFirstBadgeLife	Update Kicad websit links to the new domain	3 months ago
MakingFootprints	Documented creating a footprint.	17 months ago

README.md

My First PCB

So you've been building up circuits on a breadboard for a while now, and maybe soldering some of them onto some stripboard, but maye want to make them look nicer and be more robust, quicker and easier to solder? You need to design your own Printed Circuit Boards (PCBs)! It's easier than you think with KiCAD.



Start off by running through the basics in Designing my first #BadgeLife and then choose your own route through the remaining tutorials based on what you're looking to build.
Start with one of the simplest circuits for our first badge: a battery-powered LED. It won't be the most exciting circuit board but will let us focus on all the steps in making the PCB without getting distracted by how the electronics work.
Then build up your confidence to make a more complex PCB like the prototype Interspecies Gaming PCB platform above which is really only a more complicated LED badge but with directional LEDs with options to connect up simple I2C LED screens and a Raspberry Pi Zero and a Foldscope microscope for interacting with algae. The slow careful ad-hoc interleaved material experimentation and process of assembling technoscientific objects like PCBs with others in a makerspace is a place to learn but also a space where critical reflection can happen. Are we making e-waste? What is an ethical approach to small scale 'indie' manufacturing? Why are LEDs so cheap?

cheapjack/**NMC3DPrintClub** Public

Code | Issues 8 | Pull requests | Actions | Projects | Wiki | Security | Insights

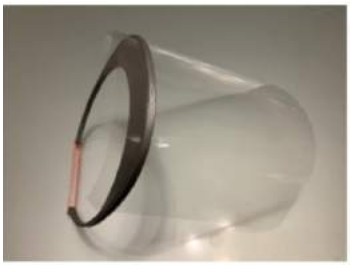
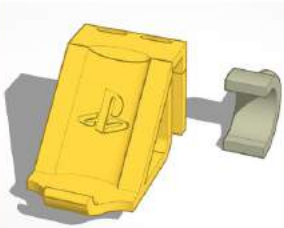
master | 1 branch | 0 tags | Go to file | Code

cheapjack face shield image in the README		19 Jan · 79 commits
InterspeciesGaming	Add file links	8 months ago
OpenSCAD	Rounded Rect helper	17 months ago
Prusa	README for the Prusa	2 years ago

README.md

3D printing community interest group at the Neuromuscular Centre (NMC)

Andy, Chris, Dennis, Jason, Kay, Paul and Ross have been experimenting with the NMC's Prusa i3 Mk3 3D Printer experimenting making desktop logos, straw holders for drinks, phone holders and wheelchair frame blanking plates since 2019. Since our first introductory workshops where many of us were 'newcomers' to digital fabrication, borrowing a printer from DoESLiverpool, the group have become 3D printing 'oldtimer' experts, modifying their own & others printers.


Through caring for our printers we've also cared for each other. We've printed to help with social accounting at the NMC, make Christmas gifts and cards, hack wheelchairs and game controllers, make name badges, stamps and moulds and make PPE In design and collaborate with the wood shop in the NMC Shed Club. We also built a kit, FlyFarm for interacting with fruit flys to explore how scientists study and develop treatments for Muscular Dystrophy.

We are currently based in the Retreat in the NMC garden which we are turning into a makerspace and artist residency space.

cheapjack/**SourdoughBreadboy** Public

Code | Issues | Pull requests | Actions | Projects | Wiki | Security | Insights

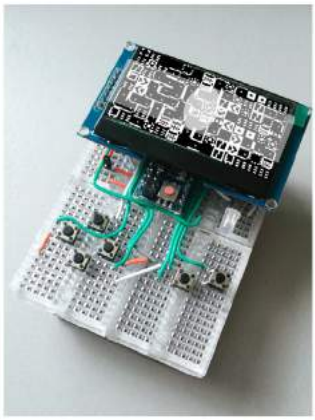
master | 1 branch | 0 tags | Go to file | Code

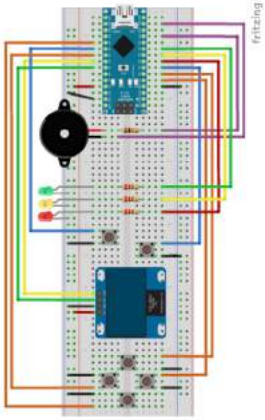
cheapjack removing old template		29 Aug · 13 commits
images	slimboy breadboad images and fritzing file	2 years ago
MET-Matrix.md	update the matrix	7 months ago
breadboard.fzz	slimboy breadboad images and fritzing file	2 years ago

README.md

Historical Materialist Breadboy NOT necessarily boys NOR necessarily human

Historical materialist fork of the Arduino based BreadBoy (Arduboy Community Forum 2019) a non-soldering DIY breadboard based arduino gameboy based on the Arduboy.
Inspired by Mikroskopisk PacMan, (Institutt for mikro-og nanosystemteknologi (IMST) ved HSN Universitetet i Sørøst-Norge, Kunnskap for fremtiden 2016), SourdoughBreadboy is a speculative handheld biotic gaming platform and part of ongoing Interspecies Gaming inspired by Science and Technology Studies.





We use the Slimboy Arduboy2 fork to make a resource constrained platform for experimenting with handheld microscopic inter-species gaming using Prakash Labs DIY paper Foldscope. This is combined with the scientific craft practices of microbiologists in the Lab From A Chip kit which SourdoughBreadboy can be used with. Games on the platform allow graphics to interact with *Euglena gracilis*, a ubiquitous light sensitive photosynthesising algae in microfluidic environments made from impressions of old vinyl record grooves. The platform allows for a variety of slide based microbiological experiments for learning across species.

cheapjack/**ProtestsForProtists** Public

Code | Issues 8 | Pull requests | Actions | Projects | Wiki | Security | Insights

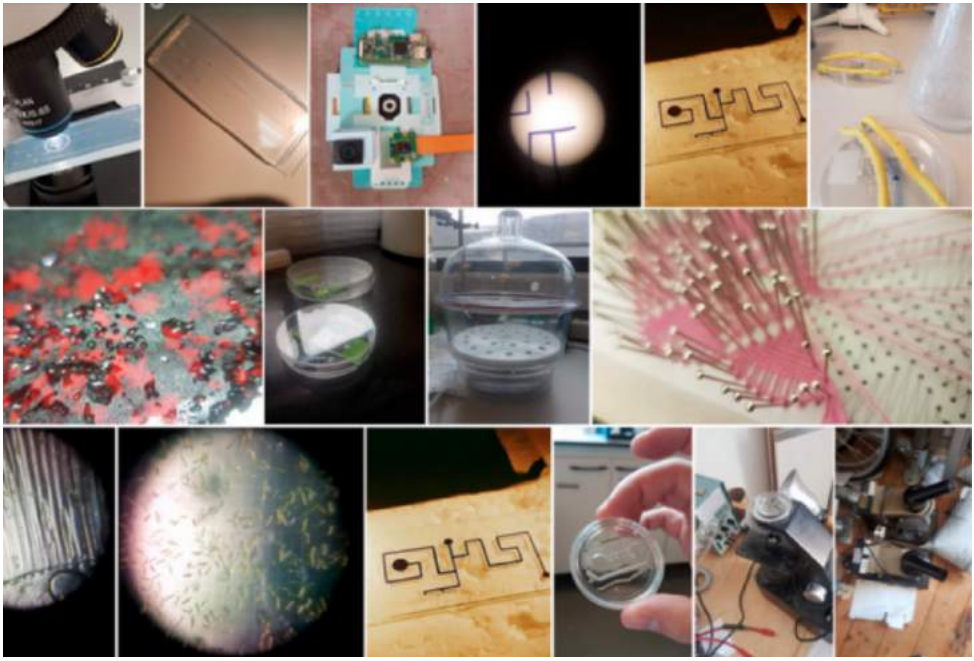
master | 1 branch | 0 tags | Go to file | Code

cheapjack updated with BlackBox link		23 Aug 5 commits
images	Fixed more representative image	3 years ago
making	Build and Make files for microscope stage and fols...	3 years ago
DIYMicroscopes.pdf	updated printouts and a guide to Hemocytometers	3 years ago

README.md

Makefest workshop for protesting biodiversity with various protists

Instructions and makefiles for the ProtestsForProtists event by Domestic Science
Armed with DIY microscopes count up hidden micro-organisms to protest against bio-diversity collapse in the back of your kitchen cupboard!



Learn how to count microorganism populations like a pro with a haemocytometer and use your camera phone to take and tweet pictures of microorganisms like *Saccharomyces cerevisiae* (yeast) and *Euglena gracilis* (algae) moving in millifluidic spaces based on street maps of climate protests on the microscope slide. This workshop provided passersby at Liverpool Makefest 2019 a space to talk about biodiversity and climate change at all scales of biological life. Streaming as and when wifi allows on the CriticalKits Twitch Stream.

DoESLiverpool/**WearableTechBadgeWorkshop** Public

Code | Issues | Pull requests | Actions | Projects | Wiki | Security | Insights

master ▾ | 1 branch | 0 tags | Go to file | Code ▾

JackiePease Merge branck 'master' of github.com:DoESLiverpool/WearableTe..		5 Feb 64 commits
drivers	added details for the Cp2102 drivers from shri..	2 years ago
examples	Updated main.py_single_colour, lights.py	2 years ago
images	revised images for corrected voltage divider	2 years ago

README.md

Get started with wearables, neopixels, ESP8266 & Micropython

Make a small interactive rechargeable wearable badge over 4 weeks to get you started in the world of wearable technology.

Designed to give you an understanding of basic fundamentals in electronics, embroidery and coding in the versatile programming language micropython to control interactive intimate wearables. We'll use DIY conductive yarn pressure sensors and variants of low cost ESP8266 development boards that can help you deploy all kinds of wearable (and non-wearable) technology. With this experience you'll be able to prototype and deploy wearable tech for art, performance, fashion, product development.
It's a chance to share your ideas with peers and meet other members of the DoES Liverpool community and get to know our facilities for the future. All materials are provided, with extensive workshop notes, reference and resources here plus your own kit featuring an ESP8266 development board, Sublimation printed sensor, single and 6-ring NeoPixels, and a rechargeable battery pack you can for your next project. Under 16s must be accompanied by a parent or guardian, suitable for ages 12 and up.

cheapjack/**WaxPlotters** Public

Code | Issues 8 | Pull requests | Actions | Projects | Wiki | Security | Insights

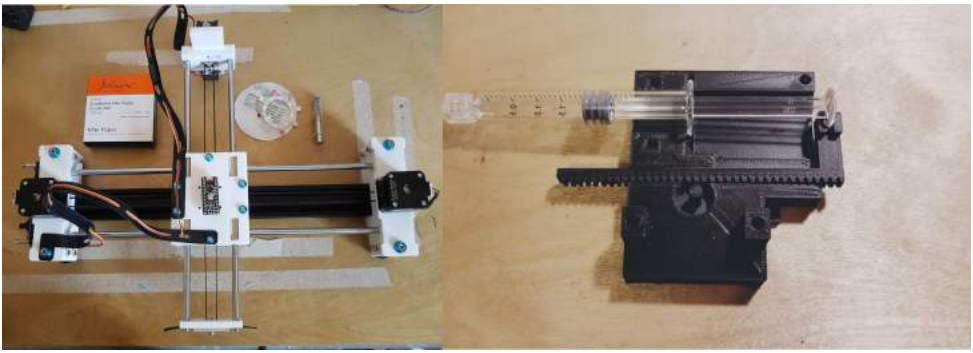
master | 1 branch | 0 tags | Go to file | Code

cheapjack streamlining text		7 Aug 7 commits
Arduino	Added LAMP_SHIELD schem	7 months ago
images	Added LAMP_SHIELD schem	7 months ago
README.md	Added prototype Arduino code and updated ...	7 months ago

README.md

Open Sourcing Pen Plotters for Interleaving Microfluidics and Textile Making

Adapting Eleksdraw cutter plotter with the BREADBOARD-LAMP heating system for extruding wax and custom biomaterials for prototyping paperfluidic diagnostics and CNC textile making.



Wearable Technology Interest Group at DoESLiverpool developed a hybrid open source plotter kit that used existing maker-accessible low cost components, to draw, cut, heat and extrude a range of materials accurately by Computer Numerical Control (CNC). The kit re-uses the approach to low cost Arduino temperature control by Nickel Cadmium wire from the BREADBOARD-LAMP project combined with a 3D printed syringe extruder and stepper motor to extrude wax onto lab grade filter paper for prototyping paper-based diagnostics following research into 'paper fluidic' literature (Pal et al., 2017), (Pearce et al., 2016), (Siegel et al., 2010) and (Seok et al., 2017). Wax heated and extruded along paths made using gcode tools in Inkscape and a simple multi platform serial interface form millifluidic channels in the paper substrate & can be used as a form of CNC batik for textile making . Head swaps out with pen holder to annotate paper while a cutting head completes the paper prototype. Interchangeable glass syringe head means it can accommodate biomaterials from the https://materiom.org/cookbook.

This kit attempts to interleave all the practices in the research, microfluidics, fluidic temperature control, rapid prototyping, field diagnostics, CNC, Gcode & Grbl tools and methods of 3Dprinting, biomaterials, 2D plotting, textile making, and cutting and biological technique.