Closing Gaps in Plastic Recycling:
Co-Design Methods Applied to Unaddressed Waste in Moray

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by
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Corrections

I have addressed the following minor corrections fed back from my viva examination:

Correction 1: “Draw out the significant contribution within the work surrounding the role on how you engaged people within the research.
Add the following points to section 5.3.3 in the thesis (a paragraph or two for each point):

- the reciprocal nature of how you engaged with P@B
- the value of volunteering as an approach within ethnography
- you went beyond ethnographic methods by giving of yourself and materials in each of your engagements with ‘participants’ – i.e there was clear value in the way you gave materials, skills like mending machinery and gave your time in ReBoot.
- Your approach used ‘care’ as a key characteristic of engagement – this should be articulated. Using ‘care’ is not necessarily how other researchers would have operated and you achieved rapport and interesting research findings because of this – there is an ethical, mindful, relational quality to how you have worked – we would like you to add a couple of paragraphs to describe that this is the case, because we can see value in this.”

These subjects have now been covered in several paragraphs in the new section 5.3.4

Correction 2: “Add the following points to Chapter 6:

- You had some lovely slides in the presentation – these need to come into the thesis, i.e. slides from timeline onwards.
- Expand on the recommendation slide in the final section in the thesis to make these points as clearly in the writing as you did in the presentation and discussion afterwards:
  - Materials and samples online
  - The knowledge exchange impact
  - Highlighting the potential economic, social, and cultural value of this work. A short paragraph on each would suffice in the Findings, Limitations and Future Research chapter.”

For this I have included the additional information from my viva presentation in section 6.

Correction 3: “Figures: Figures 25, 26, 27, 28, 29 and 31 are illegible at A4. Please review this.”

and

Correction 4: “Figure 32 – please state in caption that this image is included merely to suggest the full picture of the analysis space and that although none of it is readable each section is expanded in the following figures 33, 34, 35, 36, 38, 39 & 41.”

Since it was not feasible to make these screenshots of virtual sticky-note clusters legible in the print version. Instead I have deleted the surplus figures, then described and quoted some of the salient points raised. Otherwise I refer to Appendix K, which can be zoomed in digitally and will be provided as a plotter print to the GSA archive.

Correction 5: “Anonymise the names of your participants (e.g. use participant A, participant B or pseudonyms).”

In section 4.2 and Appendix F I have replaced the initials of the interviewees with numbers and made further efforts to redact names or potentially sensitive parts of the conversation from the transcript.
Some remaining initials have also been removed from Appendices I, J and K, instead only using the character pseudonyms that I chose for participants.

Abstract

This Action Research project explores how geographically remote communities can make creative use of waste polymers for which there is no economical supply chain available to recycle them, using social enterprises in the Scottish Highlands as case studies for development.

Each year, 5 million Scots purchased 3 new electrical items on average, weighing an average 5.9kg, from which only 1.8kg of waste was recycled, according to Zero Waste Scotland in 2012, and the UK generated 1.6 million tonnes of E-waste per annum according to the Global E-Waste Monitor 2020.

ReBOOT, a charity in Forres that recycles IT equipment from across the Grampian Highlands, observed that the majority of materials they processed, by volume, were the hard polymers commonly used to encase electrical goods.
The cost of shipping this material exceeds its value for the size of delivery batch that ReBOOT are able to store, so alternatives are needed, as sending the material to landfill costs the charity money, while Moray's landfills are now closing in favour of a planned incineration facility in Aberdeen, adding to the country’s carbon footprint.

Other works considered include the Precious Plastic project, a global Open Source Hardware movement to tackle similar problems, which has developed some key tools for processing polymers at a small town scale. This is being experimented with by Plastic@Bay, a Community Interest Company trying to make saleable products from polymers recycled from beach cleans in Balnakeil, the most north- westerly village of the North-West Highlands.

This study investigates how Co-Design methods may be able to find appropriate ways to recycle such unaddressed materials, aiming to reduce electronics polymer waste by making it available as a higher value product or as raw materials for local craft businesses. Particular attention is paid to ethics and the value of reciprocity in generative research.

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Glossary of Terms and Acronyms

Punctuation:
In this work, double quotation marks (“”) have been reserved to verbatim quotations of other works, whereas single quotation marks (‘’) are used when referring to the name of something but not to what the name itself refers (a ‘use-mention distinction’), when paraphrasing a sentence that would be messy if separated up by ellipses (…) to indicate gaps, and for very short quotations indicating for example that the choice of naming something was made in the work cited.
The latter use is sometimes referred to as ‘scare quotes’ when used to distance a writer from usage of a term, but in this work the attribution should not be taken to imply disagreement or irony.

ABS:
Poly(Acrylonitrile-Butadiene-Styrene), a thermoplastic copolymer.

Copolymer:
A polymer with a mixture of different monomer units within its molecular chains, producing new material properties blending those of the contributing ingredients.

Downcycling:
This term was coined to draw attention to the fact that in most forms of recycling, the extracted materials become degraded (such as by breaking and shortening of polymer chains) or contaminated by other waste, and so the resulting material and products that can be made from it decrease in value, often preventing the material from being used in its original application again (McDonough and Braungart, 2002), unless significant energy is invested in *refining* the material.

Municipal:
Referring to the provision of services funded and/or controlled by a regional government or council, or sometimes charities and other third-sector organisations, especially at the town and county scale, this is sometimes being used as a catch-all replacement for ‘local’, ‘council’, etc.

PCBs:
PCB has been used to refer to both PolyChlorinated Biphenyls (industrial chemicals once used widely as an electrical coolant fluid, but entirely banned in the latter 20th century after they were found to be both carcinogenic and neurotoxic in humans), and Printed Circuit Boards (the core component of nearly all electronic devices). In this context, it has been reserved for the former use (the chemical), as circuit boards are only briefly mentioned in the introduction.

PE, LDPE, HDPE:
Poly(Ethene), A.K.A. Polythene and PolyEthylene, a thermoplastic polymer, often sold in Low Density or High Density grades, where the short-chain LDPE is often used in very flexible products such as bags, and HDPE finds use in juice and milk bottles and their lids, or waste pipes and other sanitary containers.

PET, PETE:
Poly(Ethene-Terephthalate), A.K.A. Polyester and PolyEthylene-Terephthalate, a thermoplastic polymer with high optical clarity, often used in bottles and downcycled into textiles.

Polymer:
Polymers are materials consisting of large molecules constructed from many repeating units, often in chain lengths exceeding hundreds or thousands of ‘monomer’ units.
These are often colloquially referred to as ‘plastics’, however, for clarity the word ‘plastic’ will be reserved here as far as possible to its technical usage, referring to a material behaviour common to many polymers,

especially above their glass transition temperature: where deformation causes permanent changes in an object's shape, in contrast to *elastic* behaviour where it returns to its original shape after a force is removed. (Ashby and Jones, 2005, pp. 76-77, 101-102)
In many public-facing interactions, such as this document's title, the opposite has been the case, in order to make introductions more accessible to the public.

POPs:
Persistent Organic Pollutants, such as the former meaning of PCBs, are a class of substances noted for persisting in the environment through resistance to natural degradation processes, and which often 'bio-accumulate' in living organisms through dissolving in fats. When they concentrate in the tissues of predators, they can cause a variety of health problems such as endocrine disruption, for which reasons they are now regulated.

PP:
Poly(Propene), A.K.A. PolyPropylene, a relatively brittle thermoplastic polymer with a profound weakness to ultraviolet light degradation; often used in low-cost ropes, dairy packaging and outdoor furniture with added dyes to protect it from sunlight.

PPP:
The Precious Plastic Project, a global Open Hardware development project that provides designs and instructions for low-cost small-scale recycling machinery.

ROAR:
This was the name chosen to refer to a collaborative recycling project between two Moray-based charities, *Moray Reach Out* and *ReBOOT*, by the team carrying out the project.

SEPA:
The Scottish Environmental Protection Agency, an agency of the Scottish government that regulates activities affecting the environment, collects statistics on waste handling, advises and sometimes directs funding to projects, especially with the related initiative 'Zero Waste Scotland'.

Thermoplastic:
A polymer that can be returned between a molten or solid phase many times by heating it. Compare with Thermoset – a polymer that forms permanent bonds after the curing of a resin and will not melt with heat, but can break down with enough heat or oxidation; for example, natural latex rubber, epoxy resins, PolyUrethane rubber,

Upcycling:
Where 'Downcycling' is commonly held to mean recycling that decreases value, the converse term 'Upcycling' is used to describe activities that re-use dismantled and recovered materials directly in a creative process that increases their value, instead of chopping up or melting them.
From a Materialist perspective, there is no such thing as 'upcycling', because entropy leads all ordered matter to break down over time, and so every re-use results in a degraded material.
The term depends upon a Social Constructionist world-view, making a claim to 'value' in an object that is relevant within the lifetime of a human society. That tension is at the core of this work.

WEEE:
Waste Electrical and Electronic Equipment describes a type of waste regulated by the European Economic Community directive of the same name. This scheme restricts what materials producers can use in equipment sold within member states, and requires them to contribute to the eventual costs of recovering the materials from their products, while placing responsibility on member states to collect and process this material. The focus has been on the prevention of toxins escaping into the environment.

Acknowledgements

To my supervisors, I would like to thank George Jaramillo and Jay Bradley for their literature recommendations that helped to bridge my understanding into the field of design research, and Paul Smith for his constructive professional critique and advice that helped to keep me on track.

To all the study participants who provided their insights, I am grateful for all that they brought to the table and hope that I did some justice to their contributions with what I managed to fit into the final work.

To the management and staff at ReBOOT and Moray Reach Out, I am thankful for their patience and support over recent years while I completed this work through great personal difficulties.

To all the developers of Free and Open Source Software packages, such as the LibreOffice and Mozilla suites, and especially the Zotero bibliography software that seamlessly integrated the two, the free community service of Jitsi Meet for platform-independent voice and video calls, OBS Studio used to record those calls, and Shotcut used to edit a tour video, I give my thanks for their hard work on those systems that enabled me to compile this work.

I am also grateful to the team of Miro virtual whiteboard for providing a free academic license to their web-based Service As A Software Substitute, which enabled me to continue meaningful engagements with study participants at a distance, after responses to the spread of SARS-CoV-2 interrupted the middle of this research.

Finally, I wish to thank Highlands and Islands Enterprise for sponsoring the tuition fees for this research degree under the Creative Futures Partnership, and Culture Café for covering the costs of my initial conversational engagement / participant recruitment event.

Declaration

I, Andrew James Drummond, declare that this submission of full thesis for the degree of Master of Research meets the regulations as stated in the course handbook. I declare that this submission is my own work and has not been submitted for any other academic award.

Signed,

Andrew James Drummond

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January 2024

Preface

Ten years prior to the commencement of this research, I began to ask questions that led me here.
My initial inspiration came from dealing with the recycling scheme prepared by Glasgow City Council while studying there for my first degree in mechanical engineering.
Their kerbside system had one bin for three types of materials (card & paper, metal cans, and plastic bottles), which would be great for ease of use, but every 'wheelie' bin had a triangle-key lock and a brushed opening that was too small for some types of packaging, and required significant effort on the part of a resident to push things into the bin one by one, at a time when most people were not used to this. The spray-back one received from the brushes on a wet day seemed intended to discourage recycling, so it came as no surprise to me to learn that Glasgow consistently had one of the lowest recycling rates on the Scottish mainland, according to SEPA's annual statistics.

Around the middle of my course in 2009, through environmentally-focused media outlets I learned about the 'Great Pacific Garbage Patch' (Kostigen, 2008) and of many instances of waste material being mishandled, such as electronic waste that was effectively dumped onto the shores of poorer countries unequipped to handle it (Milmo, 2009).
I gradually became incensed to see inefficiencies in the system everywhere that could have been easily addressed with design, but the very simple lesson I found was that the materials in greatest market demand would always be dealt with first, and everything else consigned to landfill or incineration, until such time as more machinery and overheads could be afforded to handle it. That day of dealing with the waste slipping through gaps in the system never seemed to come, and fringe pollution concerns turned into a global crisis.

Most of the problem was technically feasible to solve, in that the necessary machinery existed to do the job, but the socio-economic system surrounding the application did not allow it to be solved, where money acted as a ticket of permission to use energy and materials for the aims of the bearer, and the city council apparently either did not have that permission or the will to use it.

Seeing how the market system was favouring irrational wants, fuelled by the previous century's push for a consumer culture, with no end of polymers available from cheap oil, I recognised that something had to be done outside of the under-funded municipal system to address this.
Moving the zeitgeist from one of endless growth and ignorance of the consequences, to a comprehensive handling of all 'waste' in a circular economy reflective of nature, with an accompanying culture that would have to express the same disgust at all forms of waste, appeared to be a difficult and generation-long task that is still being approached by many others today.
Meanwhile, the problem of pollution generated by this inefficiency was growing every day, and so motivated by the stance of "If not you, who? If not now, when?", I began to investigate any options that were open to a hobbyist for polymer recycling.

Starting with saving bottle caps that weren't being collected, then melting them down in foil trays in an oven, in order to form billets that I then milled by hand with a rotary tool, before eventually spending my last student loan payment on a kit to jump on the hobbyist 3D printing bandwagon;
I then spent a few years finding that, despite advances in online communication, one resourceful hobbyist with few resources in the highlands, will take a very long time to solve a problem of this scale, that those with spaces for collaboration sped past me in innovation, and that larger institutions need to be engaged in order to make a timely difference.

The current leg of this story begins in 2014, when I found a community in Forres that supported these ideas, within a melting pot of people from different walks of life that provided potential for great creativity, and housed a social enterprise dedicated to electronics recycling. From that point, it took the following years for us to build the case for this research & development, and progress formally began when appropriate funding opportunities coincided with a compelling case.

With mass media finally turning their attention onto this issue that had become a crisis in the intervening time, we could show clearly that this was an idea whose time had come.

One of the first acquaintances who I made in Forres, back in 2014 when I would travel from the Northern Highlands just to visit the meetings of a group trying to establish a makerspace, was a pensioner involved with the Findhorn Foundation, who when I expressed my interest in trying to recycle old polymers into useful materials, told me of her frustration with a lack of understanding of which polymers were accepted in the council's recycling bins and suggested that I should produce a simplified guide to it since I understood it so well, because the council's guide was several pages long.
I doubted at the time that I would be able to do so, and I still doubt my ability to write something on the subject that is sufficiently clear, concise, simple and accurate all at the same time, however I do now recognise the dire necessity of it being done.

Surrounding the polymer pollution issue, there is a growing 'perfect storm' of social, economic and environmental crises that threaten the stability of the very industry that we may rely on to solve some of the problems that it has created (Drummond, 2018; Joseph, 2017, pp. 310–320), providing further urgency.

Close to the start of this research project, I noticed that in the 'bottles & cans' wheelie bin shared between myself and my immediate neighbours, one (or more) of my previous neighbours at the time kept putting items in the bin that were not accepted by the council. This included not just PP trays, but even crisp packets. I was confused to see this at the time, but now long after having heard of private recycling schemes to reclaim crisp packets, I can make a guess that this could have been this resident's only avenue of participation, by trying to signal to the council that they want these materials to be recycled.
I say that fully aware that I am projecting a piece of myself into a theory of somebody else's behaviour, because I did that sometimes when I was younger, with trays and yoghurt pots that weren't asked for. I only stopped when I came up against the Highland Council system, where the bin collectors were tasked to glance and check what was in each bin before loading it up, and would leave the bin full at the kerbside with an advisory sticker on it if any unwanted materials were seen inside.
This problem of well-intentioned contamination of the recycling stream has been noted as a serious issue, termed 'wish-cycling' (Price, 2020).

Only through the course of this study have I come to be able to verbalise my own motivations for previously putting the 'wrong' polymers in the council bins despite knowing what they were.
This came from a frustration with not only the gaps in what materials were collected or recycled, but a lack of transparency in the reasoning for it and how materials were being handled. The council weren't exactly advertising tours of their recycling facilities, so there was no way for the layman to know how much hand-picking or automation was included.
For example, only in the last few years have we heard that bulk polymer sorting in large-throughput parts of the supply chain was tending to be done by infra-red sensors, which could not distinguish those items of packaging dyed black for UV resistance, and so industry responded by phasing out black trays in ready-meals.

Through this work I have found a way to satisfy my cry to be involved in a participatory democracy, and have tried to give others a chance to do so too, wishing to not only tell my story but create a more generally applicable guide to anyone else attempting such an endeavour.

1. Introduction

1.1 Research Context

This research approaches a local problem found by ReBOOT (Moray Computer Recycling), a charity and social enterprise in Forres, which collects computing and electronic waste from small towns and cities across Moray and surrounding regions of North-East Scotland (ReBOOT, 2019).
ReBOOT employs staff, trainees and volunteers to collect equipment, assess and refurbish higher quality items for re-sale, and dismantle older or broken items into their component parts, which are then shipped to various refineries and scrap merchants in return for funds that make up a large part of the charity's running costs (McGrath, 2019).
For the most part, the materials recovered are bulk metals such as steel casings, copper wire and aluminium heat-sinks, and a tiny percentage of gold within printed circuit boards and processing components, which have a disproportionately large market value (ibid.).
They are then left with a large but comparatively low-density bulk of polymer casings (Figure 1), for which they have no accessible market, because its value is outstripped by the cost of shipping it (ibid.).

Figure 1: Stored electronics casings in Forres. Photograph. (Author's own, 2015)

This material, which is not collected for recycling by the local municipal recycling service, had only two possible means of disposal – general waste bins, for which the charity paid for material to be sent to landfill, or saving it up until there was enough to fill a bulk material lorry to send to dedicated processors further south, for which the charity *still had to pay* (McGrath, 2019).

Since the Moray Council bins were collected on a fixed cost basis, this created a perverse incentive for ReBOOT to fill their trade waste bin to the brim with casings, and minimise the rate at which the excess would build up in their yard before they could fill said lorry (ibid.).
However, the charity's board recognised that doing this would not be in keeping with their charitable aims, and so approved a project to investigate other uses for this waste stream.

This project, with input from staff and volunteers, identified processes that might be feasible to implement at the small scale of this charity, and established a collaboration with Moray Reach Out (MRO), a multi-initiative charity that provides a kerbside materials pickup and sorting service in the east of Moray and into the west of Aberdeenshire, among other projects that provide opportunities targeted for vulnerable adults (Moray Reach Out, 2019).

Under a collaboration agreement of the ensuing ROAR project, MRO provided a service to granulate various types of polymers using a new granulator, attempt to clean the output and supply this in a form usable by ReBOOT, who would test possible products with desktop-scale production machinery such as a granulate extruder, a 3D printer and a compression moulder (McGrath, 2019).
I took a part-time role within that development project alongside this research, helping to test the processes involved.

ReBOOT have previously held volunteer days out, typically held on the national Volunteers' Week, where they would shut down operations for the day to engage staff, trainees and volunteers in exercises of scoping out future directions (Figure 2), or 'scrapheap challenge'-style creative activities (Figure 3).

Figure 2: ReBOOT in Reflection. Photograph. (ReBOOT, 2014)

Figure 3: Volunteer Crafts at ReBOOT Volunteers' Day. Photograph. (Author's own, 2015)

ReBOOT have had artists in residence briefly before, but they are few and far between.

The community surrounding Forres was of particular interest as a design research opportunity due to the unique confluence of creative cultures there.
The town is surrounded on all sides by groups with contrasting mindsets, such as:

- the highly pragmatic garrison of Kinloss Barracks, formerly RAF Kinloss, many of whom have settled in the local area since retiring;
- the liberal and spiritual tendency of the world-famous Findhorn Ecovillage;
- the lean and quality-controlled approaches at Greshop industrial estate, which features two major engineering firms, one focused on timber structural frames (JJ Joists) and another on precision cut metals (AJ Engineering), and at Forres Enterprise Park, featuring one of the nation's few circuit board manufacturers (Makar Technologies);
- the grounded, grass-roots ecological approach of the local Transition Town initiative and recycling / waste-prevention charities ReBOOT and Moray Waste Busters;
- a restless Extinction Rebellion action group that formed within the study timeline;
- the broad scientific scope of The T-Exchange, a proto-makerspace with a widely distributed member-base and no permanent home yet;
- the innovative and interdisciplinary practice of the Glasgow School of Art's relatively new satellite campus at the Altyre estate, with a heavy focus on health and sustainability research.

Between these, there were also a wide variety of artisans and artistic studios who could benefit from accessing stocks of scrap materials, as shown on the following stakeholder map.

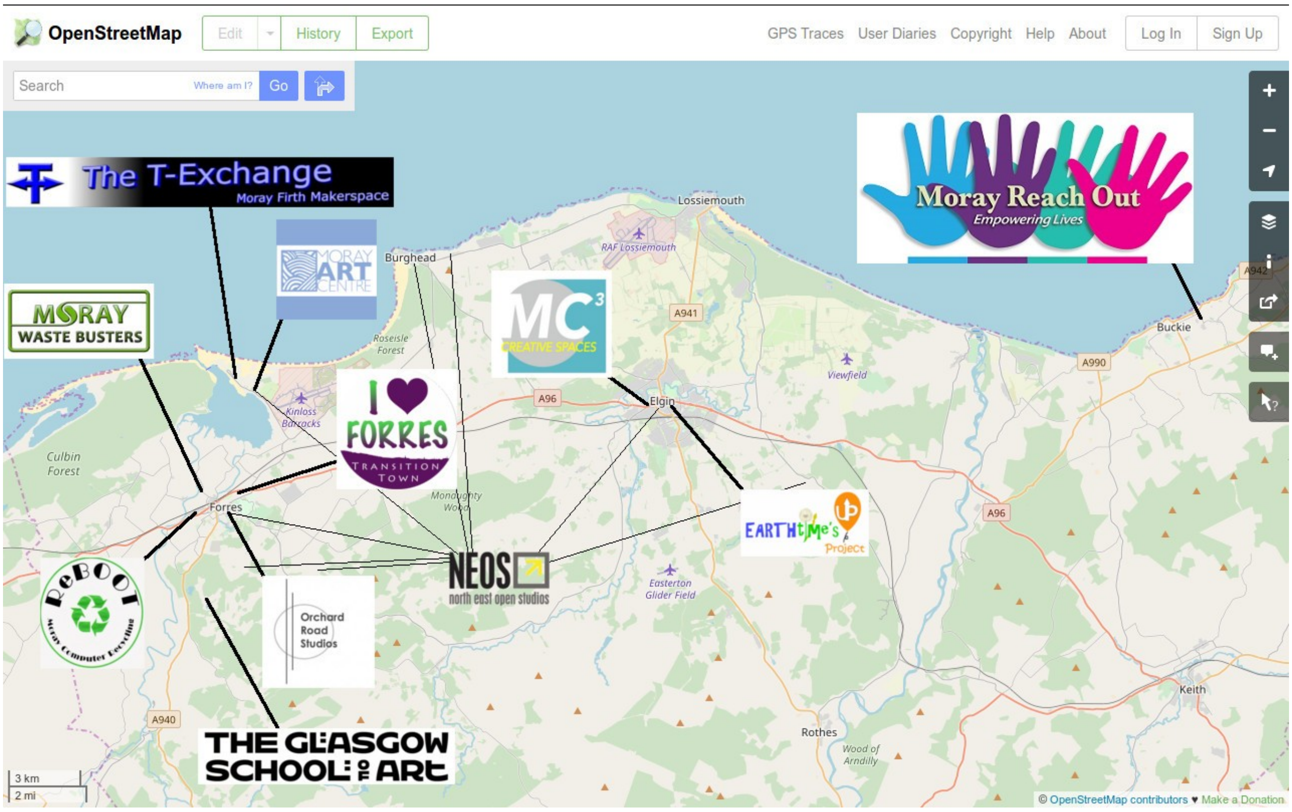

Figure 4: Stakeholder Map. Diagram. (Author's own, 2019)

However, the MC3 Creative Spaces studios and Earthtime's UP Project on Elgin high street have both now closed.

1.2 Research Questions

- How can small towns, such as in North East Scotland, make creative use of lower-value polymer waste streams?
    - Sub-questions:
    - What are the needs of local creative people such as artists and makers, and how do they perceive and interact with recycling services at present?
    - What kind of recycling service will enable local creative people to sustain productive small enterprises using recycled materials, at a minimal barrier to entry?

1.3 Aims and Objectives

Aims:

- To find ways of reducing the waste of recyclable polymers from electronics, by putting them to use locally.
- To support development of new entrepreneurial sectors that make creative use of these bulky low-value materials.
- To provide a set of recommendations transferable into other scenarios where a waste material is not being dealt with for similar reasons.

Objectives:

- Reach out to local artists and makers to collaborate on creative uses of this material.
- Make recommendations for a formal service through which local recycling organisations can supply reclaimed materials at a minimum cost.
- Test some proposed product designs.

2. Literature Review

This chapter examines the history of related practices, both in terms of wider theory and the context of the work, and assesses where this research fits into the surrounding field of enquiry.

2.1 Participatory Design

The field of Participatory Design (PD) grew partly out of pressure from the civil rights movements of the 1960s and '70s, which demanded more democratic participation in decision making (Arnstein, 1969; Schön, 1984), and a Scandinavian design movement in the 1970s that sought to develop ICT solutions well-suited to users' time-saving needs by involving them in the design of that hardware and software (Andersen et al., 2015; Schön, 1984).

Donald Schön (1984) relates an evolution in professional practice, from a growing crisis in public confidence in the authority of professionals or 'experts' through the 1960s, to new methods applied by systems engineers to complex problems, and a change in the roles of town planners, from centralised planning to mediation between private construction initiatives and regulators.
He emphasises the importance of problem *setting* (choosing and defining the bounds of what is being investigated) to be crucial to solving complex problems, and describes a tension between the priorities of *rigour* and *relevance* in research (ibid.).
For example, engineers can quite effectively find ideal forms for wings in Earth's atmosphere that perform in their task admirably, and their designs may stand the test of time. However, when a system designed from prior knowledge is put into practice in a setting that hinges on human interaction, such as a kerbside collection system or a healthcare system, there are often failures when a local culture was not taken into account, and a system provided to them operates inefficiently or is outright rejected by the community.

Schön gives examples from fields as wide as airspace defence, hospital medicine, and interventions to address malnutrition in rural Colombia; where traditional top-down system design had failed, while newer methods, involving those who would be using or affected by the system in its design, showed stark breakthroughs in progress.
The last of those examples is described in more detail, showing how confronting the problems at an interpersonal level resulted in '*Reflection-in-Action*', the main topic of the book:

> "Wilson and Ekroad designed experiments to test the students' hypotheses but also held themselves ready to respond to happy accidents, such as the discovery of highest corn growth at the bottom of the hill.
> …
> [Wilson] had begun with the image of a nutrient flow model that would organize all of the variables recognized by the conflicting research perspectives on malnourishment, and he had intended that outside experts would use that model to diagnose and cure the malnourishment problems
> …
> as he became more fully aware of the methodological difficulties in constructing the model and of the dilemmas of implementing it, he was led to restructure his image of intervention. It would not be outside experts but community members themselves who would use the nutrient flow model idea to diagnose their own malnourishment problems and design their own interventions." (Schön 1984, pp. 178-179).

This type of research, aimed at improving the situation in a workplace or other setting with the involvement of those embedded within it, "acting together on a particular cycle of activities, including problem diagnosis, action intervention, and reflective learning" is known as 'Action Research' (Avison et al., 1999).

Schön then went on to describe modern practice in city planning and business management, where he portrays modern planners as having shed the old vestments of centralised planning:

> "The public at large, and planners themselves, were becoming increasingly aware of the counterintuitive consequences, the harmful side effects and the unwanted by-products of implemented plans. Plans designed to solve problems either failed to solve them or created problems worse than the problems they had been designed to solve. Some of the phenomena planners were most anxious to influence—poverty, crime, urban congestion and decay—seemed tenaciously resistant to intervention." (Schön 1984, p. 183).

-now acting as mediators, who "convene interested parties, helping them to understand one another's position, to identify common interests, or to fashion an acceptable compromise." (ibid.).
He concludes the book by saying that "in order to broaden and deepen their capacity for reflection-in-action, professional practitioners must discover and restructure the interpersonal theories of action which they bring to their professional lives." (ibid. p. 314).
Schön's work thus comes across as optimistic for improvements in professional practice, and gives a positive and diplomatic case of its evolution so far.

Sherry Arnstein (1969) stated more bluntly how participation in government, "in theory, the cornerstone of democracy", was fought for by the 'have-nots' of the USA.
In an editorial with the intentionally provocative pathos of a manifesto, she describes points on a continuum that she calls a '*Ladder of Citizen Participation*', from plutocratic exercises, where all participation by the poor was staged as a complete sham used to manipulate them, to instances of democracy where communities take control of a local enterprise (ibid.).

Arnstein weaves a mixture of anecdotes and cited examples of where these intermediate points or 'rungs' appeared in various settings, such as committees set up to include city planning professionals and local community members, where the locals were given a stage to voice their views, but were ultimately ignored and out-voted by the professionals, sometimes with vested interests in a particular outcome (ibid.).
These 'consultations' serve as landmark examples of how not to conduct PD if one is searching to create a system in harmony with its end users.

Although Arnstein's case is weakened by repeated use of feasible yet uncited and contentious anecdotes, such as what 'mayors boast in private' and retelling a story of medical malpractice as though writing for a tabloid, the cited work does indicate a tension between the 'American' and 'Scandinavian' application of PD, by showing where there was resistance to citizen participation in the USA from government institutions, whether or not this was due to racism, conflicts of interest, or merely being too entrenched in regulations and surrounded by bureaucracy to see the perspective and speak the language of the have-nots.
It is also useful to be aware of the possible levels or continuum of participation, the illusions and fallacies around some weaker or 'tokenistic' forms of participation, and the damage that can result from misguided actions.

Andersen et al. (2015) juxtaposed PD with two concepts from Actor Network Theory, that participation by individuals is often 'overtaken' (i.e. their agency can be over-ruled by legal structures, other individuals they relate to, or even objects that they interact with), and that participation is 'partially existent' (i.e. participants are never *fully* participating, and there is always variability in the type and level of participation in any scenario).
As an example of this model of participation as a 'matter of concern' (where the practice to bring about participation is an important part of the work, and never deemed complete) rather than a matter of fact (where participation is assumed to have occurred), they showed the usefulness of this relation with reference to their work on the 'Teledialogue' project, which sought to create better means of communication for children in contact with social workers in Denmark.

In the course of the project, the children's agency was interfered with by government regulations on the standards of communication that were allowed to be used with them (they preferred skype for family conversations but this was deemed not secure enough, assuming to act *for their own good*), and by friends and family members who wanted to control, encourage, forbid or join in with their participation in the study (ibid.).

PD as a field and theory finds its relevance, and has informed this work, by demonstrating boundaries of what has been achievable, and external tensions that have affected attempts to increase participation in design and development projects. This historical experience is important to keep in mind for the design of an effective study that allows the target group to participate as much as they would like to.

While the debates of the 1970s over citizen participation in the development of their living environment still echo today in many disenfranchised communities, there has been some concern that the practice of PD has focused more on individual projects and missed opportunities for transformative work in inter-organisational and governmental spheres of work (Kensing and Blomberg, 1998).

2.2 Co-Design

Sanders & Stappers (2008) described how practices in design have diverged from previous 'User-Centred Design', methods primarily from North American industry, which centred on the perspective of professional designers, providing designs for assessment by end users who had little participation in the design process itself.

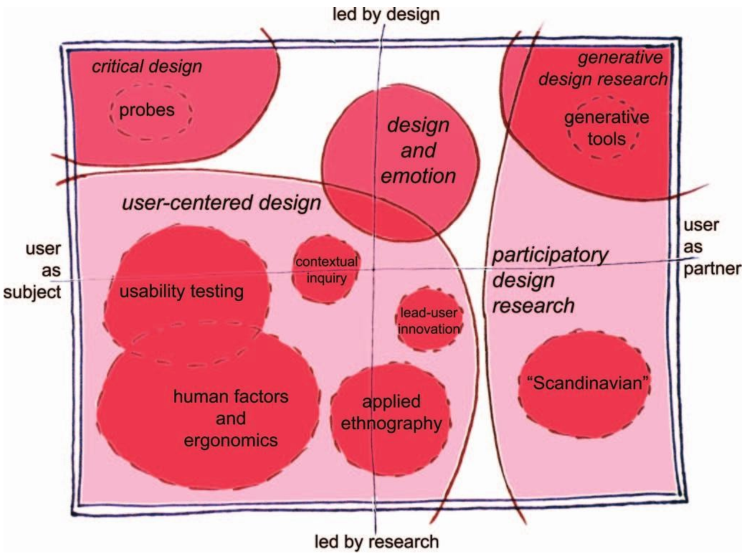

Figure 5: A landscape of design research. Diagram. (Sanders & Stappers 2008, fig.1)

New areas that they identify in their 'landscape' have far greater involvement and input by participants in examples of design research, where they refer to 'Co-Design' as "the creativity of designers and people not trained in design working together in the design development process." (ibid.).
Design researchers are described as having evolved from being 'translators' between traditional designers and users, to becoming 'facilitators' of interaction between research participants, enabling their innate creativity to come out, and ideally helping them up to greater levels of creativity – illustrated by the difference between embellishing a ready-made dish, cooking from a recipe, or creating an entirely new one (ibid).

In their textbooks on the matter, Sanders & Stappers (2012) go on further to describe how the creative process can be useful in uncovering knowledge typically inaccessible to other practices. They point out that what people *say* in interviews scrapes only surface-level thoughts available at the time (e.g. their plan for the day), that observing what people *do* illuminates a deeper level of habit that they might forget or be

unaware of (e.g. how they act around others), while below that lies *tacit* knowledge (things that they know but cannot readily verbalise, such as how to hold a pencil), and *latent* knowledge (things that they haven't thought of yet, but can readily form an opinion on based on experience, such as the usefulness of a new product feature) (ibid. pp. 52-54).
Schön also touched upon these concepts of tacit and latent knowledge, describing similar situations of sports/musical skill as 'knowing-in-action', and responding to unexpected balance of a weighted object as 'theory-in-action' (Schön, 1984, pp. 56-59).
They then explain that by guiding participants through a 'path of expression', where they are deliberately prompted to consider a present situation, compare it to their memories of the past, and then after some time is given for ideas to incubate, to express their dreams for the future, participation can bring out this latent knowledge (Sanders & Stappers, 2012, pp. 55-70, 74-75).
These concepts have had great utility in shaping the later practice of this research, as detailed in section 3.

2.3 Action Research in Recycling

Most action research connected to the recycling industry that I found in a literature search has been used to poll public opinion in order to improve municipal services in ways to increase collection rates or the quality of service delivered to the public (Siu and Xiao, 2017) or the quality of support for recyclers (Gutberlet, 2008; Gutberlet et al., 2013).
This practice, for example, showed how researchers had to respond to the unexpected behaviours of residents in use of bins, where some residents would already sell some materials to private recyclers, and didn't consider others valuable, while "some residents tossed rubbish such as used tissue and peels into or near [the recycling bins] … There was actually a rubbish bin located nearby; however, the cleaners often closed the lid. Many residents were not willing to open it because of the hygiene issue." (Siu and Xiao, 2017)
Adapting to such behaviours, where people show their preferences in action, bears similarity to the modern acceptance of 'Desire Paths' in infrastructure design (where people taking shortcuts across routing layouts that don't suit their needs tend to create distinct new beaten paths across green areas over time, revealing more efficient routing options) that have moved from 'Keep Off The Grass!' signs to intentional delays in the finishing of path construction (Kohlstedt, 2016).

(Keramitsoglou and Tsagarakis, 2018) involved a PD approach to the creation of recycling bins, in the sense that a variety of options were provided by designers for assessment by members of the public, but not 'Co-Design' where users would be involved in generating possible options themselves.
This followed an earlier study, where the public were merely asked for their opinions with an exploratory questionnaire on such aspects of a recycling system as "what materials the residents are willing to recycle; how many recycling bins or bags could be located at home; the type of collection of separated waste; what economic incentives should be imposed; how responsibility for the collection of recyclables should be shared among relevant agencies." (Keramitsoglou and Tsagarakis, 2013).
The authors noted that "Public participation in designing a recycling scheme has not been common practice so far." (ibid.), which both raises opportunities for research, and concerns around Arnstein's 'ladder' being in play.

This leaves an apparent gap in scientific literature on how community members could be involved in designing systems to recycle those materials not covered by pre-existing systems.

2.4 Grass-Roots Innovation Tackling Complex Problems

There is now a globally widespread subculture of 'hackerspaces' and 'makerspaces' where not only is access to productive technology shared, but 'socially transformative innovations' are experimented with, such as at Hackathons and the Innovación Ciudadana network events (Smith, A., 2017).
Smith & Stirling (2018) proposed that grass-roots innovations (such as the development of open-source technologies and citizen science) can 'promote more democratic innovation', 'support other citizens in the practice of democracy', 'create systems that empower other citizens where that might otherwise be

suppressed by mainstream interests', and 'nurture social diversity that is important for the health of democracy'.
They point to how innovation with a goal of sustainability directs innovation towards "practices that transform markets, public services, communities, and societies more generally into more socially just and environmentally resilient forms", but that the dominant existing economic relations are mostly directed towards closed innovation by private firms in pursuit of 'economic growth' (ibid.).

There have been some relevant examples of this type of action applied to other materials not covered by kerbside recycling, namely textile waste.
Broega et al. (2016) looked at Co-Design of products using waste fabric from the fashion industry, while Smith et al. (2018) reviewed a project aiming to combine the efforts of two Makerspaces across Scotland towards creating a circular economy in textiles, and found that their participation in round-table discussion "played an important role in exposing power relations between stakeholders and to the systemic challenges of the circular economy in textiles." and that the makerspaces' "physical capability for technical experimentation and their openness" made them ideal sites for agile innovation (ibid.).

Open-Source Development in Polymer Recycling

A perfect example to Smith & Stirling's (2018) notion of "empowering sociotechnical configurations that might otherwise be suppressed by interests around more mainstream innovation systems" is the project from which most of these makers' desktop 3D printers derived from.

The (self)-Replicating Rapid-prototyper (RepRap) project was originally conceived by Adrian Bowyer as a biomimetic way of approaching the ideal of a self-replicating machine idealised by John von Neumann (Jones, R. et al., 2011).
Modelling on the mutualism between different organisms seen throughout nature, such as the red clover plant and the humblebee, instead of the complete autonomy only seen in some very simple bacteria, the machine's activity and reproduction would be dependent on the action of humans, who would be rewarded for the interaction by the production of useful devices (their 'nectar') and parts kits (the machine's 'children') for their friends.
The RepRap was thus proposed as a 3D Printer capable of printing those components that were not common off-the-shelf parts, and in its release as an open source design:

> "The RepRap machine is intended to evolve by artificial rather than natural selection; that is, to evolve as the Labrador has evolved from the wolf, rather than as the wolf has evolved from its ancestors. It is hoped that this evolution will come about by RepRap users posting design improvements on-line that may be adopted in future designs of the machine and then in turn downloaded by old and new users." (ibid.)

This is exactly what took place, by making 3D printing accessible to the average robotics hobbyist, causing an explosion of evolutionary divergence that has become nigh-impossible to document (Gilloz, 2012; RepRap Wiki, n.d.). With hundreds, possibly thousands, of different varieties of RepRap in the world today, adapting to local requirements for production and available materials, much of the documentation for developments took place on blogs, if at all.
Its most remarkable achievement in democratising technology was simply in cutting the monetary cost of owning a 3D printer, by a factor of more than 30 (Jones, R. et al., 2011).

While the RepRap project has aimed to also tackle polymer recycling since its early days, keeping track of this development has been hampered by the continuum of documentation quality from very little in the way of peer-reviewed journal papers, through high-quality blog articles from post-docs, to vast piecemeal accounts of amateur (and often hazardous) materials science experiments.
Some notable contributors include Joshua Pearce and the Michigan Tech Open Sustainability Technology research group (Baechler et al., 2013), and a student group at TU Delft (Braanker et al., 2010), both covering the very practical aspects of how a small-scale recycling machine to feed a RepRap could work.

Pearce's colleagues and students even tried mounting an entire pellet-to-filament extruder onto the gantry of a large-format 3D printer, in order to to turn chopped and cleaned waste polymers directly into new objects (Woern et al., 2018).

Producing a stock material for local makers to use was seen as a possible direction early in this project, since this had recently been tested with recycled car dashboards by a Dutch design consultancy called Better Future Factory (TheCivilEngineer.org, 2017) and there were several options on the market at the time (Lansard, 2016), based on open hardware designs.

After several years of distributed development on this front, a final-year project by student Dave Hakkens, which produced open-source designs for small-scale recycling machines in 2013, was iterated as a larger scale research & development project when he won funding from an award in 2015 to continue the work (Spekkink et al., 2020).
The Precious Plastic project (PPP) was then founded and grew in similar fashion to the RepRap project, with development by interested volunteers across the globe (ibid.), and similarly brought the financial investment cost of recycling machinery down by nearly as much as the RepRap project had done with the desktop 3D printer.

The achievements of the Precious Plastic project served as a major foundation for establishing the feasibility of recycling polymers in regions that are typically deemed not populous enough to site handling centres and machinery, or with materials for which there is deemed to be not enough supply or demand in order to justify investment in machinery designed to handle high throughput.

There has been criticism directed at some innovations coming from makerspaces, such as there being a tendency to default to producing physical objects to solve what may be very complex social problems. While these prototypes can be extremely socially useful, more attention needs to be paid to solving social problems that are often root causes creating needs that technologies only patch over (Smith, A., 2017).
Open-source innovation also experiences pressures from surrounding conventional commercial enterprises, which can sometimes perpetuate exploitative relations in poorly conceived 'hackathons', where companies receive free labour from most participants, only to reward the winners of a competition (ibid.).

There has also been debate over the merits of these technologies being co-opted and marketed as a way for casual hobbyists to produce toys and trinkets, and whether that may serve as a way for young people to find their way into this community, or merely add to the destructive effects of consumerism (ibid.).
In the famous example of Makerbot, some members of a makerspace community utilised open hardware designs from the RepRap project to found a private company selling 3D printers, which saw wide market appeal with casual hobbyists, only to close off any innovations of their own, and in doing so earned the ire of the community they were once part of (Drummond, 2013; Smith, A., 2017).

Keeping these issues in mind will be important to the ethical considerations of this research, to make sure that participants are duly recognised and compensated for their efforts, and important to considerations of research contribution, to avoid merely focusing on a product as the outcome.

2.5 Communities of Practice

Wenger (1998) defined Communities of Practice as self-organising groups of practitioners with a shared interest around the work that they do, who actively share insights and help each other.
Wenger (1999) gives examples of a CoP in action by drawing on interviews with claims processors within an insurance company, as their business department internally grappled with the most time-efficient ways in which to have people apply rules, calculations and judgements to claims that were sent in, while the process had been partially computerised and a great deal of error-checking was involved.

In two vignettes on that setting, Wenger describes how professional practitioners develop routines, jargon and communication practices that help them to meet the needs of a highly structured work situation that is alien to their life outside of it, how they sometimes get on with methods without understanding the reasoning behind them, and develop coping strategies for this. Claims processors find their place within a company that feeds them information on a need-to-know basis (ibid.).

Typically a CoP is developed not intentionally, but as a means to ends where people gather in "sustained pursuit of a shared enterprise", whether that is "from ensuring our physical survival to seeking the most lofty pleasures." (ibid., p45)

> "As a community of practice, [participants] make the job possible by inventing and maintaining ways of squaring institutional demands with the shifting reality of actual situations.
> … Their practice … supports a communal memory that allows individuals to do their work without needing to know everything" (ibid., p46)

Some benefits of these groups are that they develop professional skills and new knowledge, transfer best practices, generate new business ventures, and they can help to solve each other's problems quickly (Wenger, E. C. and Snyder, 2000).
In order to harness the benefits of Communities of Practice,

> "successful managers bring the right people together, provide infrastructure in which communities can thrive, and measure the communities' value in nontraditional ways." (ibid.)

Through bringing together these communities, sustained changes to complex problems can be made by their group efforts.

The relevance of CoP to this research includes not just a descriptive model of how a social enterprise might already function, but if conscious attention is paid to nurturing what community is there and the correct ingredients for a healthy CoP are assembled in support of new projects, there is potential for a powerful boost in productive efficiency.

2.6 Sustainability and Circular Economy

The terms 'Sustainability' and 'Circular Economy' have diverged into many different contexts and definitions since their coining, muddling understanding in some uses (Geissdoerfer et al., 2017; Kirchherr et al., 2017). 'Sustainability' has its root in forestry management, with the concept of not taking more from woodland stocks than will grow back the next year (Geissdoerfer et al., 2017), and evolved into a commonly accepted use in 'sustainable development', as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (ibid.).

There have been many attempts by intentional communities and 'Transition Towns' to push for social changes towards a localised circular economy that avoids the waste and instability of global trade (Barry and Quilley, 2009; Scott-Cato and Hillier, 2010). Makerspaces and Remakeries could form the centre of developing a localised circular economy (Drummond, 2018; Smith, A., 2017), but their social innovations need to be adopted by other organisational forms in order for any large-scale change to take place (Drummond, 2019; Smith, A., 2017).

In the area of polymer waste management there is currently fierce debate over the relative merits of recycling, incinerating or otherwise treating various polymers, based on the different pollution risks such as POPs and greenhouse gases.

Much concern is pointed at the open burning of waste, where incomplete combustion causes a highly toxic and persistent pollution load (Cogut, 2016; Verma et al., 2016). Properly implemented high-temperature incinerators tend to be clean-burning (Buekens and Cen, 2011; Cogut, 2016) and can entirely eliminate POPs from the waste stream (Matsukami et al., 2014), however, the problem of open burning continues whenever waste is handled by poor countries unable to afford proper incineration facilities, where socio-economic problems of international waste trading result in global health impacts (Cogut, 2016).

The issue becomes complicated by the current crisis over reducing anthropogenic greenhouse gas emissions to net zero, and there is therefore some argument in favour of sequestering polymers in landfills in order to prevent or delay the carbon from their petroleum source being added to the atmosphere (Demetrious and Crossin, 2019).

This then becomes further complicated by concerns over the nigh-unstoppable release of 'microplastic' particles (Völker et al., 2019), which have now become detectable in nearly all foodstuffs (Cox et al., 2019), and the potential for toxins to leach out of landfills into groundwater.

2.7 Summary

Qualitative research methods such as Participatory Action Research or Design Research, in all their forms, have potential to bring about positive changes to complex problems and in situations where quantitative methods are inappropriate, for instance due to uncontrollable variables and contexts that are sensitive to local cultures.
When applied through appropriate methodology, and adapted to the context in focus, new knowledge can be uncovered by these research methods, and more efficient organisational structures, processes and tools can emerge.

However, its strength in adaptability must also be viewed with caution by prospective researchers, as the work carried out cannot simply be *replicated* in the way of a controlled laboratory experiment, and attention must always be paid to navigating the barriers and intricacies of a local context to enable those recruited to participate to the fullest extent practical.

This research sets out to improve existing mostly-effective recycling systems where there are gaps in the materials that are handled, within a community motivated by approaching *zero waste*, while the research that has been found so far deals only with setting up bare-bones systems and making them acceptable to the communities that they are intended to serve, or is applied to other classes of materials such as textiles.
My research is therefore positioned within the niche of applying Co-Design methods to divert potentially useful raw materials from landfill or incineration where there is not a market for them in their current form, with special focus on this contextual issue of polymer casings from WEEE recycling.

3. Methodology

This chapter lays out the underpinning theories that guided this research, the practical methods that flowed from this theory, and the rationale for this choice.

3.1 Epistemology

As alluded to within the glossary, this research is approached from the epistemological angles of Social Constructionism, which holds that knowledge is created in artefacts by the collective action of a society, the Post-Positivist perspective that the presence, bias and activity of a researcher cannot be separated from the result of research, and a backgrounded perspective of Positivism and Objectivism (not the Rand philosophy), which take empirical evidence as the best way of assessing the nature of an objective reality only partly accessible by our senses (Crotty, 1998).

These all have relevance to this research, for instance, physical characteristics of the materials being investigated were provided by work with a Positivist approach.
That knowledge then informed the activity of myself and participants taking a Social Constructionist approach to design of systems that address the research questions. The knowledge created by this process has narrow relevance to a context with its own time, place, materials and culture, but may prove to be relevant to other contexts that share similarities.

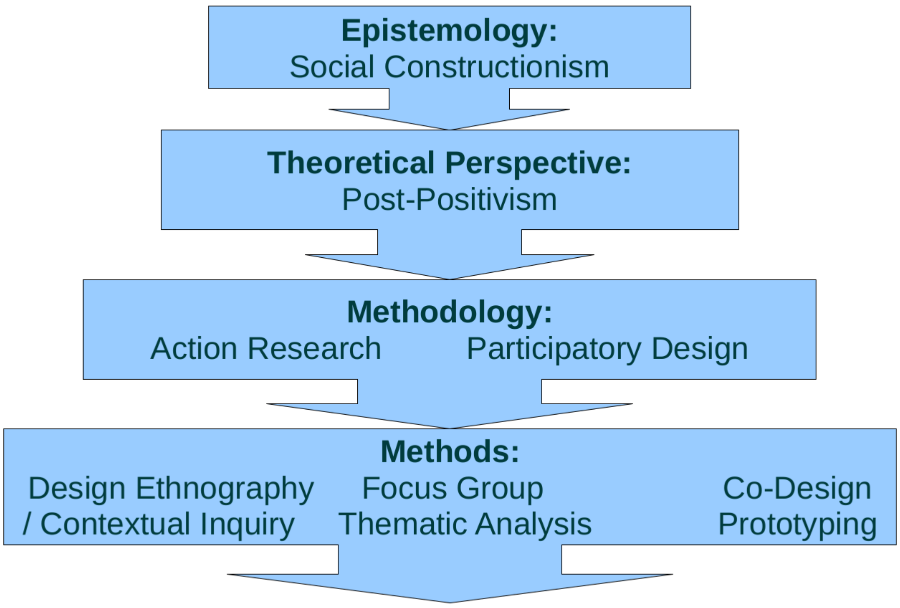

Figure 6: Illustrative structure of methodology. Diagram. (Author’s Own, 2020; Based upon Crotty, 1998, fig.1)

3.2 Methodological Positioning

Because this work is exploratory, with a scope that is lacking in prior research, working with a small sample group, and many variables that could be examined are unknown, it is most appropriate to take a qualitative approach to research (Creswell, 2014, pp. 61–62).

The broad methodological position of this study is within the field of Action Research, insofar as that it is working to create a tangible change within an organisation and community through repeated cycles of asking questions, taking action based on those, and reflecting upon the results before choosing the next actions (Avison et al., 1999).

In practice this had similarities to Grounded Theory, in that there were multiple stages of data collection and refinement of both the methods and quality of data being gathered. However, this research was not trying to establish a theory of a phenomenon or process, but instead to generate proposals for the alteration of systems existing in the world or the creation of new ones.

In order to do this, I took a Participatory Design approach informed by the 'Generative Research' teachings of Sanders & Stappers (2012), because it is appropriate for this type of context-sensitive problem, in which I want to give a voice to the Tacit and 'Latent knowledge' (ibid., p.52) of practitioners who would be likely to make use of recycled materials in their craft, and use that to inform the design of recycling systems that could serve their needs.

My methodology was Generative in the sense of being design-led, motivated by a participatory mindset and empowering concerned people to realise alternatives to their current situation (ibid., p.20). However, this research has not met the commonly accepted definition of Participatory Action Research because participants have not been involved with the longer journey and design of the inquiry itself, only a few specific interventions.

3.3 Methods

Because the aim of this research is to access the latent knowledge of creative practitioners, my plan was to apply the 'path of expression' method recommended by Sanders & Stappers (2012), i.e.

> "1. start with observing and documenting their *current* activities (what people do) around the topic of the study
> 2. then recall memories from *earlier* experiences using a Make exercise that includes photographs and other evocative triggers
> 3. reflect on those memories and possibilities for the *future* with a make exercise that allows for abstract and/or experiential expression
> 4. then express in a make exercise with a Make tool such as Velcro-modelling to create artifacts for future experiences." (ibid., p. 75, italics in source).

Informal Ethnography

The preliminary stage of this research was an informal approach to 'Ethnography', described as

> "The study of people in their natural settings; a descriptive account of social life and culture in a defined social system, based on qualitative methods (e.g., detailed observations, unstructured interviews, analysis of documents)." (Bowling, 2014).

Normally within the scope of a design research project, with short timescales, a modified form termed 'Design Ethnography' would be applied, where

> "ethnography as practiced by professional ethnographers or anthropologists must be distinguished from design ethnography. While true ethnographers may immerse themselves in a culture or specific population for months or years at a time, designers are more typically seeking sufficient information from time-sampled observations of behaviors." (Hanington & Martin, 2012, p. 60).

However, in this unusual instance, I the design researcher *was* embedded in the context under study for a few years before the formal commencement of research. This consisted of volunteering and working with ReBOOT and other local charities focused on sustainability and wellbeing, and networking with craft practitioners and influential members of the local community.
Since this activity was not considered research at the time, and was certainly not informed by formal training in the methods of ethnography, I refer to it as 'Informal Ethnography', which has achieved the same ends as 'Design Ethnography' but in more depth.

The knowledge gained by this close observation of the operations of these social enterprises, and connection with the community, comes with advantages of deep insight into the system that one is trying to improve, and in recruiting participants to the study. It can also come with potential disadvantages, of participants already acquainted with me bringing expectations to their involvement, and of bias to the situation.

Achieving the right balance of insider insight and fresh perspectives to tackle the problem at hand should be a *matter of concern* for researchers, just as Andersen et al. (2015) posited about the status of participation in design research.

Some of this knowledge has been covered in the introduction, and is discussed further in section 5.

Engagement 1 (scoping) – Focus Group Meeting
In order to address the first research question, "What are the needs of local creative people such as artists and makers, and how do they perceive and interact with recycling services at present?", and my first objective, "Reach out to local artists and makers to collaborate on creative uses of this material." I organised a meeting for the dual purposes of gauging the feelings of local creative practitioners on the issue of unaddressed recyclable materials, and to recruit those who were available to get more involved as research participants.

My reasons for doing this are in how it can quickly produce valuable information in depth and relevance.

> "The power of focus groups lies in the group dynamic that it creates. When properly recruited, and under the guidance of an experienced moderator, participants can quickly accept one another as peers. In a peer setting (where the fear of being judged is diminished), participants are more likely to share experiences, stories, memories, perceptions, wants/needs, and fantasies.
> A well-moderated focus group will leverage the nonthreatening group dynamic to get past generalizations and start to peel back what is valuable and important to the group, and what makes the group unique." (Hanington & Martin, 2012, p. 92).

Particular focus on the target groups for the event, as described below in section 3.4, was used in order to bring together a group who could bring about this dynamic.

Engagement 2 – Focused Interview / Case Study
This investigation was taken to follow up with two guest practitioners from the first engagement event, when there was an opportunity to visit their workshop, in order to find out more about how their project started, and answer some key questions around how they had engaged with their local community and any barriers faced. The interview lasted 15 minutes, forming part of a relatively shallow Case Study (Hanington & Martin 2012, p. 28), for the purpose of comparing how another group tackled a related problem in another context.

Thematic Analysis
This was chosen as a method to draw insights from the first engagement transcript, because it was recommended for dealing with large conversational transcripts, and has established procedures as one of the most common approaches to qualitative data analysis (Bryman, 2012, p. 578).
The transcript was divided up into 'codes', snippets of conversation that addressed a single topic, the themes identified for each code were written down alongside, then these were reviewed before mapping out their relations.

Engagement 3 – Reflective Meeting
Towards addressing the latter research question, "What kind of recycling service will enable local creative people to sustain productive small enterprises using recycled materials, at a minimal barrier to entry?" further engagements were held with a select few participants who volunteered and gave their consent to take part.

The first event ended a cycle of Action Research on *reflection* to begin a new one with *questioning*, and participants were brought to the stage of 'recalling earlier experiences' within the 'path of expression' (Sanders & Stappers, 2012, p. 75).

In order to first sensitise the group with details of the research problem of ReBOOT's polymer casings, I was going to organise a tour of the work site before the session, but this ended up being a recorded video tour, due to being unable to meet in person.

Interim Homework – Parallel Prototyping
Following reflection, I assigned participants the task of Parallel Prototyping: asked to work on a few different product directions at the same time, to later compare them and potentially settle on one or more feasible option(s) (Hanington & Martin, 2012, p. 122).

Engagement 4 – Reflective Meeting 2
With a greater familiarity for the problem space, accumulated through both discussion and physical experience of the materials, participants were asked to create a collage of their personal experiences, any issues that arose, and consider how they would like to see a recycling system that serves them in future.

Analysis On-The-Wall
When analysing data from generative design sessions with a small number of people (<10) and a small team, this method was recommended by Sanders & Stappers (2012, p. 212-216) as being effective and relatively efficient for drawing insights from the limited data, by arranging freehand affinity diagrams or matrices of coded data in order to find patterns, as compared to analysis with a database, which is more suitable for handling the many multivariate connections between participants, tools, sessions and other contexts when handling larger datasets (ibid.).
Therefore this method was chosen, and given the already digitised nature of the data collected in distanced workshops, I decided to perform the analysis by arranging notes within the virtual whiteboard space, in order to both avoid repeated back-and-forth between paper and digital formats, while also aiding its transference into print publication.

3.4 Recruitment
The first engagement exercise was publicly advertised (Culture Cafe, 2019b), with the help of a project that both supported in setting up the event and acted as gate-keepers to a large mailing list of local art & craft practitioners who had taken part in their events before. I also placed an advertisement in the Rainbow Bridge, a monthly magazine of the Findhorn Ecovillage, asked existing contacts to spread word of the event, and practitioners who I thought had a relevant interest I expressly invited as guests.

This was done in order to maximise exposure to groups who were interested in this kind of change-making, for what without the context would have just been a free lunch and a blether.
The event itself was then used to recruit research participants, by offering attendees to this public event an opportunity to sign up to a smaller mailing list in order to hear more about future events.

Conveniently, there is an active community of science & technology enthusiasts/hobbyists within this project's geographic area known as The T-Exchange, who have many 3D printers between them, and seek to found a formal makerspace (Moray Makerspace, n.d.). Although I mentioned this project to some 10-20 gathered at a couple of their meetings, I was surprised to have no uptake from the group.

I also attended a separate Culture Café event hosted by Moray School of Art the following month for the purpose of networking (Culture Cafe, 2019a), at which a fellow postgraduate student expressed interest in participating in this study.

By the time a set of workshops were arranged, nearly all the attendees of the first meeting who had expressed interest then dropped out for various reasons. Therefore, focused recruitment for a few creative practitioners was repeated via those networks and personal contacts, while the student at MSA got back in touch with me and was involved in the later stages of the research.

3.5 Ethics

Although ReBOOT and MRO have a lot of volunteers and service users who may be considered 'vulnerable adults', their interaction with those charities is not the focus of this investigation, and as such they were not targeted for recruitment, in order to simplify the research.
However, the possibility was left open for them to take part if they expressed interest in doing so, and if so then the charities would gatekeep or watchdog this in order to help protect their rights.

Information sheets and consent forms were prepared in order to let participants know the study's purpose and their rights, and they were always informed of their rights.
The only time that something was asked without filling in consent forms was during the first engagement, a public event where guests to Culture Café meetings understand that they may be photographed for marketing purposes, and I expressly asked the group in the room for permission to include them in a photograph.
With the later engagements happening over distance, most of the consent forms were returned via post or email and only one taken in person on the same day.

A more material concern of this study's ethics, and one of the focuses of investigation, surrounds the handling of toxins associated with some polymers. Since some toxic flame retardants in office equipment have been voluntarily phased out by manufacturers in the last two decades, and only wholly banned in recent years (Zanolli, 2019), while ReBOOT has been dealing with a lot of legacy equipment, some of it poorly labelled, which may contain toxic flame retardants, participants must be made aware of this issue and shielded from the risks of it.
Participants supplied with these materials were given guidance on how to handle them with appropriate PPE and workshop ventilation. For example when cutting recycled ABS, following guidance along the lines of other similar workplace hazards, such as the sawdust from MDF and other formaldehyde-resin engineered wood products, and otherwise instructed not to heat or melt the material for the purposes of the study.

Part of the aim and hope of the interaction is to find ways of guaranteeing safety to recipients of scrap material, and avoid 'creating problems worse than the problems this was designed to solve' as Schön (1984, p. 183) warned about from prior lessons of planning failures.

Finally, in any prototyping workshop, attention must be paid to the question of intellectual property. Participants were informed that any work produced and published may render an invention un-patentable by establishing prior art, and so permission will be double-checked before including anything in the final publication.

4. Fieldwork

In this section I describe the stages of my work done to gather information on the issues being studied.

4.1 Scoping conversation

An informal public engagement event was organised for the multiple purposes of facilitating focused conversations, recruiting participants, and gathering information on the community's priorities.

The planned format of this event was based upon my prior experience with the 'World Café' method, as seen in practice by Transition Town Forres at some of their AGMs, used for brainstorming new directions from charity members and stakeholders.
This would involve setting up several small round tables and having attendees split off into different conversations at each table, often with each having a different theme, periodically having attendees rotate to other tables in order to mix fresh perspectives, then finally report a summary of their findings back to the group at large. (Hopkins, 2011, pp. 220-222)

The event was advertised by Culture Café (CC), a local project that has facilitated many such gatherings on different themes, typically for some public consultation or to highlight an enterprise or new artistic publication. (Culture Cafe, 2019c)
Before organising this event, the researcher participated in a few of other people's CC events within Moray, to get a feel for how the setup usually worked, and to network with artists in the local area before reaching out to target groups for a focus group to invite.

In addition, a set of fact-sheets pinned to boards (see Figure 7, and Appendix A for more detail), about common polymers and the processes used to form them, and a set of question sheets placed on tables, were prepared as prompts to conversation, and a map of the region was presented with simple paper 'flags' provided to pin on locations of stakeholders.

The sheets on the tables each had a question or two at the top, and were otherwise blank in order to facilitate note-taking on that topic. The 'food for thought' questions presented were:

- How could your studio work with plastics?
    - Do you currently use scrap materials from any source, and how could this be easier to access?
- If plastic no longer entered or left Moray, how would we manage its use?
- How do you feel about or relate to Moray's recycling systems at present?
    - How could they be better for your needs?

Figure 7: Display boards. Photograph. (Author's own, 2019)

My expectation for this interaction based on experience at those AGM events was that most of the information generated would come in the form of notes taken at multiple conversation tables, with interesting snippets of conversation captured by audio recording, reflections drawn from participation in some of those conversations, and possibly discoveries of new places on the map.

Based on past CC events, with the bookings and interest shown there, the event was planned for 20-30 attendees, but only 12 showed up; 5 male and 7 female.
Attendees included:

- myself,
- a colleague from the ROAR project,
- a co-founder of Culture Café,
- two post-doctoral researchers involved in a similar project tackling marine polymer waste,
- a retired medical doctor,
- a school teacher,
- a local poet,
- an activist previously involved in organisations trying to find uses for waste in Germany,
- two active gardeners,
- and an interested pensioner who gave no other introduction.

However, with a hands-off approach taken by the researcher, allowing attendees to interact how they felt most comfortable, a starkly different reality emerged.
After the displays were examined as attendees arrived and introduced each other, there was little to no use made of them, or the conversation prompts on tables.

The attendees decided to bring their lunch tables together and combine into one single large conversational group with one voice at a time, rather than interact separately.
A similar setup had been seen before at other small CC events, and so this may be what the attendees expected or felt comfortable with, just as much as an on-the-spot decision.

Figure 8: The café table huddle. Photograph. (Author's own, 2019)

In retrospect, this had a great benefit to analysis of the conversations, as those times with multiple conversations happening were far more difficult to hear and transcribe from recordings of the babel picked up by dictaphones.
With 12 attendees including myself, this made sense as the group was at a critical minimum size for holding the World Café format (Hopkins, 2011, pp. 222), while quite large for a single conversation.

While the conversation flowed naturally, it circled themes of the major issues of the day in polymer recycling and pollution, covering projects that some attendees were involved in, problems that they identified with the current economic system, and sources of potential hope or solutions.
Very little of my own prompting or contribution was made, yet this still brought about the best expected outcomes described by Hanington and Martin (2012, p. 92); generating insights on how the group saw and interacted with recycling processes over a long period of time, explaining what was not working for them, sharing how they felt about it, what hacks and workarounds they had developed to get by, and how they related to one-another.
This conversation has been analysed for thematic content in section 5.1.

4.2 Case Study – Plastic@Bay

Two of the guests invited to the scoping conversation were a pair of post-doctoral researchers, both prior acquaintances, who were working on a related project in an even more rural setting – marine polymer reclamation and recycling in Balnakeil, Sutherland.

4.2.1 Workshop Observation

Plastic@Bay had already been extruding and pressing shredded polymers collected from Balnakeil Beach, in extrusion and compression moulding machines from PPP designs, while the ROAR project was considering purchase of a compression moulder and wanted to know how well the ABS granulate produced so far would fare in such a press.
With this opportunity showing multiple benefits, I made a visit to their workshop for a mutually beneficial exchange – testing this new granulate in their press and interviewing the team about their work, while helping to troubleshoot a faulty extrusion machine (Moreau, 2019). The visit lasted two days, with some positive outcomes.

Plastic@Bay were set up in a shop-front of Balnakeil Craft Village, with the rearward half closed off as a machine workshop, and the front half dedicated to displaying found objects from their beach-cleans, summaries of research findings, educational material on ocean pollution, and products for sale such as various shower soaps or shampoos in polymer-free packaging or brushes using natural materials.

Figure 9: Plastic@Bay shop centre stage, looking into the workshop beyond. Photograph. (Author's own, 2019)

Figure 10: Right-side of the shop, displaying some tiles pressed from ropes, and blackboards showing some statistics on their beach-clean activities. Photograph. (Author's own, 2019)

Figure 11: Left-side of the shop, displaying objects found on beach-cleans. Photograph. (Author's own, 2019)

Some of the issues that arose in conversation were typical to being an early adopter of open-source hardware: difficulties in sourcing good-quality kits, deciphering poor wiring documentation, replacing poor quality components and dealing with machines constructed far outside of the needed tolerances.

Plastic@Bay had acquired a much smaller granulator than the one used by MRO in Buckie, but still of professional quality, which was better suited to the small scale of their operation (Figure 12). This used the same mechanism of operation as the one at MRO, featuring several wide chisel-like blades on a single rotor, chopping pieces off whatever was dropped into the hopper, before a perforated sizing screen.

Figure 12: the small granulator at Plastic@Bay. Photograph. (Author’s own, 2019)

Despite its relatively small size, this granulator was still difficult to deliver (D’Arcy, 2018), but produced a similar quality granulate (see Figure 13).

Figure 13: above: Plastic@Bay's beach-picked PP barrel granulate, below: post-WEEE ABS granulate from ROAR. Photograph. (Author's own, 2019)

When I arrived, Plastic@Bay had recently received a new extruder built to a PPP design, which they had tested for half an hour before it stopped working:


Figure 14: Aborted hand-guided tray extrusion. Photograph. (Author's own, 2019)

The extruder was constructed by a workshop in Catalonia, who I am told spoke highly of themselves on the PPP forum, but the build quality was actually poor, with unclear wiring (it all used the same blue insulated wires, and some temperature sensors were incorrectly wired), and something having stopped working on the machine, which was thought to be the controller.

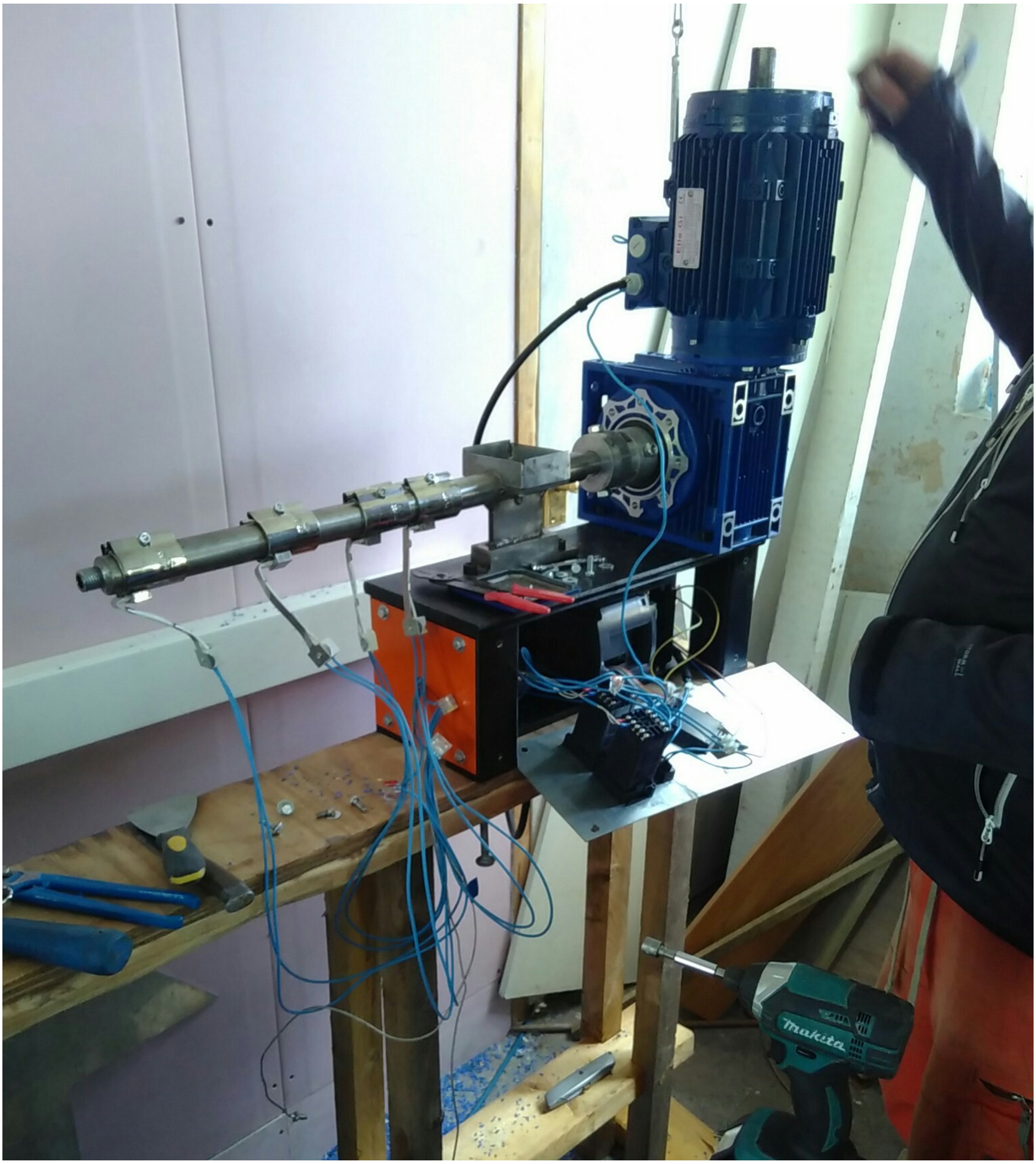

Figure 15: The extruder at Plastic@Bay. Photograph. (Author's own, 2019)

They had already removed the cover from one end of the motor that held a cooling fan, as the fan was visibly broken from the outside when it arrived, and complained to the supplier.

A compression moulder had also been built locally to PPP's rudimentary first-generation design, using an electric oven and a car jack.

Figure 16: The Precious Plastic Project Compression Moulding Machine V1 (on left) at Plastic@Bay. Photograph. (Author's own, 2019)

This was welded together for them by a blacksmith in Lairg, who they said was more used to artistic blacksmithing than engineering fabrication, evidenced by some rough measurements used in construction.

A steel plate inside the oven was used to press against the back of any mould placed in the oven. This plate should be parallel, but is about 10 degrees off. Unfortunately this was welded in place in such a way that it would be very difficult if not impossible to cut it out and correct the angle without taking the entire assembly apart.

Figure 17: Oven internals. Photograph. (Author's own, 2019)

They were fixing electronics on the temperature controller too, as a spade connector had come loose due to using poor quality connectors with a short crimping area holding the wire.

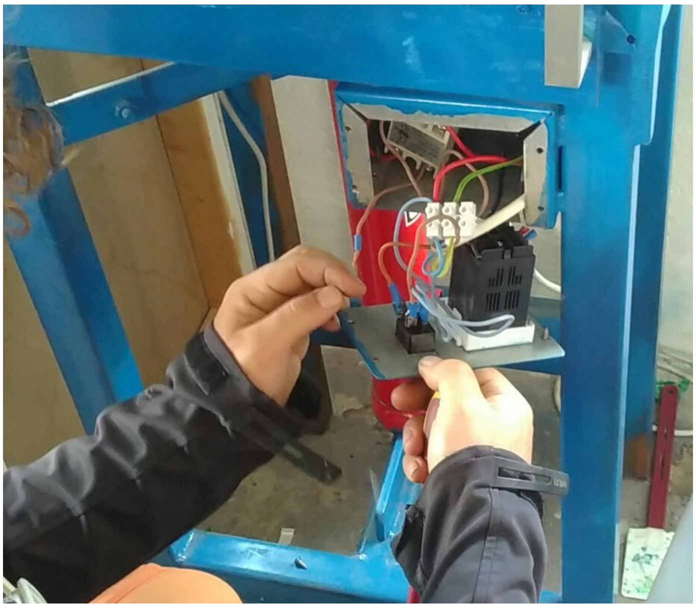
Figure 18: Fixing the compression moulder's temperature controller. Photograph. (Author's own, 2019)

On day 2, after getting the oven running, they sanded and polished the mould plates with a 400 and then 1000-grit pad (palpably smooth) to remove any previous residue and prevent the new polymer from sticking. They typically also used a fine coat of mould-release wax due to the tendency for HDPE to stick to metals, but this is not as necessary with ABS.

We poured most of the ABS sample into a mould and allowed that to warm up in the oven, increasing the target temperature incrementally after poking the granules with a spatula to test whether they stuck together showed that they did not clump at all until around 165°C.

> Technical note: ABS has a glass transition around 105°C but no true melting temperature, due to being amorphous rather than crystalline, instead having a wide range over which its viscosity decreases with temperature, with most injection moulding and 3D printing taking place from 210-230°C. These temperatures can vary with the relative balance of its three monomers and chain length. (Omnexus, n.d.; Rahman et al., 2016)

So far Plastic@Bay had been moulding tiles from chopped fishing rope and cutting these into table coasters. One side of these tiles was textured due to leaving the upper side of the mould cold before the press was closed, and the reverse side was smooth. If all parts of the mould are pre-heated then both sides should be smooth.

Figure 19: A beach-polymer tile with a flow-pattern surface created by melting it without pressing the top. Photograph. (Author's own, 2019)

Since they had polished the mould plates, our sample of post-WEEE ABS granulate produced a very fine looking tile for a first attempt, despite not having enough material to fill the large mould being used with that plate mis-alignment.

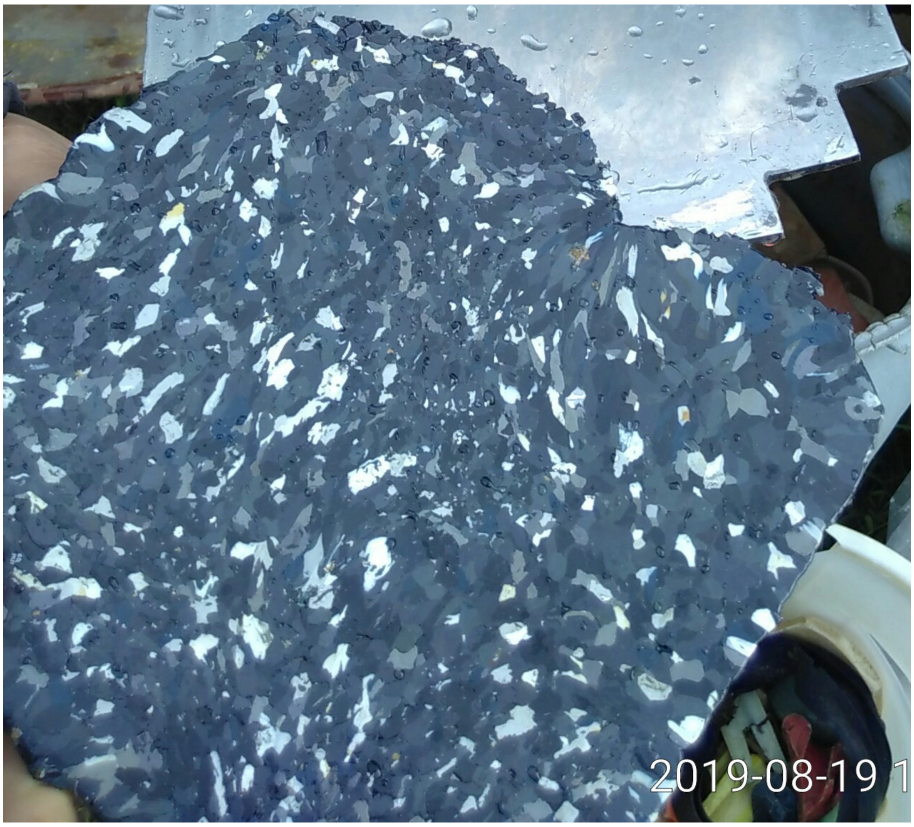

Figure 20: A freshly moulded post-WEEE ABS tile, water-quenched, with a finish like polished granite. Photograph. (Author's own, 2019)

4.2.2 Interview Questions

As a semi-structured interview, I asked Joan and Julien questions such as how they started up and approached any community engagement.
With an aim to gain insight into the social, structural and organisational difficulties and assets in such an endeavour, the following questions of interest were set out:.

1. When did you start?
2. How did you get started?
3. Where did your funding come from?
4. Did you have much support to set up your project (e.g. from a Business Gateway or Third Sector Interface)?
5. How was this received by the community?
6. What was the biggest hurdle that you have overcome?
7. What challenges are you facing at the moment?
8. Has there been any commercial success, and was this more or less than you anticipated?
9. Do you have any volunteers?
10. What lessons have you learned from the project?
11. What would you do differently next time?

My hope was for this to find some transferable insights into possible stumbling blocks or approaches worth looking into for our project in Forres, so that I could then answer my research questions of what works well in such small-scale settings.

One of them taking care of the administrative side of business, highlighted the struggle to get funding and support for setting up a social enterprise, as most of the nearest organisations to support them were based in Inverness, over 100 miles away largely by single-track road, so they could not take part in training courses, for example.

There was also confirmation of some common themes for small start-up social enterprises, that while TSIs are sometimes quite helpful, some business support organisations tend to be too focused on bigger profit-making ventures to be of any help to them:

> "Yeah, so [Name] is this Third Sector- they have representatives all over the highlands, and he's our representative here. So he was quite helpful. Although I didn't take any of his advice. He was very helpful, you know. [Chuckles] I thanked him. With regards to how we change into a Community Interest Company
>
> …
>
> And then with- I think it was Just Enterprise, I looked to them for advice.
>
> … Because there's so many of them and I got kind of sent around different ones, you know. They had a guy who- I mean it did seem to me that they weren't really very interested, because we didn't really have any money, or you know- at the start. We really just had this idea. So, I asked them for help, and they just never- this guy never got back to me.
>
> And then in- we were looking for funding and we decided that we would apply- because we were more of a- with this Precious Plastic idea, we were more of a small business.
>
> So that's why I went to Just Enterprise, because we could write applications regarding funding for academic work, but this- we never really started a business before.
>
> …
>
> Yeah, so then I got on to Just Enterprise or whatever to look for more help, because I had to start up this business you know, and I really didn't know about tax or employing people at all, this kind of thing.
>
> ... you know, told me what to google, like I could have googled it, you know. I still at the moment, I'm blindly doing our finances, going on the HMRC website and I'm still not sure I'm doing everything completely correct.
>
> But they never really helped, you know. Whereas I was talking to a lady when I did a course with SSE, from Lairg, and they came out and visited her and spent two days with her in Lairg, like you know, helping her set up, so- anyway.
>
> … I think with them, like you're probably okay in Moray, but like they have a lot of courses and stuff, and they're all in Inverness, and you just can't go, you know." (Plastic@Bay Researcher, interview on 19/08/2019, Appendix F)

-that they sometimes get taken advantage of by suppliers:

> "this electrician who wanted to overcharge us. They think that just because you've got a grant, you can just get money from- you know, they think that we've loads of money, that we're not [interviewee] working for free, you know, we're like totally killing ourselves to do this, and they're like "oh, you've got all this grant", so they just charge you whatever. Think they can charge you whatever and then- that's the attitude basically that [name] had, especially this electrician, but got another electrician in the end." (ibid.)

-while also raising the difficulties with budgeting, that come with trying to build something from an open-hardware design that specifies the lowest possible material costs but not labour costs:

> "Interviewee: But yeah, so it's great that SSE are totally flexible. They haven't come near us. … they just want the project to be successful, and they're leaving it up to us to do what we want, so I think we vastly underestimated everything, you know?
>
> The cost of everything. But now what we're going to do is, at the end of it, when it's up and running, we're going to make a new budget so if another community group wants to apply for some kind of funding, we could give them an accurate- you know.
>
> Andrew: Your outgoings?
>
> Interviewee: Budget, yeah. And that was down to Precious Plastic as well. They make everything seem so cheap, you know?
>
> Andrew: Yeah.

> Interviewee: So I basically put in my funding just what they had, you know the bill of parts that they had?
> Andrew: Yeah.
> Interviewee: Going for like, £300 for a shredder, £300 for the extruder, you know.
> Andrew: Wow.
> Interviewee: Which they're just like, "oh, you can just go out to the-"
> Andrew: "*just go out to the scrap yard, and everything's there.*"
> Interviewee: Yeah, yeah." (ibid.)

An interesting snippet was also heard in the background when a couple of tourists walked into the shop. While looking at the educational display on beach polymer pollution, one muttered something about it being "depressing" before they both walked out without any other interaction.

Despite all this, Plastic@Bay were gradually seeing some success in sales to tourists, prior to restrictions on travel.
Beyond all their measuring and modelling of polymer waste flows around the coast, Plastic@Bay have also since measured PCBs on polymer nurdles found on Durness beaches (D'Arcy, 2020).

4.3 Material Exploration

Part of my work with ROAR involved a period of familiarisation and testing of the raw materials produced by granulating waste material collected by those charities.
Given very tight time and resource constraints, this practice took a course of Reflection-In-Action, as adjustments were repeatedly made in attempts to refine a method that would produce useful outputs.

With one goal of the project being to turn the granulated ABS computer cases into a filament suitable for 3D printing, ROAR bought an entry-level desktop extruder: the Noztek Pro, one of the first generation of commercial offshoots from the open source Filastruder project, which I tested with virgin ABS pellets and with 3rd-party recycled ABS pellets.

Figure 21: The Noztek Pro extruder in use with a filament winder produced by the same company, which repeatedly had blockages in winding. Photograph. (Author's own, 2019)

After several weeks of testing and tuning, running into a wide variety of problems, several small coils of re-extruded filament were produced, but none were anywhere near the tolerance required for FDM 3D printing, where filament is typically 2.85±0.05mm or 1.75±0.05mm. The variance here was often ±1.5mm due to a lack of feedback control in the rate of extrusion and spool winding.

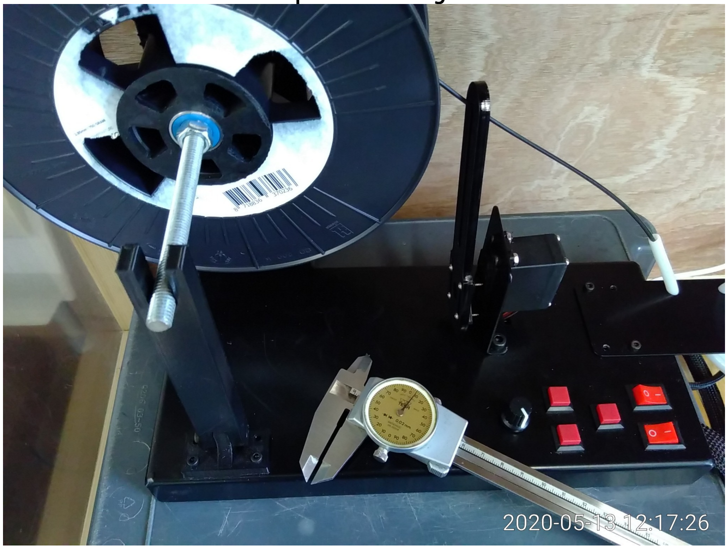

Figure 22: One example of the filament measured at 2.1mm. Photograph. (Author's own, 2020)

Noting that Noztek were already selling a second generation of machines for over 5x the price, with a tolerance puller and water bath, it was determined that this rough early-adopter machine would at very least require a lot more time in tuning to produce anything usable for FDM, if that was even possible, and otherwise might only be useful for extruding rough rods out of wider dies.

After seeing the first post-WEEE ABS sheet pressed with Plastic@Bay, the ROAR team considered buying a sheet press from CR Clarke, a professional workshop equipment manufacturer, and so sent some granules for them to test in their own lab. Seeing positive results with granules after drying, the group purchased an R30 Sheet Press for further trials.

This machine was easier to use from the start, producing sheets immediately in a PTFE-lined mould provided with the press, so long as the granules were dry enough (otherwise steam bubbles formed).
Work became more difficult with bare metal moulds manually coated with wax, while the advantages of the PTFE-lined mould were soon lost, as that coating broke down much like a scratched frying pan, but overall the process was successful enough to produce a stock of sample materials that could be experimented with in this study.

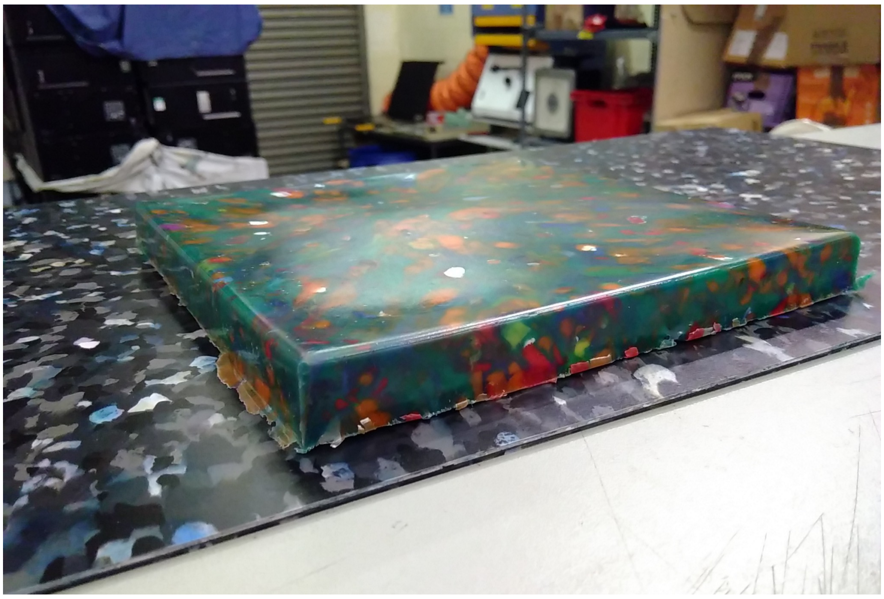

Figure 23: HDPE tile and ABS sheet samples, with pressing station in the background. Photograph. (Author's own, 2020)

Figure 24: One participant's material sample pack. Photograph. (Author's own, 2021)

Appendix G provides a summary of my experimentation within the ROAR project.
All of the technical work described was done by myself, while my colleagues focused on the marketing and supply-chain parts of the project's feasibility study, except for the prototyping of bags in which to wash granules in a domestic washing machine, which were produced by staff from the crafts and embroidery shop of MRO.
In those cases, after testing zip or velcro-closed fabric bags to contain granules for batch washing, which failed to stay completely closed, the most successful approach was found to be tying a rope around the opening of a pillowcase-like bag with double seams.

4.4 Co-Design Workshops

I had wanted to invite participants recruited via the scoping workshop to gather at ReBOOT and play with some of the materials processed there, to get a feel for what was on offer, and generate ideas for how this could be provided in a way to suit them.
Due to government restrictions on gathering at the time, I reworked these workshops as online meetings, with an introductory video and material samples mailed out to participants. As a result the work was delayed until late in 2020, only to be put off further by scheduling conflicts and the loss of some possible participants.
In the meantime, two had left the country and one died, but luckily another interested participant who had been out of touch all year got back in contact.
After failing to get a few people to fix on the same date over the end of 2020, these workshops were finally held across Q1 2021, outwith the original project timeline.

4.4.1 Session design

Whereas my original intention had been to bring participants on-site to the charity, to see the work-flow in action and get a broad and in-depth experience of the range of materials available, the alternative that I worked out was to provide goody-bags of a few materials and use a combination of video-chat and an online collaborative whiteboard service to discuss and sketch out possibilities.
In place of a physical tour of the work-site, I took a video walking around the workshops, then edited that into a presentation (Appendix H) to be viewed by participants before they attended the first session.

To seed discussion, I drafted a work-flow diagram of a typical large-scale polymer recycling process along with the one being used at ReBOOT, along with preparing a toolbox of thematic images and areas set aside for participants to collage ideas.
My initial idea for the whiteboard (Figure 25) was to present those flow diagrams of a large-scale recycling process alongside the current processes used between ReBOOT and MRO, in order for participants to compare and contrast these, and to present the initial results of my thematic analysis (section 5.1) in a mind-map, in order to get their feedback and validate how much this made sense as a summary of the problem space and find out what they considered to be the core themes and most important issues.

The first two diagrams in Figure 25 show how polymers move through processes that break them down, clean them of contamination and reform them into new products.
The second diagram is a broader overview of the operations at ReBOOT and how they interact with parts of both a linear resource-extractive economy and a circular economy, showing the processes by which WEEE is triaged upon arrival and fixed or dis-assembled for recycling.

Before this digital 'toolkit' was completed, initial ideas around the recycling process work-flow and what would be asked of participants were shown to research supervisors and the manager of ReBOOT, for their feedback, in order to improve on the design.

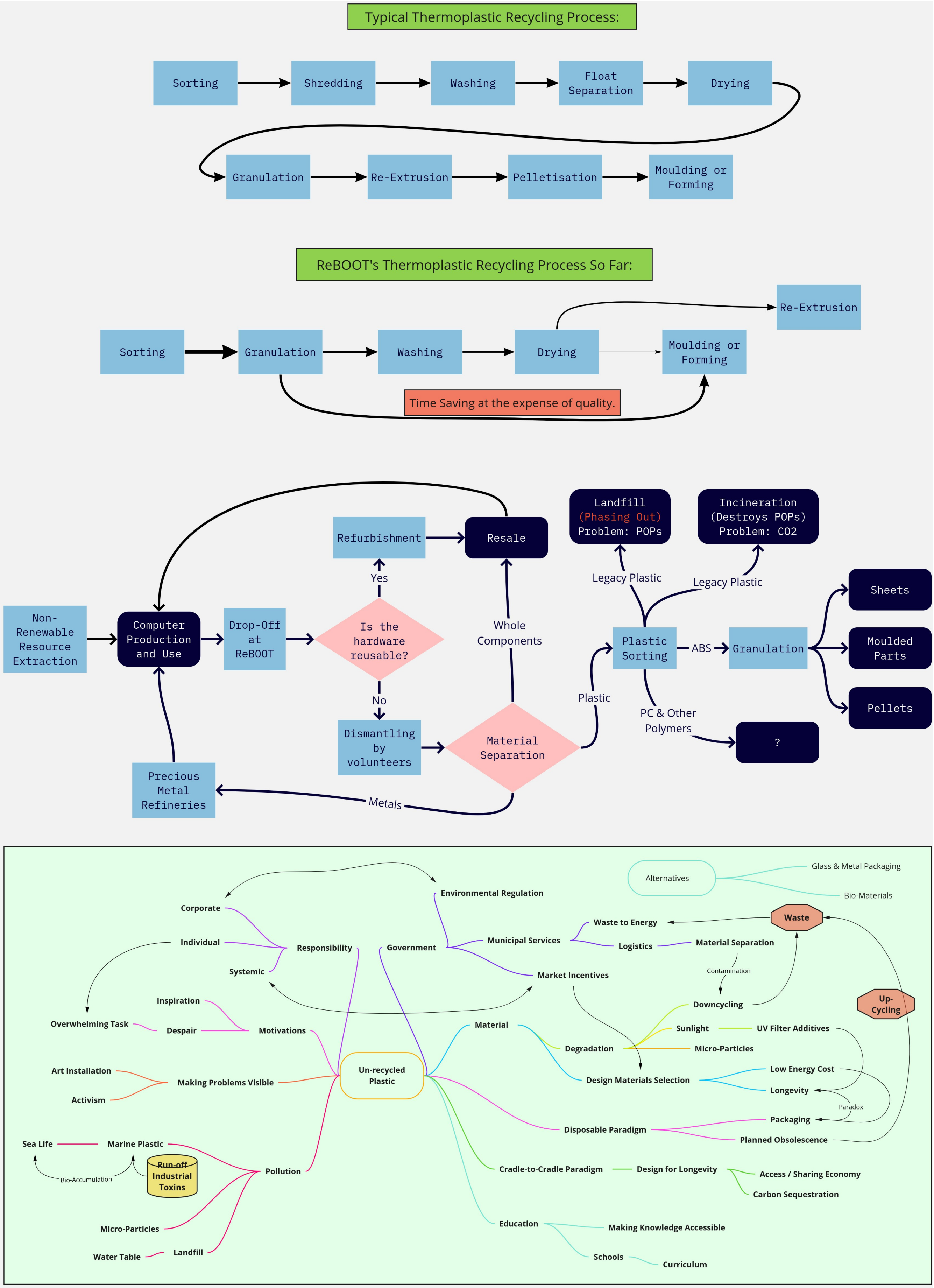

Figure 25: The initial online whiteboard ideas. Screenshot. (Author’s own, 2020)
The mind map at the end can be seen in more detail in Figure 29.

The manager and my supervisors approved the diagrams as representative, and provided me with suggestions for setting up the workshop sessions:

- establish ground-rules for the sessions and involve participants in the setting of those rules;
- lay things out in a clear order on the workspace;
- explain the aim and plan for each session at the start of each session;
- first show participants around the space and what can be done in Miro using a screen-share in the video chat, so that their attention would not be lost on immediately playing around with the tutorial;
- lock elements that formed the background and guidelines or any diagrams that should not be altered, so that they can't be moved accidentally;
- take notes for participants wherever they were more comfortable to say something out-loud than write it down, giving a paraphrased version of what they said and then sense-check this;
- lay out notes around each work-area or for example the thematic map being examined, with questions to answer, colour-coded to separate them;
- possibly use 'dot-voting' when trying to identify what the key themes were on the map;
- add a set of pictures of what could be in each 'goody-bag' of material samples;
- and have a separate 'parking area' for ideas outside the scope of the research context.

Based on that advice I iterated the virtual work-space into that shown in Figure 26, where participants could zoom in, change or add to my diagrams, place their own comments in virtual sticky notes, and produce collages with a virtual scrap-book that I began to populate with relevant images from Wikimedia Commons, Openclipart and my own photographs.

I selected some of these images to juxtapose some older design practices that allowed long-term reuse of products; such as washable glass milk bottles displaced by blow-moulded HDPE ones, or the cast-iron Singer sewing machines manufactured 100 years ago in Glasgow that still work today, compared to some examples of flimsy short-lived polymer designs ('living hinges', multi-material tool handles, or a child's weak toy spade) and some renownedly sturdy ones (early Nokia mobile phones).
Interspersed with those were photographs of possible creative outputs (extruded benches and a beach sculpture produced elsewhere, various sculptures produced at ReBOOT including a 'kaiju' sculpture that I helped a trainee to construct, 'bugs' by a previous artist on site, and frisbees that I produced in our press with an off-the-shelf mould) and some ideas of the current recycling system (an embossed packaging label, Moray Council's kerbside recycling guidance and a photo of the entrance to a recycling centre).

I laid out the work space (Figure 26) into four areas: two for reflecting and commenting on the current system in the first session, followed by offline play and prototyping with the materials available, and two more spaces for a second session to document what participants had created, and evaluate the ideas that they came up with.
My hopes of completing the work in two sessions turned out to be quite optimistic. In practice, the first workshop ended up being another space where participants vented a lot of frustrations with the current recycling system and their creative efforts, although this itself was still valuable. Much of the time was spent forming a rapport between new participants who were not present at the in-person focus group, and one post-doctoral researcher who was present.
There was a bit of 'passing the baton' as the Plastic@Bay researcher did not express interest in experimenting with the material samples prepared, but helped to set the scene.
Since one participant was unable to connect to the video call due to his old computer freezing up and gave up part-way through, I later had a brief catch-up with him over the phone to explain what we covered before the second session.
Then in the second session, another participant was unable to make it home in time while caught in heavy snow, so we made what progress we could there and then held a third and final meeting to bring together our ideas.

Figure 26: The whiteboard as laid out in preparation for the first online workshop. Screenshot. (Author's own, 2021) Please Note: This figure and others of the board are intended to represent the broad design, not to be legible in print at A4. See Appendix K for more detail.

Parallel Prototyping homework

To facilitate this, I provided participants with samples of materials that had been produced by the ROAR project, such as granulated HDPE or ABS, and pressed sheets thereof, in order to explore creative possibilities for the use of these materials. A selection of several different materials was displayed on the whiteboard for participants to choose from, and safety instructions were provided, for example to not melt these materials. The samples also included a small pot of PolyCaproLactone (PCL, a.k.a. Polymorph), a biodegradable polymer used in some hobbyist crafts, because of its interesting property of melting at only 60°C, which makes it handleable like a putty with only the heat of melted wax, after soaking in hot water. The purpose here was to provide a tangible experience to illustrate the state changes of a polymer, without the health risk of exposing participants to high temperatures, or the time cost of teaching a course on materials science.
In that sense, this was intended as an 'experiential tool' to provide a short-cut to comprehension of material properties.

Figure 27: The whiteboard in between the first and second online workshops, with participant notes added. Screenshot. (Author's own, 2021)

My planned theme was to aim for something that inspires or helps people with recycling, but with options left open to the practitioners' dreams.
The virtual whiteboard was left open so that participants could return to what was discussed, and any ideas that emerged in the shower could be noted down in-between meetings, but no more were added until the following meeting.

Figure 28 shows how much had been added after the final meeting. These contributions are detailed further in section 5.2, and the entire board provided as a large-format image in Appendix K.

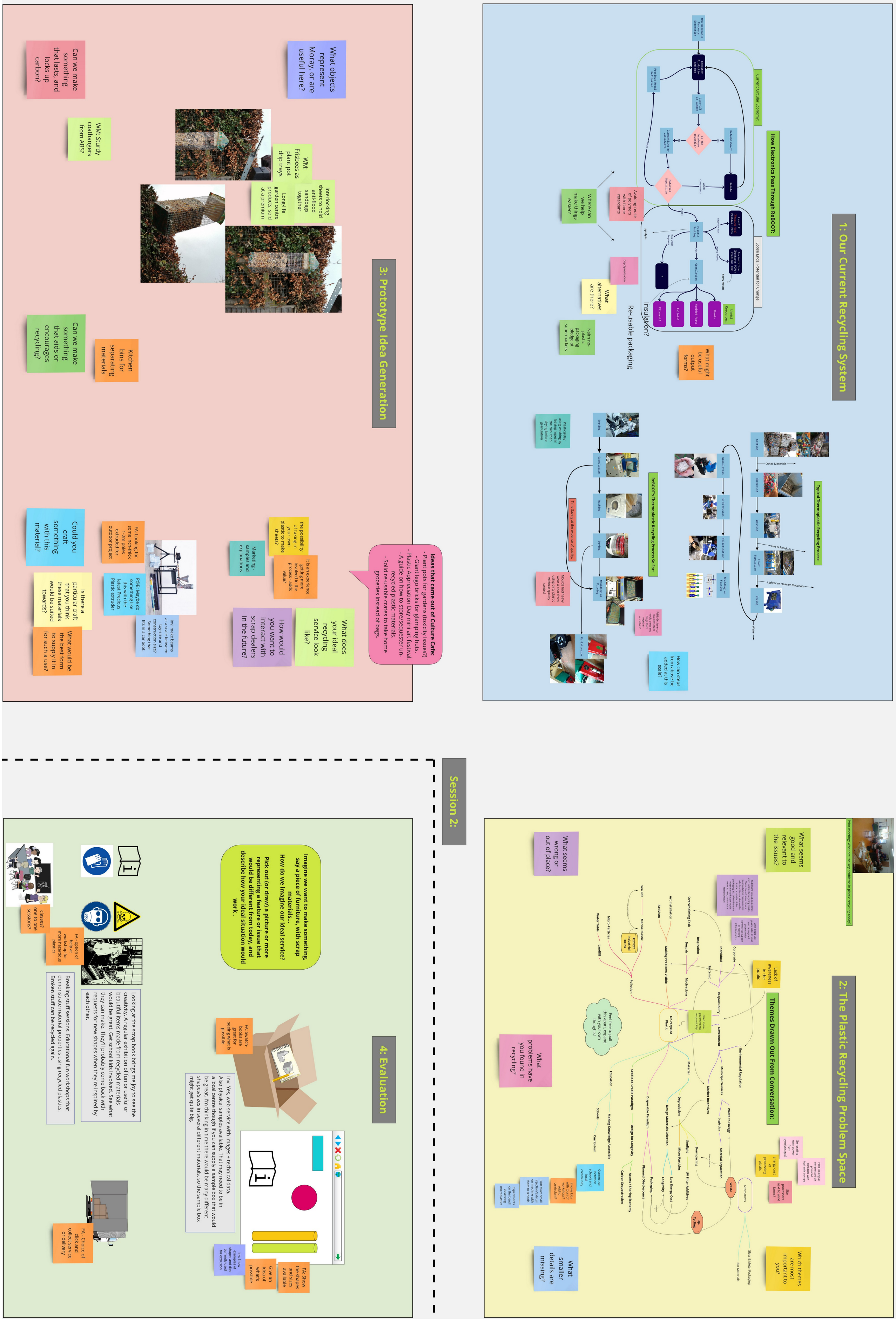

Figure 28: The work-areas of the virtual whiteboard after online workshops. Screenshot. (Author's own, 2021)

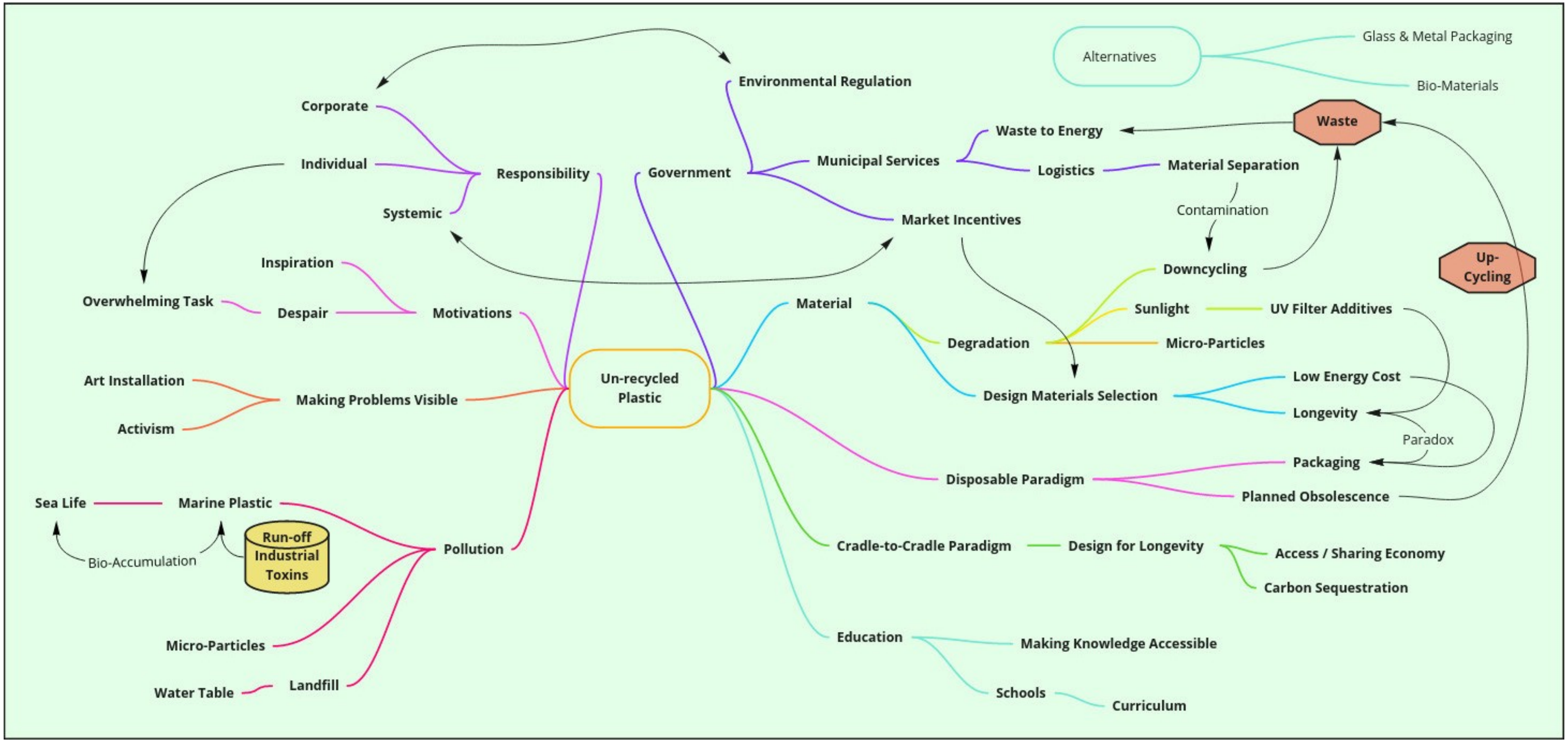

Figure 29: An initial broad thematic map of topics discussed at the April 2019 Culture Café, assembled as a mind-map in Miro. Diagram. (Author's own, 2020)

5. Analysis and Discussion

In this section I examine the data collected so far, explain how I have processed it, discuss any insights that can be drawn through this analysis, and discuss how this answers my research questions.

5.1 Thematic Analysis

From the core conversation that lasted about 2 hours following half an hour of introductions, a transcript of around 20,000 words was split into 221 'codes' (fragments of conversation, each mostly a few lines long, which address one or more subjects before changing topic), with 234 unique topics or sub-themes identified within those codes.
Using (Bryman, 2012, pp. 576-581) for guidance, the transcript and coding were done manually in order to gain familiarity with the data, and so that interesting forgotten points could be noted down along the way.

I noted relations between themes both by which themes were discussed together and by intuition of topical hierarchy. In order to verify that the most important themes were highlighted, I also tallied the codes into a spreadsheet in order to see which topics were brought up most frequently. While this gives a quantitative measure to a qualitative analysis and strays towards mixed methods, it must be noted that the dividing lines between what makes up each discrete chunk of conversation in coding has been decided based on my discrimination, and this subjectivity influences the outcome of this measure.
Nevertheless, this process was useful for the task at hand, as it aids in the otherwise purely subjective effort of identifying the core themes of the conversation. See Appendix C for the full collated list of codes and themes.

During this process and a third formal pass through the data, some close and redundant topics that always addressed the same issue (e.g. 'separation' and 'sorting'), or where different terms were used for the same topic on different days of coding (e.g. 'disposable culture' and 'disposable paradigm'), were combined into single topics. Also some topics were taken apart where they contained elements in common with other codes (e.g. 'rope re-use' split into 'ropes' and 're-use').

This is a fairly large sample for using such a method, which has a downside in the large amount of time needed to complete the analysis. However, there is a major value in this scale of conversation, as the journey that it took over the course of two hours touched upon many aspects of this wicked problem, which are difficult to hold in one person's head all at the same time.

Combined with all the notes stored on the whiteboard, time was also taken after the workshops to listen back on the conversations recorded there, transcribing the discussion and highlighting salient quotes to be copied onto indexed cards for later use in analysis on the wall.

By examining those links between themes in their topical hierarchy and how they were discussed together, a mind-map (Figure 29) was drawn up to give a sense of the problem space and what was discussed. The mind-map starts from a central point with the theme of the day – unrecycled polymers, and then spreads out into the major topics discussed, and finer points beyond those.
Cross-links are made with arrows where one topic seemed to affect another. For example, focus on individual responsibility with global problems was perceived to lead into being overwhelmed; large-scale systems as being responsible for pollution were closely tied to market incentives that affect the movement of these systems and the choice of materials in manufacturing; corporate responsibility is affected by environmental regulations; and there is a paradox where packaging is desired to last as long as possible in order to preserve food, but once used we wish for it to biodegrade quickly.

Here I will describe some of the key themes that emerged from all of those conversations in my fieldwork.

5.1.1 POPs and Toxins

A major theme throughout was of toxins associated with polymers. There was some confusion here around two different issues after discussion with the pair of researchers from Plastic@Bay. That of existing pollutants which stick to polymers, and that of potential pollutants embedded within polymers by design.

There has been growing public concern in recent years over the spread of 'microplastic' particles in the environment and their potential to poison the food chain. (Völker et al., 2019)
A large part of this precautionary-principle driven concern centred around the ability of these particles to act as concentrated carriers for organic POPs due to their typically hydrophobic and lipophilic properties. (Andrady, 2011) However, further research into this issue suggested that microplastic's role in bioaccumulation of POPs has been insignificant compared to the passage of those pollutants into the food chain by existing biological routes, (Koelmans, 2015) or that strong evidence either way is lacking, (Rodrigues et al., 2019) and more concern should be placed on those polymers (such as used in electronics) that carry POPs in the form of embedded flame retardants (Lohmann, 2017).

Some of this concern was echoed by participants, after discussion of POPs attached to ocean plastics, with possibly misplaced concerns over the spread of POPs by use of recycled plastic plant pots or linings thereof:

> Development Colleague: If you make a plant pot, when you grow foodstuffs in the plant pot, would there be toxicity passed into the food, or would you have to line it with something?
> Environmental Post-Doc 1: Potentially, yes. I would put a- I would separate the soil from-
> Development Colleague: So what could you use for that?
> Pensioner: Plastic.
> [Laughter]
> Findhorn Gardener: High quality plastic!
> [Laughter]

and soon after:

> Environmental Post-Doc 1: I don't know, but you can use plant-based polymers which are fine, you know-
> Development Colleague: -right.
> Environmental Post-Doc 1: -and change them every year.

In a later intervention there was also a concern raised over a perceived risk of phthalates originating from PET bottles, in which the non-toxic polymerised terephthalate is often conflated with the broad catalogue of phthalate plasticisers, some of which act as endocrine disruptors.
However in that case there has been a more concrete (if small) risk found of contamination by the antimony catalysts used to produce PET, and possibly plasticisers in recycled material (Sax, 2010).

This deep concern around making clear the presence of any toxic substances with a recycled product turned out to be very relevant later on when examining WEEE materials.
During the course of this research, new regulations came into place on the handling of materials containing POPs (DEFRA, 2021), causing great confusion for small social enterprises such as ReBOOT who suddenly needed to adapt to sorting out devices that may or may not have used toxic flame retardants, with often poor labelling on casings and no way of checking other than trying to find the contact details of every manufacturer.
Some of the issues around how best to deal with these pollutants may be solved by cutting-edge technologies alternative to incineration, such as supercritical water oxidation, which can even allow the separation of glass fibres from thermoset resins (Karuppannan Gopalraj and Kärki, 2020; Epoxy Europe, n.d.), but these kinds of solutions are well out of reach for small communities.
On one hand, previously dispersed POPs in the environment such as PCBs had been observed to adsorb onto the surface of small polymer particles and 'nurdles' (small pellets of virgin polymers shipped directly to manufacturers), which were then eaten by marine fauna, transferring the POPs into their fatty tissues and bio-accumulating further up the food chain (Devriese et al., 2017).

On the other hand, some polymers such as Poly(Vinyl Chloride) (PVC) have been observed to produce dioxin-based POPs when burned in open fires (Buekens and Cen, 2011), or have been associated with plasticisers (softening additives) such as Phthalate esters, which are endocrine disruptors in humans among other animals (Heudorf et al., 2007), and some polymers such as polycarbonate (PC) and epoxy resins use ingredients such as Bisphenol A (BPA), which can be harmful to marine life if some enters the environment that has not completely reacted in production, or separated through degradation (Corrales et al., 2015).

5.1.2 Accountability

Another re-occurring theme throughout the conversation was the concept of *responsibility* for the problem, i.e. whether and when emphasis is placed upon individuals with an 'every little helps' mentality, or upon manufacturers to choose appropriate materials and processes within in their design procedures, or governments to regulate those manufacturers, or popular media to influence the public's perceptions of the issue, or any other notion such as a culture or paradigm that encourages certain behaviours and choices.

For example,

> Attendee 6: You need to give people alternatives as well, to make those sensible long-term choices.
> Attendee 1: I like the um- related to what you were saying [Attendee 6]- something as an individual, not as a family, apart from like, just dealing with the general despair of all this. At the moment, every time I have a piece of plastic in my kitchen, I feel a bit shaken before putting it in the bin, I think, what can we do? And um, so there's that despair, but I quite like this, I don't know, this kind of different closed loop- the idea of how can we so something where I feel like as an individual I'm making a difference.

And much later in the conversation,

> Attendee 1: The thing is, this despair thing interests me, because it's like- when you talk about making it really visible, and go "yeah yeah yeah"- and then I think, well that might just make me want to bury my head in the sand if every time I look out my window I see a pile of-[inaudible]
> So the thing is that, how can we inspire the ch- ... rather than being complicit in keeping it all at arms length, how can we create communities which call me into action in an inspiring way?

5.1.3 Sustainable Design and the Low-Cost Disposable Paradigm

Several instances came up of issues that participants found with a paradigm of goods designed for low-cost and disposability, sometimes known as 'Planned Obsolescence'.
For example the teacher mentioned her children being unhappy with plastic crockery produced specifically for parties, the German activist mentioned old damaged flat-pack furniture being piled up in the streets and picked up by poorer students before the rest was disposed of by the council (which I can corroborate from my experience in Glasgow), and the dance practitioner mentioned his frustration with people putting tea bags into general waste when he tried to compost all of his.

The German activist also pointed out that there were areas where re-use could have different environmental impacts to disposables, such as where disposable nappies used more resources, but washable ones used far more energy in washing them at high temperatures to sterilise them, so in some instances it can be unclear where the best compromise is.

There is also a contradictory issue with some of the polymer processing equipment used by Plastic@Bay and ReBOOT mentioned in section 4, where building prototype open hardware for recycling at a small scale has resulted in some unusable hardware and thereby created waste in an industry trying to eliminate it.

5.2 Analysis On-The-Wall

Based on the advice of Sanders & Stappers (2012) on appropriate analysis methods to the scale of a generative design project and available resources, I settled on a variation of 'Analysis On The Wall'.

Conventionally, this would have taken place in a physical space with a team of researchers who all had access to the workshop transcripts (ibid., p. 213). Due to limitations on time, spaces available and the bounds of a student project, I did this virtually, using the same online whiteboard service.
One benefit of doing this when clustering data on-the-wall (ibid., p. 118), was that easy and instant duplication of the digital 'sticky-notes' and quote 'cards' allowed clusters around different themes to be preserved and added to later, without excessive photocopying or the risk of having physical notes literally *fall off* the work surfaces between sessions (ibid., p. 214).

While highlighting quotes and copying them onto the digital 'cards' along with brief interpretations of each quote's meaning, I noted down ideas that emerged as potential themes to cluster the data around.

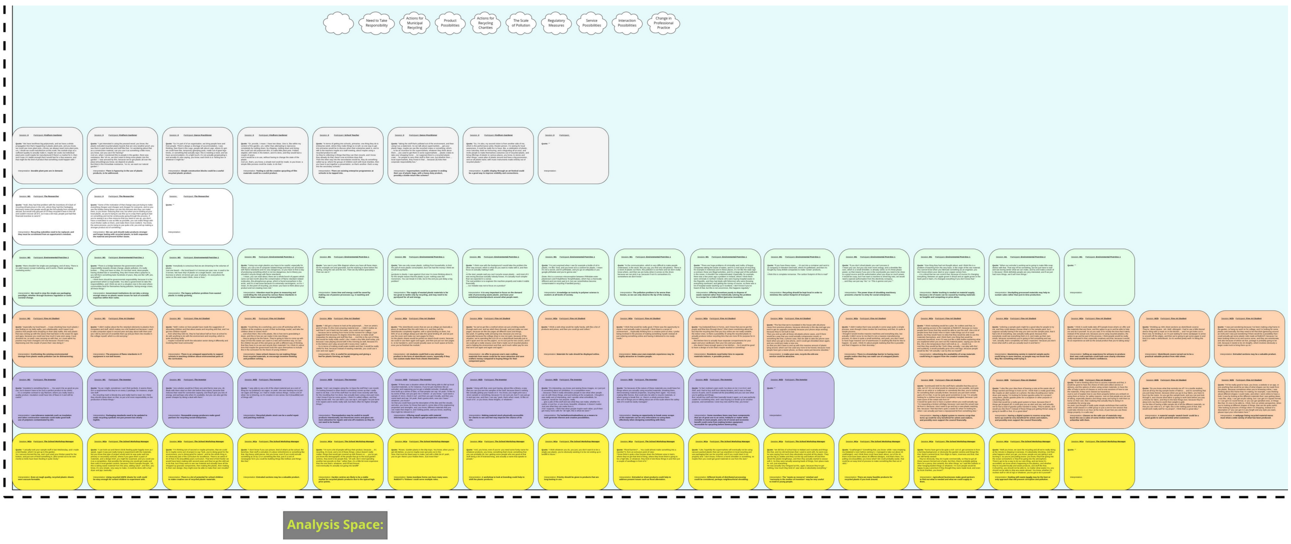

Figure 30: Digital quote 'cards' input to the virtual whiteboard for analysis. Screenshot. (Author's own, 2021)

These 'cards' were then moved around the board to whichever theme seemed to hold the strongest fit; duplicated whenever necessary as they matched more than one theme, or in some cases arranged spatially in between those themes.
This process can be iterated and built out to greater depth, especially with a group of researchers, but overall it was the fastest stage of the analysis in this case, taking a few hours after a day of filling in the cards.

One aim for this sort of analysis was to move upwards through the 'DIKW' (Data, Information, Knowledge, Wisdom) hierarchy, finding higher-order patterns across individual observations (Sanders & Stappers 2012, pp. 200-206) and using multiple perspectives to 'triangulate' or corroborate various observations and ideas (ibid., p. 221).

In this instance, where each contributor to the conversations has been colour-coded, some of the best information is present where a wide range of voices have agreed on the same points, as this provides greater confidence for a view or preference to be held broadly within a creative community, where this type of small analysis cannot hope to reach the representative value of a broad and well-selected survey.
This turned out to happen throughout the themes examined, and where possible, I have placed quote cards that touch on the same subject in direct contact or overlapping in order to visualise this level of agreement.

Figure 31 shows the themes that I found to group all of the cards, with lines showing some shared cards. These can be viewed in detail on Appendix K, but will be examined here.

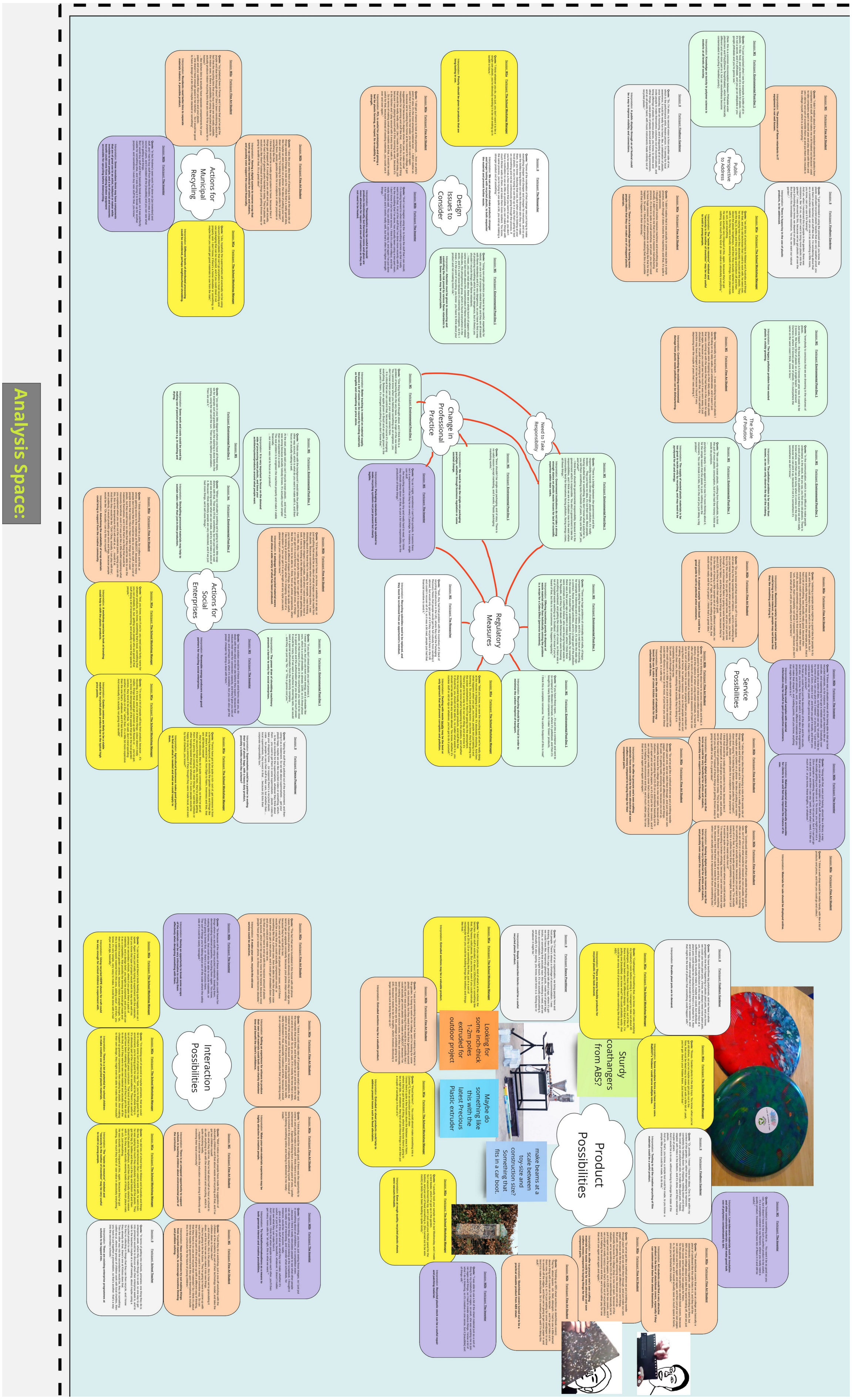

Figure 31: Clustered cards on the virtual 'wall'. Screenshot. (Author's own, 2021)

5.2.1 Themes found in Analysis On The Wall

Service possibilities had suggestions for ways to make the materials on offer most visible and accessible to possible creative users, such as with swatch-books, an online catalogue and opportunities to come see and feel what was available in person.

> “I suppose ordering a sample pack might be a good idea for people to try out, and they could always choose what’s in the sample pack, but I suppose actually having it the way you sent out the sample pack, that it had a bit of everything, was actually really good, because then everybody could see everything that’s in it, and make up their own minds, because sometimes you’re going to find something and say “ooh, actually, that’s completely not what I expected.” because you don’t know what stuff is until you actually touch it and feel it.” (The Fine Artist, 2021, Appendix J)

> “if there was a situation where all this being able to dial up local recycled materials... so that people can say “oh yeah, I’d like to try some of that, can you give me 2 metres”, or you know, “I just want a sample of 10cm, check it out”, and then you get it locally, and then you come back and say “oh yeah, that’s gonna work, now can I have-” whatever, you know? ... Along with that, even just having, almost like a library, a way that you can just see the samples of the stuff, because there’s nothing like actually getting your hands on it.” (The Inventor, 2021, Appendix J)

Product possibilities had several viable ideas for what to do with post-WEEE ABS and bottle-cap HDPE, such as producing custom sketch-book covers for artists, extruded sections as raw material for artists and for furniture construction, plant pots and coat-hangers pressed at a sturdier thickness than usual, insulation, and flood barriers.

> “they sell the sketchbooks completely together, with a spiral binding on them, but 99% of us at college always just take the spiral binding off, and we just use the cover and make our own pages for them. So the plastic sheets would be perfect as sketch-book covers, because we could re-use them again and again - And then just put our own pages in, to be handed in, and it would actually save so much space at home, once you’ve finished the module.” (The Fine Artist, 2021, Appendix J)

Interaction possibilities described ways in which members of the public could participate in the recycling process, or experiences could be created as a product.
For instance, by having artisans come in to make their own unique materials on the machines as part of a guided class, or holding art/design competitions that use samples of the materials in partnership with educational institutions.

> “I think that would be really good, if there was the opportunity to come in and actually make it yourself. I think there’s a sense of achievement... Especially thinking from a creative point of view, I prefer being involved in the process of making something myself, instead of just ordering something online and having it delivered to me ready-made.” (The Fine Artist, 2021, Appendix J)

> “I can look out and there’s birds feeding quite happily even as I speak. Again it was just really trying to experiment with the materials, but you know that type of project would work its way quite well into primary or secondary schools, where if you gave them a pack of materials, and a design brief, you might be surprised, and you could use it as a competition, that possibly the winning one would get made and then sold in local garden centres, because I think if people thought, “oh, this is taking waste material from this area, adding value”, and then, you know, it’s very simple, very easy to make. It could be done with a hair dryer and jigs, basically.” (The Workshop Manager, 2021, Appendix J)

Actions for social enterprises involved marketing ideas, such as making connections with garden centres as outlets for recycled plastic products and places to gauge demand.

Actions for municipal recycling included making unwanted and broken items more easily available to be dismantled for upcycling their parts.

> "I also like your idea there of leaving a note at the waste site of things wanted and things to look out for. I think that's a really good idea, like maybe an alert system on a phone- the idea of putting your name down and saying "I'm looking for broken gazebo poles for a project",
> ...because then if things get dropped off, it could give you an alert and say, well actually, we've had a load of gazebo poles handed in today. They're plastic, and would you like them?
> ...it's the stuff that's saleable that they put on sale, isn't it? It's not what would be classed as non-usable, and quite often as an artist or a craftsman or somebody like that, you're looking for something that's actually broken, because you just want certain parts of it or that. It can be quite good sometimes to say "I'm actually looking for a clothes horse that's completely mangled, because I just want some of the metal rods from it!" (The Fine Artist, 2021, Appendix J)

> "I had to buy stuff from Waste Busters, and it was a cheap source of parts, and it avoided all the [inaudible] and you can see what you're getting and things.
> But I would buy stuff and then basically break it apart, so it was perfectly usable for something else, and I was buying it to break up for another purpose, and sometimes I even buy new stuff for that, you know." (The Inventor, 2021, Appendix J)

Regulatory Measures and a connected theme **Change in Professional Practice** suggested ways in which governments may be able to provide rules and incentives to improve current polymer recycling, such as requiring resin recycling codes to be legible, and incentivising local and intra-national recycling of waste instead of exports.

Other themes of note, but not within the scope of this study, included **Public Perspectives to Address** and **The Scale of Pollution**, which provided ideas for where to target information campaigns – see Appendix K.

5.3 Discussion

In this section I discuss how my research questions have been addressed by the output of my interventions, then reflect on some insights and theory that can be drawn from the data and practice.

5.3.1 What are the needs of local creative people such as artists and makers, and how do they perceive and interact with recycling services at present?

This was answered by several comments made around possibilities to run a material supply service. These centred around recommendations to provide ways for artisans to experience the materials before buying them, such as coming in to a workshop or store room to see and feel what was on offer, or having sample packs sent out to them, similar to the samples used in this study or the swatch-books provided by textile suppliers.

5.3.2 What kind of recycling service will enable local creative people to sustain productive small enterprises using recycled materials, at a minimal barrier to entry?

This was the most positive surprise, as I expected little to be achieved here in a short time, but the participants came up with a useful set of ideas that could bridge the knowledge, skills and wealth gap with suggestions for making selections of materials available and making custom materials available for artists who could come along and make their own, simultaneously helping recycling charities short on staff time.

5.3.3 Communities of Practice

At ReBOOT, trainees and volunteers are briefly inducted to a set of practices employed to track and manage inventory, due to the sometimes sensitive nature of the charity's work that involves wiping used hard drives of personal and business data, or keeping track of what has been done with equipment containing components with toxic materials in them.
Up until this point, the latter focus had mainly been on concerns around heavy metals such as lead, mercury and cadmium, but as increasing regulatory focus has been placed upon toxic flame retardants that were widely used in office equipment over the previous few decades (Sharkey et al., 2020), new practices are being created and old ones modified in order to keep better account of these materials.

Any given volunteer might not understand the reasoning behind *why* they separate steel computer chassis, polymer fascias, aluminium or copper heat-sinks, various batteries, copper cables and fibreglass circuit-boards into different bins, boxes or trays, but there is ample labelling and signage to direct them, and more experienced volunteers or staff on-hand to help.
Many questions about unusual pieces of equipment get passed around Workshop 3, the main area where new items are booked in, triaged to different areas and the oldest ones are dismantled. Often the workshop supervisor will resolve those trickier questions in between managing the logging of new items, checking for storage media, and assigning people to build pallets of some boxed materials, components and equipment to be shipped to dedicated recyclers and precious metal refineries in England.

Communities of Practice find relevance here in figuring out how to pass on the practices required to process WEEE polymers into feedstock or products.
For example, I have briefly instructed a few volunteers, trainees and staff in the use of the compression moulding machine that was purchased for the project, and written a short guide for its use, but when I cannot be present to assist people who are new to its use, there must be a 'communal memory' to carry on that knowledge. Already there have been a few accidents caused by inexperienced individuals taking initiative with the hardware, which resulted in damage to expensive mould platens.
This could be blamed on a lack of comprehension of the material's limits, where engineering knowledge can't be expected to be imparted in on-the-job training, but part of the problem lies in the economy of scale. Large manufacturing enterprises have long since heavily automated moulding processes, to remove the risk of natural human error, for example where alignment pins in a mould are guided exactly into place by machinery.
Budget constraints of a small recycling enterprise may create far more room for error where more work is done by hand, which necessitates more involvement of training and support.

The constraints of using more manual labour can create opportunity for more errors or even greater precision in some processes, depending on how much time is available. That time is in tension with the availability of volunteers and the financial needs of the social enterprise to cover its expenses by creating something of value.
For example, in the sorting of WEEE polymer casings there was not space and resources available to use a metal-detecting conveyor belt system (which itself is limited in its detection range) to catch metal screws, nuts and springs that had not been removed. Therefore, a manual checking system was used, with volunteers throwing polymers into different bulk bags depending on type (see Appendix H).

This revealed the difficulty of finding and reading the finely-printed marks that identified the polymers used in injection-moulded parts, which might be rapidly identifiable by a machine observing the infra-red reflectivity of the material, unless dyed with carbon black to prevent UV degradation, as was commonplace in equipment manufactured after the 90s. In some cases, it may be difficult or impossible for an automated conveyor system with cameras to identify these faint marks where design choices have put them in difficult to view areas.

Many issues arose within the testing of machines for small-scale material reclamation.

When handling more than one material stream with a single shredder or granulator, and the machine is used in batch processing rather than continuous, there was great difficulty in between each batch of cleaning out the tailings of a previous batch and preventing them from contaminating the next batch.
Especially where the materials themselves were contaminated before shredding (for example, food residues on bottles and tubs, and small easy-to-miss secondary material parts on electronic casings, such as steel springs, label stickers and translucent 'light-pipes' for LEDs) as manual checks could not guarantee a perfectly clean supply, this presented an inevitability that some material coming out of the process would be contaminated.
Therefore, it is of high importance to develop an automated separation mechanism, such as a float/sink tank, for use at this smaller scale, otherwise the output may be damaging to the moulds and dies of later forming processes, or at best must be considered as a downcycled material.

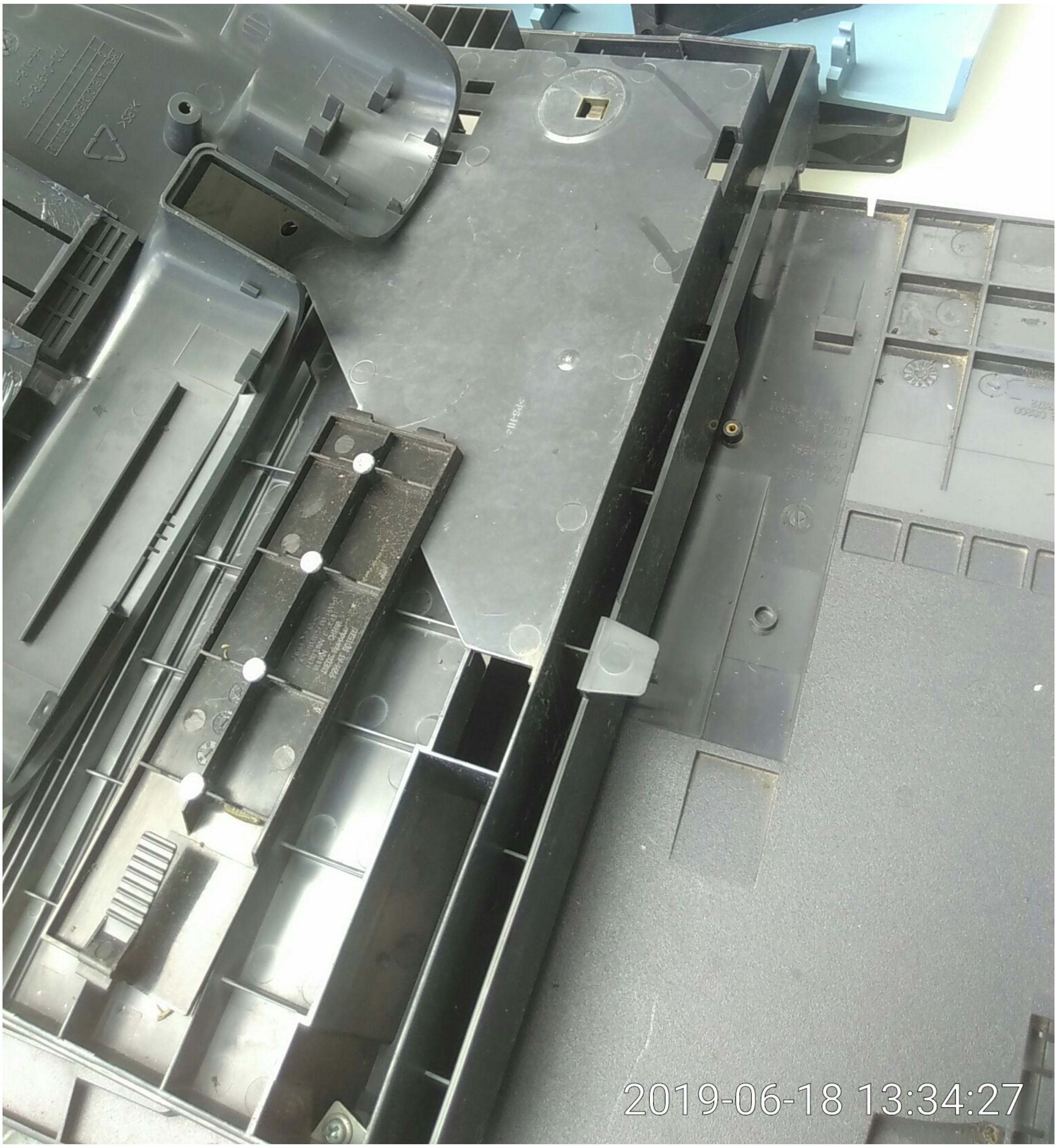

Figure 32: Casings being sorted, with fine-print mould labels and some screws and brass inserts that were missed in disassembly. Photograph. (Author's own, 2019)

The results of metal parts being missed can be damage to the blades of a granulator and mould platens, although a flotation tank would ideally be used between those stages in order to remove contamination. The results of labels being missed or misunderstood can be the waste of usable materials or the contamination of recycled materials by incompatible polymers or POPs.

For the group of concerned citizens and creative practitioners who I gathered to discuss the wider recycling systems that we use, our CoP was a shared experience of dealing with the difficulties and inefficiencies of municipal recycling systems that seem designed in isolation from their users.

5.3.4 Reciprocity and Care in Action Research

Participants in social research and particularly in ethnography can be harmed in ways unforeseen by researchers by mere publication of anonymised accounts, which can cause upset and embarrassment, even if not publicly through journalism, then often privately within community relationships. (Murphy and Dingwall, 2001)
As such, there should be a clear benefit to communities to outweigh any such potential harm.

Actively practising reciprocity in Action Research, has been noted to support the loyalty of participants and may increase the quality and quantity of data generation and research findings. (Gosovic, 2019)
Throughout this enquiry I have done my best to practise reciprocity, such as through providing lunch to an informal focus group, helping to troubleshoot machinery for fellow researchers, and providing material samples for craft participants to play with.

My hope that providing PCL as an experiential tool would be useful, was partly justified by feedback:

> "I did get a chance to look at the Polymorph. ... It's- from an artist's point of view, it's the most amazing material ever. ... I didn't realise as well that if I put it back into hot water, you could re-use it again. ... Like I made a tiny little shell today, just because I was playing around with it this morning as well, because it's in the kitchen and I play around with it every time I walk in, which is ridiculous. ... in terms of making small-scale models and that, it would be really useful for that, because instead of wasting materials, you could use it over and over again." (The Fine Artist, 2021, Appendix J)

However, when participants have a closer relationship with a researcher, then there is more potential for harm if they are more likely to disclose private information to someone they see as a friend (Murphy & Dingwall, 2001), so I have been careful to look for instances where over-sharing could occur when quoting my participants, and weighed the benefits of presenting relevant statements.

My background, as a volunteer and employee for ReBOOT, presented benefits and challenges here. Volunteering and working within the organisation allowed me a deeper insight into its workings than might be available to a researcher who only intended on studying it.
My familiarity with other volunteers, which had brought reciprocal benefits in the past, then led me to avoid recruiting research participants within that team, due to concerns for how our working relationships, friendships and the researcher-participant relationship could potentially interfere with each other.

6. Findings, Limitations and Future Research

6.1 Findings

The use of Co-Design methods over distance proved highly effective at generating useful recommendations for a social enterprise to turn a waste stream into a useful product and meet the needs of local artisans, going above and beyond simple product and service design ideas to consider how to set up experiences that would benefit both parties.

Reflecting on how this work answers my research questions, e.g. the needs of local creative practitioners:
Makers often want access to parts of broken things that are otherwise unsaleable, to upcycle those parts. Therefore, some kind of open times where they can safely see what is available might save the time and energy of processing things.
Access to samples or a physical library of existing materials would help them to choose processed/downcycled materials (sheets, rods, etc.)

What kind of recycling service will support local practitioners to build creative recycling enterprises?
Craftspeople who might use recycled plastic materials could help recycling firms in the more labour-intensive processing of small waste streams in order to produce their own materials, in a mutually beneficial relationship.
Providing classes in how to safely use the materials could enable more people to expand the comfort zone of their practice, and do so responsibly.

6.2 Limitations

Due to time limitations, I did not examine another local charity, Nairn Green Hive, who have since carried on this recycling project, with machinery purchased for the ROAR feasibility study having been given to them, since said study determined that there was not enough space on the MRO and ReBOOT premises for the full process chain of machines required.
With more time, I would also have attempted to involve participants more in the direction of the research and make it truly participatory.

6.3 Future Research

The ideas generated by participants in this research already raise many possible avenues of inquiry.
For one example, it was suggested to investigate on-site or local pyrolysis of ABS as an alternative to sending it to Aberdeen's incinerator. Where possible, other emerging technologies such as de-polymerisation or supercritical water oxidation may be cleaner options, but may not be accessible far from urban hubs.

> "I added another arrow to your system of plastic sorting. I added pyrolysis, because you could put it close to your incineration, because some plants actually kind of do both, but ideally you don't want to do incineration… because you don't want to have oxygen in your plastics." (Plastic@Bay Researcher, 2021, Appendix I)

If the initial aims of this research is a motivation, then spending more time refining the use of polymer types that do not come with flame retardants, such as PolyCarbonate casings and HDPE bottle caps, could be fruitful. Otherwise, expert input may be needed in order to resolve questions around the risks of organophosphate flame retardants in ABS.

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