# The Potential of Ocean Plastic

An Investigation of Recycling Possibilities in Design and Awareness-raising Methods in Society

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Abstract

One severe and urgent environmental problem facing this planet is ocean plastic pollution. Despite various policies and frameworks, the challenge has been growing as countless plastics enter the marine environment and remain there, endangering the health of the ecosystems. As a material with excellent properties recyclability, ocean plastics have the potential to be recalled back to the production process for repurposing into a new life cycle. Citizens need to be provided with a new vision to rethink their relationship with plastics to meet this challenge.

This practice-based thesis aims to combine design and technical skills with sociological enquiry (an integration of public engagement, case studies and interviews) to explore the relationship between ocean plastic and society by investigating its impact, potential and public perceptions. Adopting a quantitative approach, the author added her design vision in the traditional scientific process, experimenting with four types of plastic waste collected from beaches in Scotland, including polyethylene (PE), polypropylene (PP), polystyrene (PS) and polyethylene terephthalate (PET), and then developed systematic methods of recycling ocean plastics. Using a combination of quantitative and qualitative approaches, the author examined public views of ocean plastic as pollution and as potential material resources in different settings, where participants were able to acquire knowledge and information about ocean plastic and interact with the recycling and making process. Findings suggest ocean plastics can be repurposed through both traditional and emerging processing methods and can be adopted in a variety of applications, except for products requiring precision due to contaminants and unknown degradation. The research also identifies public interest in reusing ocean plastic and willingness to adopt environmentally friendly behaviours towards plastic use. The study raises new implications for ocean plastic research and agendas for further research investigating the relationship between participation, emotion and behaviour change.

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**Author’s declaration**

During the period of registered study, the thesis has not been submitted for any other degree or professional qualification and is the result of the author’s independent work. The work contained herein is the author’s own except where explicitly stated otherwise in the text.

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**About the author**

I came from a transdisciplinary background. After graduating high school, I started my undergraduate study in Environmental Engineering at Huaqiao University in China. After a year of study, I found myself unable to take an interest in chemistry-related subjects. Therefore, I decided to transfer courses and completed the degree Bachelor of Engineering in Industrial Design. I continued my postgraduate study (MA) in Product Design at Edinburgh College of Art, focusing on the practice and research of reusing and recycling everyday paper waste into household products and furniture within an African context. I then develop significant interest in working and experimenting with waste materials during this process. Turning unwanted waste materials into something beautiful and functional is a very rewarding process for me, which involve material collection, testing different recycling methods and proportions, and receiving feedback from the public on the outcome. I believe that incorporating a design vision into material recycling can be effective to attract attention and thus have the potential to address material-related environmental issues.

The area where I grew up in China was an underdeveloped city with poor waste management and infrastructure. People have little awareness of waste classification and recycling. However, with little environmental awareness in mind, people's reusing behaviours are very active to save living expenses, especially with plastic and glass packaging. On the contrary, during these years living in the UK, I notice that the British actively practice more daily recycling than reusing. The differences in environmental behaviours are my other research interest.

I have always been longing for the seaside as I am from an inland city. The first time I went to a beach was at ten years old, and I was drawn to the peaceful and scenic views. I chose to complete both my undergraduate and postgraduate studies in coastal cities out of my love for the ocean, Xiamen (China) and Edinburgh (Scotland) namely. Even though both cities are touristic, the beaches are kept clean and attractive, the way that I always pictured in my head when I was young. I had a part-time job as a sale assistant in souvenir shops while studying for my Master's degree and grew an interest in the tourism and consumer experience sector. Whether purchasing from a shop or making through an activity, a souvenir is a product of an extraordinary experience, representing a certain time and place. When customers were shopping at my place of work, many of them were looking for patterns or forms that could represent the trip and experience. However, most of the products available in these shops were mass-produced in developing countries and transported long distances to the point of sale, failing the transition from an intangible experience to a tangible object. I saw the potential in combining locally collected waste materials with making/crafting in experiential marketing, and it became one of my research focuses since.

Through a preliminary study on the status of solid waste, I realised that the practice and research on plastic waste, especially in the marine environment, was much more urgent than paper waste, and people's awareness should be raised not solely on recycling or reusing alone, but the combination of reducing, reusing and recycling to solve the plastic problem. Therefore, combining my transdisciplinary background, engineering and design skills, with my interest in environmental issues and experimenting with waste materials, I focused my doctoral research on recycling ocean plastics by combining technical methods with design vision and raising public awareness through various activities to tackle the severe ocean plastic issue.

# Chapter 1. Introduction

The relationship between humankind and the natural world has undergone the most rapid transformation in human history since the 1950s (Steffen et al., 2004). The use of human-made materials increased by up to 15 times over about the same period (Allwood et al., 2012), which is associated with rapid growth in global GDP (Tooze et al., 2018). Economic expansion is inseparable from producing products, and every step of a product's lifecycle has an impact, resulting in the increase in land, ocean and air pollution, the loss of natural habitats and the exploitation and consumption of resources (Tooze et al., 2018). Plastics and polymers are the human-made materials most commonly seen in modern life, and they are one of the most crucial components of the artificial environment. Their wide-ranging characteristics from high durability and stability, lightweight (Barnes et al., 2009; LI, TSE and FOK, 2016) to tensile strength and flexibility, combined with low cost (Magnier, Mugge and Schoormans, 2019), make them excellent versatile materials (Jahnke, 2020).

However, since the modern development of plastics and their mass production, the amount of plastic leaking into the environment has dramatically increased (Niaounakis, 2017). Global plastic production has grown remarkably over the past decades, raising from 5 million tonnes in the 1960s to 370 million tonnes per year in 2020 (PlasticsEurope, 2012; 2021). All advantages soon become threats when plastic products are mistakenly discarded and enter the marine environment. Since most plastics are not biodegradable, quantities increase over time in the marine environment (Andrady, 2011). Plastics severely affect the health of the marine environment, causing entanglement, ingestion and the extinction of corals on an ecological dimension and reducing tourism income on an economic level (Schneider et al., 2018). The growing plastic pollution in the marine environment is reaching a tipping point (Raubenheimer and McIlgorm, 2018), with the Covid-19 pandemic and the increasing production and use of PPE products (De-la-Torre and Aragaw, 2021) putting further pressure.

So far, a significant amount of research is concerned with ocean plastics, focusing on the following aspects:

- statistical research on the quantity and state of plastics in the ocean (Jambeck et al., 2015; Zhou et al., 2016; Niaounakis, 2017; Okuku et al., 2021; Thiel et al., 2021),
- microplastics (Avio, Gorbi and Regoli, 2017; Jamieson et al., 2019; Nelms et al., 2019),
- global and regional waste management and legislation to mitigate ocean plastic pollution (Gregson et al., 2016; Pettipas, Bernier and Walker, 2016; Raubenheimer and McIlgorm, 2018),
- effects on marine life (Gall and Thompson, 2015; Savoca et al., 2017),
- effects on the economy (Nelms et al., 2017),
- public views on marine litter (Krelling, Williams and Turra, 2017; Hartley et al., 2018a; Magnier, Mugge and Schoormans, 2019; Botetzagias and Malesios, 2021),
- environmental education on marine litter (Hartley et al., 2018b).

However, with the state of ocean plastics and their effects well investigated and documented, research on recovering and repurposing the material is scarce. Especially when it comes to understanding ocean plastic issues, which are interpreted from geographical, ecological and statistical perspectives in most cases, the designers' voices are missing. Gutsch (2016), the founder of Parley[1] stated: "Nobody can save the oceans alone. Each of us can play a role in the solution. It is in the hands of the creative industries to reinvent faulty materials, products, and business models. The consumer can boost the demand for change." As a global problem, ocean plastics require transdisciplinary research activities because transdisciplinarity is characterised by orienting towards real-world issues and is seen as looking for universal advantages and approaches over all disciplines (Godemann, 2008).

Recycling domestic and commercial waste plastics, on the contrary, has generated significant interest globally, in part because Precious Plastic[2] offers free technology and knowledge in machine building and plastic recycling that everyone can access to. Precious plastic has become a new "movement", sparking a global craze, involving

[1] Parley is an environmental organisation that focuses on protecting the oceans.
[2] Precious Plastic is an online platform offering open source plastic recycling knowledge.

designers, makers and the general public interested in plastic recycling. However, with hundreds of thousands of workspaces recycling waste plastic in the Precious Plastic Community, only a few work on ocean plastics.

Following circular economy[3]'s principles, plastic waste collected from the marine environment can be recycled into production (Magnier, Mugge and Schoormans, 2019), although recycling ocean plastics is much more complicated than everyday plastic waste, as they often carry foreign contaminants (Vones et al., 2018) and require complex pre-treatments (Iñiguez, Conesa and Fullana, 2016). Some companies, such as Adidas and Ecover[4], have started recycling ocean plastics into new products, but they are on a limited scale that many consumers are unaware of. Some products are advertised as "made from ocean plastic" but deliberately minimise the fact that ocean plastic only accounts for a small percentage of the composition, or the recycling process is not clearly presented, giving consumers the impression of greenwashing. In addition, recycled products by these large companies often look no different from ordinary products on the market, with no obvious traces of ocean plastic at all. Therefore, the public is rarely presented potential and believable solutions to the problem, primarily only witnessing the negative impacts. As a result, the current perception of ocean plastic is pessimistic and distasteful.

Human activities are the only origin of ocean plastic, so raising awareness and changing behaviours are crucial solutions (Pahl, Wyles and Thompson, 2017). Preventing plastics from entering the ocean and reclaiming plastic from the marine environment are equally important to address the ocean plastic problem. Both solutions are highly dependent on whether the public's negative plastic-related behaviours can be changed, and whether products recycled from ocean plastic are acceptable by consumers. They interconnect with each other because, at a social level, the increasing implementation of recycled ocean plastics will raise awareness of this environmental problem (Magnier, Mugge and Schoormans, 2019). Ocean plastic recycling deserves research and public attention as a new significant environmental initiative, involving attempting to address the devastating linear economic effects through the lengthy process of collecting, sorting and recovering marine debris

[3] Circular economy refers to the economic system that aims to reduce waste and resource consumption, close energy and materials loops and promote sustainable development (Prieto-Sandoval, Jaca and Ormazabal, 2018).
[4] Ecover is a Belgian company manufactures environmentally friendly cleaning products.

(Magnier, Mugge and Schoormans, 2019). There seems to be a research gap between the tremendous effort put into solving ocean plastics pollution and public cognition on the endeavour. Besides, there is a lack of research on public expectations for recycled ocean plastics in existing literature under the "public views on marine litter" category listed earlier. Magnier, Mugge and Schoormans (2019) did the first online investigation asking if consumers were willing to adopt recycled ocean plastic products, and participants' perceptions were surveyed using a questionnaire and several images of recycled ocean plastic products. However, to date, there have been no studies on the public's evaluation of recycled ocean plastics after a physical contact and experience. No research has investigated public perceptions after they have the opportunity to interact with recycled ocean plastic and co-create objects for themselves.

Based on the current research gap, the study is led by the following research questions.

1. What are the possibilities of integrating a designer's vision and subjectivity into ocean plastic recycling?

2. After personal interaction with recycled ocean plastics, will there be a difference in public perceptions?

3. What psychological factors can influence behavioural intentions?

The ultimate objective of this research is to alleviate the ocean plastic problem, which is approached from both technical and sociological perspectives. Firstly, it aims to explore the possibilities of turning ocean plastics, the material present in abundance in the marine environment and often treated as waste, into a resource, through scientific and design approaches involving experimentation and making. Differentiating from existing cases of ocean plastic recycling, the process aims to preserve some traces of the marine history on the plastics while recycling. Secondly, the researcher evaluates and analyses the approaches used in the first process and simplify a series of methods that participants can operate at public engagement activities, seeking to raise awareness and change behaviours. At this stage, the researcher intends to provide people with limited knowledge of complex machines and design principles (Anastasiadou and Vettese, 2019) with the opportunity to be involved in ocean plastic recycling and making their unique mementoes.

As practice-based research, it involves the knowledge of science, design and social investigation in a humanities context and transcends the traditional boundaries (Choi and Pak, 2007). The methodological aspects of this study are grown out of the researcher's personal experience with ocean plastics and extended to the societal dimension. It begins as quantitative research, involving a systematic experimental process, followed by qualitative research questions regarding awareness, behaviour, education and interactions. The researcher uses the existing literature and visual materials to obtain information and understanding of the ocean plastic situation and establish an initial physical connection with the natural environment through field trips. Then the "making-as-research" method is adopted during the researcher's hands-on processes as new knowledge is generated throughout the experiment, and the researcher uses the continuously acquired new knowledge to verify the previous results. Due to the Covid-19 outbreak, the author adjusts the methodological choices to be in line with the government restrictions in order to complete the research. The author creates a new method of social investigation, using a combination of case studies, interviews and public engagement events to indirectly and directly investigate public perceptions of ocean plastics, rather than relying solely on participatory activities planned prior to the pandemic. The scientific method as an ongoing process is the overall method running through the research, as the entire research, including all methods employed, is the process of "make observations – think of interesting questions – formulate hypotheses – develop testable predictions – gather data to test predictions – refine, alter, expand, or reject hypotheses – develop general theories" (Garland Jr, 2016:9).

This study begins with a discussion of the plastic material and how it enters the marine environment, and then investigate ocean plastics and their various associated factors, including quantity, source, destination, characteristics and properties, impacts and waste management. The researcher discusses the effects from both ecological and economic perspectives to gain a thorough understanding of the damage plastics are causing to the marine environment. Furthermore, the study attempts to comprehend the situation through the macro-micro lenses (Beeharry et al., 2017), with the macro being waste management, policies and legislations and the micro being individual perceptions and behaviours. The author reviews literature on the Covid-19 pandemic as it occurred one year after the beginning of this research, and it affects the research to a significant extent. Therefore, a section on Covid-19, PPE and ocean plastics is added to this study because the pressure and impact on the marine environment caused by the surge in the use of PPE products and its impact on this study cannot be overlooked. The challenges and opportunities of ocean plastics facing human beings are then discussed to provide insights for the following research.

The study then explores awareness-raising and behaviour change interventions through reviewing existing literature. Utilising environmental education (EE) as the dominant method of social investigation in this study, this thesis reviews relevant literature to assess its applications in different sectors, including educational setting and experiential economy. Tourism industry is a representative sector of experiential economy, and its relevant literature is reviewed and discussed because the implementation of environmental education in tourism can be applied to other experience-related areas.

After reviewing the existing literature on ocean plastics and environmental education, the research focus is shifted to practice. The researcher first researches current plastic recycling methods from reviewing the literature and discussions with the technician in the Polymer Laboratory at Edinburgh Napier University. The hands-on process, also called the "making process" by the researcher, includes the entire journey with ocean plastics, involving field trips, sample collection, sample detection, pre-treatments, sample size reduction and the main recycling processes. The experimented ocean plastic samples are collected from different beaches in Scotland, including polyethylene (PE), polypropylene (PP), polystyrene (PS) and polyethylene terephthalate (PET). Compression moulding and extrusion are used to recover ocean plastics, and emerging technologies, including laser cutting and 3D printing, further processes the reclaimed materials. The research also carries out case studies to analyse the recycling methods used by other designers and makers (primarily the Precious Plastic community), as the researcher cannot adopt such methods due to the unavailability of equipment in the laboratory. Based on the experiments and case studies, the researcher evaluates and summarises systematic approaches to recycling ocean plastics.

The social investigation of this research consists of two parts – case studies and public engagement. The author surveys public perceptions indirectly by interviewing four

Scottish studios and businesses involved in plastic recycling and zero-waste practice to grasp their and the clients' views on the sustainable and recycling work. Besides this, the researcher also discusses insights on plastic recycling and citizen behaviour interventions obtained from the Global Research & Innovation in Plastics Sustainability 2021 conference. Furthermore, the thesis discusses three different public engagement activities carried out by the researcher prior to and during the pandemic to investigate public perceptions on ocean plastics before and after participation and assess awareness and behaviour change. Finally, the study presents its findings and discussions in relation to research objectives and answer the three research questions.

This study has theoretical, practical and societal implications. This topic constitutes a new domain with largely unstudied potential. First, the research contributes to ocean plastic research from a designer's vision, which is entirely new to the area. Second, it provides systematic approaches to recycle different types of ocean plastics, making ocean plastic recycling more accessible to the public and industries. Third, it adds new understanding to existing research on public perceptions of ocean plastics. Moreover, the study uses psychological factors to influence participants' awareness and behaviours. Lastly, the research follows the principles of Sustainable Design and closed-loop recycling, proposing zero-waste approaches to recycling ocean plastics.

*The impact of Covid-19 on the research*

The outbreak of Covid-19 has had a significant impact on almost everyone's life. It has severely affected this research in many aspects. A few months after the author started the second year of her doctoral research, Covid-19 was declared a global pandemic, and the UK went on lockdown. Before the outbreak, the author had planned laboratory experiments, field trips and public engagement activities during 2020-21. The lockdown had made these research activities very challenging. The challenges faced by the study include not only the suspension of research activities or plans but also the uncertainty about when the lockdown would end.

As stated earlier, due to the author's previous work experience, one of her research interests was working with experiential marketing, leading to the previous research plan focusing on the tourism sector and the relationship between environmental awareness and tourist experiences as well as souvenirs. Therefore, the author reviewed a great amount of literature and wrote a chapter on this topic. To reflect on the findings of the literature, focus groups and workshops engaging tourists in Edinburgh were planned to take place in August 2020. August in Edinburgh would have been the ideal time to conduct research on the tourism sector as before the pandemic, it had been hosting one of the biggest international festivals in the world, Edinburgh Festival Fringe, with people from all over the world travelling here every August to experience the intercultural event and Scottish heritage. However, the festival was cancelled for the first time in its history in 2020 due to Covid-19, and Edinburgh hosted very few international tourists and tourist experience events compared to previous years. The extreme shift in the tourism sector led to the change of methodologies and target participants of this research. Due to the suspension of most non-essential human contact activities, the author had to pause all plans for public engagement, prioritise the writing of the literature review chapters, and wait for everything to return to normal.

In addition, travel was suspended due to the restrictions, and therefore, the second field trip to the Isle of Harris was cancelled. Two participatory activities were planned for this trip. Thus, the author faced the problem of not being able to engage the public in the first location where she had a strong emotional connection with on this research topic. Emotion plays a significant role in this research. The cancellation of this field trip not only reduced the opportunities to engage with different public groups but also eliminated the opportunity for the author to experience the same place a second time with different emotions as well as assessing locals' emotional changes. The field trip would have also been an excellent opportunity for another material collection, in terms of quantity and types of ocean plastic. Moreover, the university was closed during the lockdown and the author did not have access to the polymer laboratory and design workshop for nearly eight months. Additionally, after the university reopened, the social distancing requirement made access to these facilities more difficult, which significantly affected the experiment process.

After waiting for a few months since the lockdown began and the suspension of most research activities, the author decided to approach the research from a different angle than planned prior to the pandemic and change the methodological choices. She wrote about these challenges in her reflective journal,

“Understanding the public’s perception, awareness-raising and behaviour intervention on ocean plastics should not be interrupted by the pandemic. It is more about engaging as many people and spreading the knowledge in possible ways than set methods. There ARE other ways.”

Moreover, the pandemic has added a significant amount of plastic waste to the environment due to the mass use of PPE. When people prioritise their health rather than the environment, it is important to remind them of the severe environmental issue and the importance of positive plastic-related behaviours. As the impact of Covid-19 on this research cannot be overlooked, it is necessary to review the literature on the situation of PPE and ocean plastic and people’s relevant behaviour to ensure the research was up to date. Therefore, due to the pandemic, the literature review chapters of this thesis are reorganised and revised, with a large number of studies on tourism omitted due to the cancellation of tourist workshops, and a section on PPE and ocean plastics added. Even though part of the secondary research on tourism is removed from this thesis, it still provides the author with valuable insights into this sector and experiential economy, which is beneficial for the workshop design.

Since it was impossible to engage the public directly during the pandemic, the author went on a detour and studied cases that already had direct contact with the public through different activities before the pandemic to analyse those “experiences of others”. Four cases were selected for semi-structured interviews for further insights into their stories with consumers and the general public. Firstly, the combination of case studies and interviews allows the author to indirectly grasp public perception regarding plastic waste recycling and zero waste as well as their awareness and behaviour change after engaging with these cases. Secondly, they confirm the importance of design’s role in plastic recycling and awareness raising and provide more insights on emotional changes from designers’ points of view.

As the research focused on repurposing ocean plastic from a designer’s perspective, the author organised lectures with undergraduate design students before the pandemic to obtain their opinions on the topic, which received positive feedback. It was extended to more online lectures during the university closure as the author sought to engage any possible public groups. Not only the change of method helped the research reach out to more audiences, but it also provided more time than other participatory activities to assess participants' perceptions and behaviour change within the educational setting and urged the author to be more sensitive to observing students' plastic-related behaviours after their participation.

The Covid-19 pandemic posed unprecedented challenges to this research, such as changes in research methods and an extra amount of research on literature, but it also brought opportunities and discoveries that the author would not have considered or noticed before the outbreak. Although many plans were cancelled, the alternative paths that the author took were proven effective and valuable. Research methods and activities that were not undertaken within this timeframe due to the pandemic provide excellent opportunities for future research.

# Chapter 2. Ocean plastics

Plastic is one of the most used materials by human beings to build the modern world. However, while facilitating development and advancement, it also causes severe environmental problems, and plastics entering the ocean is one of the most significant problems facing the earth. To understand ocean plastic and its effects, it is important to know where it comes from in the first place. Therefore, this chapter will begin with a brief discussion of plastics and then analyse the current state of ocean plastics and their impact on different aspects. In addition, public perceptions must be understood so that appropriate and effective interventions can be made to raise awareness.

## 2.1 Plastic – the origin of ocean plastic waste

From a single material throughout the product lifecycle to be part of a product, the process often involves the exploitation or destruction of natural land, production of greenhouse gas emission, transportation impact and waste generation (Tooze et al., 2018). Extraction of raw materials through activities inevitably requires a large number of resources, including energy and water (Tooze et al., 2018). For example, approximately 0.9 kg of crude oil is used to make one litre of petrol (Gervet, 2007) for the production of 0.6 kg polyethylene (Steensgaard et al., 2017). In 2020, the demand for polyethylene is 15 million tonnes, which accounts for about 1/3 of the plastic consumption in the EU (PlasticsEurope, 2021), equivalent to 22.5 million tonnes of crude oil and 25 million litres of petrol. Global plastic consumption has increased dramatically since 1980, caused primarily by plastic consumers in central Europe, Asia and Latin America (Van Sebille, Spathi and Gilbert, 2016). The excessive consumption, as well as fast disposal of plastic products, lead to a significant accumulation of plastic waste (Barnes et al., 2009). By now, about 70% of the total plastic production is out of circulation – it is either burned, landfilled, lost or recycled (Geyer, Jambeck and Law, 2017). The exponential growth in population and resource requirements is endangering ecosystems (Steffen et al., 2015), and plastic and its pollution are one of the primary issues facing the planet and life today (Jahnke, 2020).

Two hundred and seventy-five million MT of plastic waste was generated by almost 200 coastal countries in 2010, which was equal to 93% of the global population, accounting for around 11% of the total waste (Jambeck et al., 2015). China itself accounted for 28% of plastic production of the world in 2015 (Dauvergne, 2018). China alone mismanages up to 8.8 million MT of plastic waste each year, and plastic waste mismanaged from the top twenty countries (with regards to mismanaged plastic waste generation) accounts for 83% of the total in 2010 (Jambeck et al., 2015). Sixteen of them are middle-income countries, achieving fast economic growth but lack of the infrastructure to manage the waste (Jambeck et al., 2015). The packaging is one of the top end-applications of plastic products (Van Sebille, Spathi and Gilbert, 2016), amounting for approximately 40% of the total plastic production (UNEP, 2016), along with automotive, construction, electrical and electronic equipment, textiles, paints, medical products and agriculture (Andrady, 2011). It can be traced back to the 1990s when using thin, single-use plastic bags was already a widespread phenomenon, and by 2000, the global production of these bags was 0.5-1 trillion (Roach, 2003). An extensive amount of packaging is made to be disposable products, which will be discarded within a year after the production (Thompson et al., 2009), and many cannot be recycled.

The recycling rate is very meagre compared to the amount of plastic produced. In Europe, only approximately 30% of 25.8 million tonnes of plastic waste was recycled in 2014 despite waste management systems and legislation (Van Sebille, Spathi and Gilbert, 2016), and 31% of the total waste still ended up at landfills (PlasticsEurope, 2015a). Even worse, only about 40% of plastic waste is collected in much of Asia due to the insufficient waste collection systems, and the recycling rate is even lower as it is inadequate for the waste infrastructure, landfills and incineration facilities in these places to handle 80% of the non-commercially recyclable plastic waste (Dauvergne, 2018). As a result, in the past 50 years, less than 10% of plastic waste has been recovered to make new products globally (Geyer, Jambeck and Law, 2017). On the positive side, in countries such as Sweden and Switzerland, less than 5% of plastic waste is sent to landfills, and the rest is used for material or energy recovery (PlasticsEurope, 2015a), giving hope to the rest of the world that advanced and effective waste management systems can reduce the problem of plastic waste.

## 2.2 Ocean plastics and various related factors

Unless discarded plastic products are recycled or incinerated, they end up either in landfill with general waste, or in the oceans (Jahnke, 2020). Plastic waste is inarguably the most definite sign of humankind’s harmful impact on the marine environment (Woodall et al., 2014) and an obvious indicator of the Anthropocene[5] (Jamieson et al., 2019). Up to 80% of marine waste comes from land-based sources (Derraik, 2002; Andrady, 2011; OSPAR, 2014). Land-based plastic waste enters the ocean mainly through stormwater runoff, waterways or discharged into coastal waters (Cózar et al., 2014). Tyre erosion, clothes washing, and city life are causing increasing plastic pollution, which may account for around one-quarter of all plastic ending up in the oceans (Dauvergne, 2018). A third of plastic packaging is polluting the ecosystems, with tremendous quantities in the marine environment (UNEP, 2016; Ellen MacArthur Foundation, 2017). O’Shea et al. (2014) highlight that around 65-70% of the weather balloons find their way to the oceans. The remaining comes from sea-based sources including ships, recreational vessels, offshore facilities and commercial fishing boats where the waste is dumped directly into the water (Derraik, 2002; Williams, Tudor and Gregory, 2005; Sheavly and Register, 2007). The problem of discarded fishing nets is being exacerbated by the growth of the global fishing industry and the use of high resistance fishing tools made from non-degradable plastics (Niaounakis, 2017). It is also estimated that discarded fishing gear accounts for approximately 10 vol% of marine waste (Macfadyen, Huntington and Cappell, 2009). The Marine Conservation Society’s annual beach clean survey highlighted that 37% of the collected waste could not be identified clear sources because of the type or condition of the items (Marine Conservation Society, 2011).

The destination of plastic objects entering the marine environment depends on the size and buoyancy characteristics, as well as wave patterns and local wind (Ryan, 2015). Approximately 50% of the plastic produced is buoyant (PlasticsEurope, 2011). As a result, unlike other types of marine waste, due to the durability and lightweight properties, plastic transports easily by wind, rivers and wastewater after being discarded or improperly disposed of (LI, TSE and FOK, 2016), and thereby reaches different oceans and coastal environments (Wright, Thompson and Galloway, 2013; do Sul and Costa, 2014). It is estimated that 60-64% of floating plastic is exported from the coast to the open sea (Lebreton, Greer and Borrero, 2012). In the ocean currents’ pathway, some remote beaches become repositories of plastic waste, such as

[5] “The Anthropocene Epoch is an unofficial unit of geologic time, used to describe the most recent period in Earth’s history when human activity started to have a significant impact on the planet’s climate and ecosystems” (National Graphic, n.d.).

the ones on the West Coast of Scotland, with only a small part of it reused by locals (Barnes and Milner, 2005; Vones et al., 2018). The rest is photodegraded, broken down into smaller parts (secondary microplastic[6]), washed back into the marine environment and most likely ingested by the wildlife (Hopewell, Dvorak and Kosior, 2009). Plastic waste found on a beach might be from a long distance away, putting even more pressure on an already strained ecosystem (Van Sebille, Spathi and Gilbert, 2016) and challenging the implementation of management activities (Barnes et al., 2009).

The ocean's saline condition and the mild temperatures at the surface make the degradation much slower compared to the air or commercial composting facilities (Pegram and Andrady, 1989). As microorganisms accumulate, the plastic's density increases, and it descends into the ocean's aphotic and cold sediment bottom, where little degradation occurs (Ioakeimidis et al., 2016). Ocean plastic has been found in many different locations in the deep sea (Galgani et al., 2000; Schlining et al., 2013; Fischer et al., 2015; Tekman, Krumpen and Bergmann, 2017; Chiba et al., 2018); and in the Mariana Trench, there was a plastic bag found at 10898m, which achieved the deepest record (Chiba et al., 2018). Law (2017) stated that waste was found inside the ocean in all seven compartments: coastlines, biota, surface and seafloor, water column, sea ice and sediments. Other research has identified the presence of plastics in all parts of the marine environment – from poles to equator, from intertidal to deep-sea sediments (Zarfl and Matthies, 2010; Lusher et al., 2015; Van Cauwenberghe et al., 2015). By now, the most considerable amount of waste is collected from the coast, followed by the seafloor and then the rest of the ocean compartments (Schneider et al., 2018). Plastic waste of all types accounts for more than 90% of all coastal waste (Polasek et al., 2017) while waste from the seafloor contains more than 70% of plastic (Lueiro, 2013; Fishing for litter Scotland, 2015; Naturschutzbund Deutschland, 2015). The abundance of ocean plastic in the sediment is also at alarming levels. In a global comparative study, scientists found that the abundances of microplastics ranged from 2 to 31 pieces per 250 ml of sediment (Browne et al., 2011).

[6] Microplastic: defined as plastic particles smaller being between 0.1 μm and 5 mm (Galloway, Cole and Lewis, 2017). Primary microplastics are manufactured for industrial processes (Fendall and Sewell, 2009; Moore, 2008), while secondary microplastics are from the degradation of large plastic pieces (macroplastics; Cole et al., 2011).

Ocean garbage patches became known when high concentrations of plastic were detected in the central circulation of the North Pacific (Moore et al., 2001; Kaiser, 2010; Zhang et al., 2010). There are five ocean gyres identified including North and South Pacific, North and South Atlantic and Southern Indian; and it was predicted that another garbage patch would occur in the Barents Sea (van Sebille, England and Froyland., 2012). Globally, plastic has been responsible for up to 80% of all marine waste (Derraik, 2002; Sheavly and Register, 2007), and in some places, the percentages are even higher (Dahlberg and Day, 1985; UNEP, 1991; Kanehiro, Tokai and Matuda, 1996). More recently, the modern disposable lifestyle has been causing up to 12.7 million MT of plastic leaking into the oceans each year (Jambeck et al., 2015). The amount of plastic entering the Black Sea via the Danube alone was estimated to be about 4.2 tonnes per day and a total 1533 tonnes per year (Lechner et al., 2014). In 2015, it was estimated that 150 million MT of plastics were in the marine environment (Ocean Conservancy, 2015b); and since most of the plastic is not biodegradable, ocean plastic quantities increase over time (Andrady, 2011). Plastic remains in the marine environment for centuries due to its high persistence (Derraik, 2002). The remains of the first plastic products could probably be found in landfill or the ocean (Jahnke, 2020). Cózar et al. (2014) and Eriksen et al. (2014) estimate that five trillion pieces of plastics weighing over 250,000 tonnes are floating on the ocean surface, most of which are less than 10 mm long.

In the UK, scientists used the method called Ecological Quality Objective (EcoQO)[7] to determine the extent of floating ocean waste by quantifying the plastic items in seabirds' stomachs (OSPAR, 2010). The report showed that an average of 50% bleach-washed fulmars on all of the four examined North Sea regions including Scottish Islands, East England, Channel and Southeast North Sea highly breached the EcoQo level (10%; Van Franeker and SNS Fulmar Study Group, 2008). If the trend continues, the total amount of plastic entering the oceans will reach 16 million MT in 2025 (Jambeck et al., 2015; Mortillaro, 2017). To sound the alarm, Ellen MacArthur Foundation (2017)'s researchers estimated that the weight of plastics in the ocean would exceed that of fish by 2050.

[7] "In March 2002, the North Sea countries launched the North Sea Ecological Quality Objectives System (EcoQOs), aiming to provide quantitative systems to measure major human impacts on the North Sea environment and ecosystem" (Van Franeker, 2004: 7). Northern Fulmar (Fulmarus glacialis), a type of seabird is the measuring tool used to assess the state of marine plastic litter (Van Franeker, 2004). "There should be less than 10% of Northern Fulmars having more than 0.1g of plastic particles in the stomach in samples of 50–100 beach washed fulmars found from each of 4 to 5 areas of the North Sea" (OSPAR, 2010: 176).

## 2.3 Ocean plastic impact

Since no marine space has been untouched by human activities (Halpern et al., 2012), which have led to changes in marine life, habitats and landscapes (Atkins et al., 2011; Mani-Peres et al., 2016). Ocean plastic is seen as a global problem that is receiving increasing attention and affecting the health of ecosystems and coastal economy (Beeharry et al., 2017).

### 2.3.1 Ecological impact

Humans are the only species that have managed to change the environment through a variety of approaches (Forestell, 1993). The use of plastic is one of the most significant causes of the change of the natural world. Recognising the adverse effects of ocean plastic is the first step to develop effective measures (Hastings and Potts, 2013). Plastics are made from inorganic and organic materials and consist of long chains of polymer molecules (do Sul and Costa, 2014). Although plastic is considered as biochemically inert (a substance is not chemically reactive, or its decomposition is slow or negligible; Atkins and Jones, 2007; Teuten et al., 2009; Roy et al., 2011), the chain scission produces chemicals (which are incorporated during the polymer manufacturing process to improve the performance) when the plastic degrades in the waters (Browne, Galloway and Thompson; 2007; Thompson et al., 2009; Jahnke, 2020). The chemicals have an impact on the environment because they not only increase the plastic degradation time (Teuten et al., 2009) but also are hazardous to biota (Talsness et al., 2009). Bisphenol-A, known as BPA, is a recognised potentially toxic chemical byproducts from plastic degradation (Jahnke, 2020). Studies about BPA have found the possible connection between it and various hormone disruption related health effects (Tharp et al., 2012; Stahlhut et al., 2018), which means there is a potential risk of contaminating the marine life when BPA is released from plastic degradation in the ocean (Jahnke, 2020). Such additives also include *polybrominated diphenyl ethers* to extend heat resistance, *nonylphenol* and *triclosan* to prevent oxidative damage and microbial degradation (Browne, Galloway and Thompson, 2007). Various indirect pieces of evidence suggest that chemical additives in plastics may be released into organisms after ingestion (Gouin et al., 2011; Tanaka et al., 2013; Bakir, Rowland and Thompson, 2014). Not only that, plastics are susceptible to absorb hydrophobic pollutants from the surrounding seawater (Teuten et al., 2007), and if ingested, these substances can also be released into biological tissues, causing sub lethal impacts (Batel et al., 2016; Laing et al., 2016).

Plastics have a variety of impacts on the marine environment including entanglement and entrapment of relatively larger animals (such as seabirds, seals and turtles), habitat destruction, ingestion by biota, transport and bioaccumulation of contaminants (Pettipas, Bernier and Walker, 2016). Study indicates that plastic pollution's impacts on the environment tend to be most abundant in areas with the most complex ecosystems, species diversity and abundance (Van Sebille, Spathi and Gilbert, 2016). By 2015, 340 publications had documented that about 700 species had encountered marine waste (Gall and Thompson, 2015). By 2022, approximately 4000 species had been reported to be affected by marine waste (by over 1800 publications; Tekman et al., 2022). The dramatic increase indicates the existence of marine debris is threatening more and more marine life; it also shows that this environmental issue has attracted increasing attention from scholars and scientists. Plastics account for the vast majority of these encounters (Tekman et al., 2022). They are responsible for 92% of entanglement and ingestion; 71% of the entanglement accidents occurred between plastic ropes/nets and the individual, whereas ingestion mostly was encountered between plastic fragments and the individual (37%; Gall and Thompson, 2015). The number of affected species is expected to increase over time due to the increasing production (Avio, Gorbi and Regoli, 2017).

Chiappone et al. (2002) found that 84% of the sponges and cnidarians' partial or total mortality was due to tissue abrasion, which was caused by fishing hooks and line gears. Avio, Gorbi and Regoli (2017)'s study shows that lugworms' health and behaviours can be affected, and the primary productivity of their habitats can be reduced by conventional and even biodegradable microplastics retained in sandy sediments. In addition, marine waste causes wearing on the seabed and leads to toxic substance accumulation, adversely affecting the marine fauna and flora (Schlining et al., 2013). Ocean plastic is responsible for destroying and even the extinction of corals (Ramessur, 2013; Kühn, Rebolledo and van Franeker, 2015; Schneider et al., 2018), which are not only an extremely crucial part of the ecosystem but also of high cultural and aesthetic value (MEA, 2005).

The large amount of plastic entering the ocean also dramatically increases the chance of marine life dispersing through drifting materials, which represents a potential mechanism for alien species to invade new habitats (Barnes, 2002; Barnes and Milner, 2005; Andrady, 2011), thereby undermining the stability of the ecosystem. Because of the longevity of plastics in marine environment, the harm would last for decades even though no plastics were being manufactured or disposed of (Avio, Gorbi and Regoli, 2017). From the perspective of human safety and health, beachgoers face the risks of being injured by broken plastic fragments, fishing tools, and divers and swimmers could be trapped or entangled by the floating or submerged ones, as well as exposed to toxic bacteria in the contaminated water (Sheavly and Register, 2007). Human beings are also facing the risk being at the top of the food chain where the toxic substances can accumulate along (LI, TSE and FOK, 2016). Therefore, not only the marine environment and ecosystems need to be protected but also human health (Raubenheimer and McIlgorm, 2018).

### 2.3.2 Economic impact

The impacts of ocean plastic include not only immediate, short-term health issue, but also indirect but long-term impact on life quality, such as financial cost and reduced recreational opportunities (Sheavly and Register, 2007). Hastings and Potts (2013: 50) agree that waste can affect and deteriorate a variety of "natural functions that provide social and economic benefits". For instance, the impact of fisheries on the Scottish economy is about £10 million per year, whereas the impacts of waste on aquaculture were valued more than £130,000 a year (Mouat, Lozano and Bateson, 2010). In the UK, it is estimated that marine waste costs fisheries £10 million a year, including repairing gears damaged by waste; and the authorities spend about £15 million on beach litter removal each year (Mouat, Lozano and Bateson, 2010; Hastings and Potts, 2013; Newman et al., 2015). Globally, the accumulation of plastic waste in the ocean causes the economic costs of beach clean-up, which, according to a conservative estimate by UNEP (2014), may cost total economic damage to the marine ecosystems of $13 billion per year. Even in 1999, according to the questionnaires and interviews with fishermen, the decline in production rates of shellfish and seaweed caused by marine waste were 10-20% and 20-30% respectively (MOMAF, cited in Cho, 2009: 415), indicating that the rate may be much higher due to the accumulating amount of marine debris over time. *Ghost fishing* is the term used to describe the fact that marine animals get trapped by discarded/abandoned/lost fishing gear, such as nets and ropes (NOAA, 2020). It was reported that, at a depth of about 350m off the Ooljin coast (Korea), around 200kg of King Crabs, which are an economically valuable species, got caught by five tonnes of discarded fishing nets (Cho, 2009). In addition, a great number of maritime accidents have happened off the coast of Korea due to the existence of marine waste, including engine failure caused by entangled propellers and cooling water suction pipe blockage (Cho, 2009). This means that ocean plastics along with other marine waste has been posing a threat to the safety of seamen (Pruter, 1987; Jones, 1995) and can adversely affect other ships' fishing activity and traffic (Takehama, 1990; Nash, 1992; Barnett et al., 2016; NOAA, 2021).

Ocean plastic compromises the quality of the marine environment and affect coastal tourism sources, which has a negative impact on the economy. Krelling, Williams and Turra (2017) believe that stranded waste is one of the most critical aspects of beach quality by beach users. Tudor and Williams (2006) also agree that beach choice depends strongly on waste-free beach and seawater. Plastic pollution could deter the visits to the affected areas (Van Sebille, Spathi and Gilbert, 2016) since it influences the satisfaction of the visitors (Leggett et al., 2014) and makes beaches aesthetically unattractive (Krelling, Williams and Turra, 2017). In Ballance, Ryan and Turpie (2000)'s study, they found that 85% of participants would avoid visiting a beach when there were more than two pieces of waste per metre, and 97% would not visit a beach when there were ten or more large pieces.

The areas where the waste is found as well as where tourism activity occurs may not be the regions where the waste originates (Krelling, Williams and Turra, 2017). Still, local authorities have no choice but to invest extra money and efforts for beach cleaning to prevent further losses in tourism income (Mouat, Lozano and Bateson, 2010). The economic losses of stranded waste should be taken into account not only the cost of the clean-up but also the reduced interest of tourists (Ofiara and Brown, 1999; Ten Brink et al., 2009; Leggett et al., 2014). A study of twenty-one Asian-Pacific economies estimated that in 2008, an impact of $622 million on marine tourism was caused by marine waste (McIlgorm, Campbell and Rule, 2011). The stranded waste could reduce local tourism revenue by 39.1% potentially in Pontal do Paraná, Brazil, which represents an up to $8.5 million loss per year (Krelling, Williams and Turra, 2017). Ballance, Ryan and Turpie (2000) also estimated that beach cleaning costs account for about 20% of the entertainment income of the Cape Peninsula. Jang et al. (2014)'s study found a 63% drop in visitors to South Korea's Geoje Islands because of marine litter from the estuary area, with an estimated economic impact at between $29 million and $37 million in 2011. Understanding the economic impacts on tourism as a result of the growing problem of ocean plastic is an essential step in supporting effective decision-making (Krelling, Williams and Turra, 2017). Miller and Ward (2005) recognise tourism's ethical and social responsibility in terms of sustainability, and they argue that the industry must respond to the demands of consumers for sustainability.

## 2.4 Action against ocean plastic pollution

There is now an increased awareness within the international community of ocean plastic pollution reaching a tipping point due to its negative socio-economic and ecological impacts (Gregory, 2009; Mouat, Lozano and Bateson, 2010; Gall and Thompson; 2015; Raubenheimer and McIlgorm, 2018). Although the problems associated with marine waste are concentrated in the coastal and marine environments, they originate primarily from land and the solution lies mainly on land (Hartley et al., 2018a). Therefore, the best approach to reducing plastic pollution is to explore where and how to solve the problem in the plastics' life cycle before they end up in the ocean (Steensgaard et al., 2017). At the G-7 summit, the Leaders' declaration stated that they recognised that marine waste, particularly plastic waste, posed a global challenge – marine and coastal life as well as ecosystems, and human safety health were directly affected (Elmau, 2015). UN Environment Assembly encouraged resource efficiency, including "prevention and increasing collection and recycling rates of plastic waste, re-design and re-use of products, materials and avoid the unnecessary use of plastic and plastic containing chemicals of particular concern where appropriate" (Raubenheimer and McIlgorm, 2018: 288). It is supported by China, the world biggest plastic producer, as the country began to make efforts to close unlicensed recycling shops (Goldstein, 2017), ban plastic waste import and recycle more domestic waste (Dauvergne, 2018). From 2002 to 2006, three provinces in Korea raised $23.9 million for marine waste management and aimed to raise $27.5 million from 2007 to 2011

(Cho, 2009). Also, countries such as Switzerland, Denmark and Sweden, have banned plastic landfilling; more than 95% of the plastic waste is sent to energy or material recovery (PlasticsEurope, 2015a). Such legislation and policies will greatly reduce the possibility of plastic waste flowing from landfills into the ocean and influence behaviours at the macro or social level (Beeharry et al., 2017).

Other actions also have proved that the top-down (authority-citizen) regulation system is effective to address the plastic waste problem, such as the single-use plastic shopping bag charge (Larsen and Venkova, 2014; You, 2017; Dauvergne, 2018) and container deposit legislation (Schuyler et al., 2018). In 2002, the incentive program established in Incheon, Korea, paid fishermen to collect marine waste and bring it back to port (Cho, 2009). The program spent \$9.3 million purchasing 11,000 tonnes of marine waste from fishermen from 2003 to 2006 (Cho, 2009). Consequently, refund schemes and positive incentives have shown to increase material recovery substantially (Lerner, 2011) because they create win-wins or mutual benefits (Collier, 1994) for both the environment and the public. Nevertheless, incentive programs are not flawless (Cho, 2009) since such programs base on the principle of extrinsic motivation (Hartley et al., 2018a) and do not necessarily strengthen the belief about environmental issues (Cho, cited in Cho, 2009: 416). When incentives stop, it may lead to the risk that behaviour will stop (De Young, 1993; Halvorsen, 2012).

Removing plastic from the marine environment is considered to be an additional measure to cut down the impact of ocean plastic (UNEP and NOAA, 2011). The public has started to clean up beaches voluntarily since awareness of marine pollution has increased (Vince and Hardesty, 2017). In 2014, more than half a million volunteers who were mostly from developed countries reported a collection of over 7 million kg of waste along more than 20,000 km of coastline; most of it was plastic, such as plastic packaging and cups (Ocean Conservancy, 2015a; Pettipas, Bernier and Walker, 2016). In 2017, hundreds of thousands of International Coastal Cleanup volunteers organised by Ocean Conservancy (2017) collected over 1.5 million plastic bottles, more than 820,000 plastic bottle caps, almost 800,000 food packaging wrappers, more than 520,000 plastic bags and almost 2 million cigarette butts – a total of 8,346 MT of coastal waste. For years, longline fishermen who are based in Hawaii have voluntarily brought back the discarded fishing nets that they encounter during travelling back to

Honolulu Harbour to reduce the danger of future maritime encounters (Morishige and McElwee, 2010).

## 2.5 Public perceptions

Ocean plastic comes from a wide range of sources – various individuals, communities and industries, from land and sea (Hastings and Potts, 2013). Human activities are the only reason that ocean plastic pollution exists as well as the one and only solution to the problem. In order to understand public perceptions about ocean plastic, it is necessary to first investigate what the marine environment is to different social groups. Fishermen value the ocean's food sources above all else, while residents and visitors consider aesthetics, scenery and food sources are the most valuable aspects but neglect the value of the marine environment in supporting plant biodiversity, energy, trade and shipping (Huelsenbeck, 2012; Beeharry et al., 2017), despite much work on harnessing tidal energy (Allan et al., 2011). The aesthetics and scenery of coastal areas are considered peaceful, priceless and inspiring, resulting in mass migration to coastal areas (Beatley, Brower and Schwab, 2002; Marafa and Chau, 2016). Hawkers[8] believe that marine environment is not only a source of food, tourism and leisure, but also a source of their livelihood – the resources the ocean provides are eventually sold for income (Beeharry et al., 2017).

As ocean plastic is a transboundary governance problem that crosses social divisions (Jentoft and Chuenpagdee, 2009) and formal governance alone cannot solve the exponential increase in environmental problems (Vince and Hardesty, 2017), understanding public perceptions about ocean plastic is a fundamental step in raising awareness. It is also considered a foremost step towards a sustainable approach to achieve cleaner marine environments (Hartley, Thompson and Pahl, 2015) and pave the way for engaging society as well as developing and implanting feasible solutions to this global issue (Hartley et al., 2018a). Pahl, Wyles and Thompson (2017) agree that the key to tackling waste entering into the marine environment is to change public perceptions and behaviours.

It is perceived that marine waste problem is due to people's behaviours and the design of product and packaging rather than the accidental item losses or the lack of facilities

[8] A hawker refers to a person who sells goods on the street.

(Hartley et al., 2018a). Wyles et al. (2016)'s study found that the public had a more negative view on the land-based coastal waste (food packaging) than the sea-base one (fishing gears). Study by Beeharry et al. (2017) also supports this view – it was agreed by all respondents that beach areas contained most of the waste than the surface of open oceans and coastal waters, and in the water. Though participants in Hartley et al. (2018a)'s study believed most waste input into the marine environment directly from the sea; and therefore, the public needs to be aware of the various sources and pathways through which waste enters the marine environment.

Research by Beeharry et al. (2017) indicated that 68.4% of the respondents believed the lack of sufficient legislations and enforcement systems resulted in the additional marine waste, but coastal user groups did not believe that marine waste was a critical environmental and economic issue as beach's aesthetic appearance was perceived to be the most threatened instead of human health, and tourists were confident that due to the ocean's vastness, the damage caused by marine waste was not significant. Though the study did confirm that people are witnessing the prevalence of plastic waste in the ocean, with 82.4% of participants agreeing that ocean plastic is the major component of marine waste (Beeharry et al., 2017). Beach visitors support the solutions of improving education, installing more rubbish bins and fining for littering (Santos et al., 2005; Eastman et al., 2013). Coastal users ranked some actions according to the degrees of implementation difficulty, and picking up waste in the seawater was considered the most challenging, followed by asking someone to pick up their own litter, supporting legislations and policies and using reusable products instead of the disposable ones, respectively (Beeharry et al., 2017). Besides, television advertising and social media are perceived as the most effective approaches (Beeharry et al., 2017).

Socio-economic factors influence both littering behaviours (Krelling, Williams and Turra, 2017) and the intention to reduce litter (Hartley et al., 2018a) in various ways. Studies show that the lower the education and income level, the higher the littering behaviour (Santos et al., 2005; Eastman et al., 2013); age also affected the tendency of littering (Campbell, de Heer and Kinslow, 2014). In Hartley et al. (2018a)'s study, they found that women, older generations and participants with higher education levels were more likely to take actions to reduce marine waste. According to Ballantyne, Packer and Falk (2011), curiosity, practices, advocacy, and motivation to learn of the environment all increase significantly with age. Studies have shown that people are more likely to litter in an already littered and disordered environment compared to a clean one; and they tend not to litter after witnessing someone picking up litter (Cialdini, Reno and Kallgren, 1990; Cialdini, 2003; Keizer, Lindenberg and Steg, 2008; Schultz et al., 2013), indicating that positive behaviours can be influenced. Besides, beach users who pay more frequent visits and notice waste more often show higher behavioural intentions to reduce the waste (Hartley et al., 2018a). It is also perceived that people who live in rural environments litter more than those who live in urban areas (Schultz et al., 2013). Moreover, beach users' views may differ in ocean plastic pollution when their uses of the beach are different (Krelling, Williams and Turra, 2017). For example, people who play beach volleyball may be more inclined to pick up plastic waste on the beach since it affects the quality and safety of the sport whereas people who use the beach for sunbathing may be less likely to take actions.

## 2.6 Covid-19, PPE and ocean plastics

It can be seen that single-use plastics highlight their importance through Covid-19, especially in terms of virus management (Schlegel, 2020; Benson, Bassey and Palanisami, 2021). Personal protective equipment (PPE), mostly made from plastic, has been widely used in response to the pandemic, and discarded PPE has become a new type of litter found in different environments, such as waterways and tourist beaches (Benson et al., 2021; De-la-Torre et al., 2021; Okuku et al., 2021; Thiel et al., 2021). Billions of face masks and gloves are used monthly around the world (Prata et al., 2020). It is estimated that 1.6 million tonnes of plastic wastes have been generated globally per day since the outbreak and 585 million for the entire 2020 (Benson, Bassey and Palanisami, 2021). In addition, Benson, Bassey and Palanisami (2021) estimate that about 3.4 billion disposable face masks or face shields are discarded globally every day. Most Covid-19 related litter is not disposed of properly, posing the risk of entering the marine environment through surface runoff (Fadare and Okoffo, 2020; Okuku et al., 2021) and causing a potential surge in plastic pollution shortly (De-la-Torre and Aragaw, 2021). Besides, due to the possible pathogenicity, PPE items, especially disposable face masks, have never been collected by municipal workers (Akhbarizadeh et al., 2021). Plastic polymers and plastic packaging materials contained in Covid-19 related products accumulate in the environment, especially when many medical face masks are produced from electrospun nanofibers (Zafar et al., 2016), eventually degrading into microplastic fragments (Silva et al., 2021), posing a serious threat to the aquatic environment and life (Gall and Thompson, 2015). PPE debris was discovered underwater in Hong Kong (OceansAsia, 2020) and on the Mediterranean seafloor (Genries, 2020). In the Persian Gulf, medical masks and plastic gloves are the rising sources of secondary microplastic in marine environments (Akhbarizadeh et al., 2021).

Okuku et al. (2021) report that more discarded PPE is seen on remote beaches than on urban ones, while De-la-Torre et al. (2021) state that the more tourism-intensive the beach, the higher the density of discarded PPE. The density of masks increases significantly during the summer holiday season (Thiel et al., 2021). During lockdown periods, beaches' environmental quality improved, and litter density decreased because human activity slowed down (Soto et al., 2021), also called *anthropause* (Rutz et al., 2020). Soto et al. (2021) also observed signs of recovery of some bioindicators in most of the researched beaches. Okuku et al. (2021) believe beach closure and the slowdown in human activity have reduced the amount of litter leaking into the marine environment.

Heidbreder et al. (2019) argue that plastic-related behaviours are influenced by socio-psychological characteristics, but studies suggest that this is not necessarily the case when it comes to health issues (Homer and Kahle 1988; Bardi et al., 2009; Grodzińska-Jurczak et al., 2020; Botetzagias and Malesios, 2021). Studies find that the threat of the pandemic has clearly transcended the threat of plastics, which results in a hierarchical shift in values, with human health concerns exceeding environmental concerns when it comes to single-use plastics (Homer and Kahle 1988; Bardi et al., 2009; Grodzińska-Jurczak et al., 2020). The previously established connection between environmental concerns/interests and environmental impact awareness is possibly blurred by Covid-19 (Botetzagias and Malesios, 2021).

Based on this knowledge and poorly designed waste management systems in treating solid waste and current pandemic waste (Aragaw, 2020), the risk of a surge in Covid-19-related plastic waste is yet another challenge in addressing plastic pollution. As Benson, Bassey and Palanisami (2021) put it, the Covid-19 pandemic is likely to exacerbate the global plastic waste problem. It is difficult to assess the overall picture of plastic pollution since Covid-19 began when the amount of other plastic waste decreased but PPE waste increased. Nevertheless, there is no denying that regardless of the situation, plastic waste in the marine environment is continually accumulating – it is just a matter of speed. In addition, PPE has a greater negative impact on the marine environment than other plastics because of its risks of transmitting the Covid-19 virus (Chin et al., 2020; Nghiem et al., 2020; Van Doremalen et al., 2020) and entangling/entrapping marine animals. A full-size N95 mask was found in a dead Magellanic penguin's stomach in Brazil (ONG Argonauta, 2020). Research suggests that waste management and measures should be improved and taken at both the individual and authority levels to address the environmental impacts of Covid-19 (Dabholkar et al., 2017; Abdallah et al., 2020; Ilyas et al., 2020; Aragaw and Mekonnen, 2021; Chowdhury, Chowdhury and Sait, 2021).

## 2.7 Challenges and opportunities

Increasing awareness of ocean plastic problem may boost collection effects, but it will not necessarily reduce the amount of plastic in the ocean as more and more plastics are on their way to the marine environment each year (Jambeck et al., 2015) from different sources. Not to mention, Forestell (1993) argues that, to a great extent, people's attention on the environment is more on words than on actions. Moreover, ocean plastic management is challenging due to its own characteristics, such as excessive longevity (Dauvergne, 2018), vast quantities and unknown sources. For example, at a governing level, in Scotland's case, most policy and management arrangements are concentrated on land where the central pressure on the marine environment comes from; however, plastic waste also originates from the marine dimension (Hastings and Potts, 2013). Choi and Hong (2001) also identify the necessity of marine dimension legislation as the findings suggest that the lack of law enforcement is to blame for the abandonment of fishing gear. However, it does not mean that land waste management is fully in place. Steensgaard et al. (2017) warns that poor land waste management system is one of the main issues of ocean plastic pollution.

Another factor that makes solving ocean plastic problem challenging is the difficulty of recycling. Since the plastic is often contaminated, pre-treatments are required, including separating contaminants from the collected pieces and cleaning (Iñiguez, Conesa and Fullana, 2016). According to Vones et al. (2018), foreign particle contaminants, such as organisms, that have entered the plastic in the ocean may lower the quality of the recycled product. Besides, there is an economic challenge for conventional recycling methods because of the cost of ocean plastic collection and transport to centralised industrial facilities (Vones et al., 2018).

Reducing the environmental burdens, strengthening the research base of the economy and creating new jobs are the three most important challenges that Europe is facing (Gregson et al., 2016). Recycling can provide a win-win opportunity by contributing substantially to resolving these three challenges (EEA, 2011). Waste management companies claim that up to 84,000 jobs could be created in the UK by expanding recycling over the next decade (SITA UK, 2012). This can be considered as an excellent opportunity to bring thousands of people who lost their jobs during the Covid-19 outbreak back to the workplace. Jobs in the recycling sector include low- to high-skill ones, ranging from collecting, material handling (waste classification and cleaning) and processing to product manufacture (EEA, 2011). In addition, the high volume of pandemic-related plastic waste puts pressure on current waste management, but also offers more opportunity for the public to create and recycle.

Plastic is one of the biggest contributors to environmental problems, and ocean plastic is the most problematic aspect of plastic pollution. This chapter reviewed the literature of the past two decades to discuss and analyse different factors associated with ocean plastics, from the plastic material to the impact and public perception of ocean plastic, to challenges and opportunities to comprehend the necessity and urgency to address the ocean plastics problem. In addition, due to the significant impact of the Covid-19 pandemic on many sectors, the Covid-19, PPE and ocean plastic section has been added at the end of this chapter. There are both opportunities and challenges to solving the ocean plastic problem, and it is vital that all sectors of society take action to reduce the amount of plastic that has entered and is on the way to the marine environment. Through the research in this chapter, the author identified two aspects of recycling and public awareness raising to be explored in the following chapters to alleviate the plastic problem in the marine environment.

***Author's reflection***

*Reviewing the literature on the states of ocean plastic and its impact provided me with a deep understanding of the environmental issue. From a useful creation to a severe waste problem, the life of plastics tells the story that human action is a double-edged sword. It creates convenience for human life, but the misuse affects the entire environment. Even though numerous studies are focusing on plastic in/entering the marine environment, the output is usually literal, with statistics and complex technical terms that are not very understandable for people who are not familiar with that area. Thus, the great effort spent in researching ocean plastic may not be recognised by the general public or lead to behaviour change. Therefore, I believe that it may be beneficial to "translate" the insightful scientific information into something easier for the public to comprehend. This is the gap that needs to be filled by designers who can interpret scientific facts into understandable messages and stories. Scientists, designers and the general public should work together on this matter.*

## Chapter 3. Awareness-raising and behaviour change

The Gaian[9] hypothesis by James Lovelock suggests that the balance of the earth comes from the local activities of individual organisms and provides a new drive to the saying "think globally, act locally", and humans are the only creatures on this planet that are able to work on this action (Lovelock, 1986; Forestell, 1993: 278). To act on this theory, the adoption of educational approaches to change community behaviours in different environments has been proven successful (Duckett and Repaci, 2015). This chapter reviews the literature on Environmental Education (EE) and discusses its effectiveness on public behavioural change in and beyond the traditional education settings. It then analyses different factors that influences awareness raising and behaviour change and discusses the role of authentic souvenirs and experiences as an educational tool to form positive environmental behaviours. This chapter thus sets the stage for the use of ocean plastic in educational activities for awareness-raising and behavioural change in later chapters.

### 3.1 The role of environmental education in behaviour change

Waste management is a corporate effort of different stakeholders (Guerrero, Maas and Hogland, 2013). The identification of marine waste as legislation, law enforcement, educational and cultural matter has been regarded as the potential solution to prevent waste from terrestrial sources (Golik and Gertner, 1992). The general public is identified by a list of main stakeholders as the most essential stakeholders in reducing marine waste (Joseph, 2006). Because technological solutions may not be enough to contain the problem, a perspective is needed that highlights the impact of human behaviour (Heidbreder et al., 2019). Ocean plastic has been recognised as a cultural problem due to its association with human behaviour (Golik and Gertner, 1992). Generally speaking, culture is linked to individual's core values and norms at the micro-level, while it is also closely connected to the society at the macro-level (Bandura, 1986; Erez and Gati, 2004). Government, environmental groups and industries have been taking steps to tackle the ocean plastic problem at the macro level. The clean-up phase is currently the main policy approach's focus, but addressing the

[9] Gaia is an ancient Greek word for the Mother Earth.

complex multi-sectoral problems surrounding littering and other plastic-related behaviours should also be paid attention to (Hastings and Potts, 2013).

As at the micro-level, the key factor fundamentally connected to the awareness, perception, attitude and degree of concern about environmental problems as well as the motivation to participate in solutions is human behaviour (Rees and Pond, 1995; Hartley, Thompson and Pahl, 2015). McKinley and Fletcher (2012) also agree that individuals are capable of making a change in marine environment health by taking the right action. In a given situation, the influence ought to in theory run from “abstract values to midrange attitudes to specific behaviours” – an order that may be referred to as the “value – attitude – behaviour” hierarchy (Homer and Kahle, 1988: 638). One of the most essential and challenging tasks now is to effectively persuade the public to quickly adopt environmentally responsible actions in their lives (Ballantyne and Packer, 2011). One of the solutions is to manage plastic pollution at source, for example by raising public awareness of the threat of plastic waste (Van Sebille, Spathi and Gilbert, 2016).

Environmental awareness, which is recognised as understanding human behaviour’s impact on the environment (Kollmuss and Agyeman, 2002), has a “cognitive, knowledge-based component” as well as an “affective, perception-based” one (Biasutti, 2015: 738). Due to the complexity, the development of sustainability requires transdisciplinary research activities (Godemann 2008). Education is perceived by the UN and its agencies, governments and the EU as a major approach to address sustainability issues and considered to be important to “help people build personal and social capacity so that they, as learners and social actors, are enabled to grapple with sustainability issues and relate them to their own lives and work” (Scott and Gough 2004: 3). Environmental Education (EE) has been recognised as a vital role in improving individuals’ and communities’ understanding of the relationship with the natural world as well as in enhancing the awareness, attitudes and behaviours to protect the environment (Stapp, 1969; Palmer, 2002). Ramsey and Rickson (1976)’s widely accepted model of EE described that increased knowledge would lead to favourable attitudes that prompt people to take action to improve environmental quality. Forestell (1993:277) argues that “knowledge without behaviour leaves no discernible trace of change”, and on the contrary, “behaviour without knowledge will last only until the next fad”.

Education must be given to people of all ages for awareness-raising of environmental responsibility (Earll et al., 2000). The awareness and actions about waste require both sides’ efforts – the willingness of educators to integrate marine waste knowledge into teaching and the willingness of students to take action to solve the marine pollution (Hartley et al., 2018b). The integration of marine education along with other pollution issues and waste management into education settings through curriculum reform and activities could be of great value as it is an effective way to target young people to promote positive change (i.e., use of substitutes, re-use and proper disposal; McPherson, 2015). Studies show that young people have the awareness of environmental problems (Cohen and Horm-Wingerd, 1993; Kahn Jr and Lourenço, 2002), can have ecologically responsible behaviours (Evans et al., 2007), and can foster other’s attitudes and behaviours (Duvall and Zint, 2007; Damerell, Howe and Milner-Gulland, 2013). In different countries and regions such as United Arab Emirates, the UK and Hong Kong, school children actually already have high awareness of the problem (Hartley, Thompson and Pahl, 2015; So et al., 2016; Hammami et al., 2017), and younger individuals show additional willingness to relinquish up their convenience for the sake of the environment (Elgaaïed-Gambier, 2016). In addition, scholars who conducted environmental education activities with school students suggest that such events can improve participants’ environmental knowledge, attitudes and behaviours (Hidalgo-Ruz and Thiel, 2013; Hartley, Thompson, and Pahl, 2015; Hartley et al., 2018b). Other researchers also agree that it is potential to promote public understanding and action within education sector about marine waste issues (Hartley et al., 2018b) since it is an essential agent of social change (UNESCO, 2014).

Participants’ evaluations indicated that a learner-centred approach was crucial in attempting to shift perceptions and conceptions of environmental and sustainability problems (Scoullos and Malotidi, 2004; McNaughton, 2012). A story named *The Journey of Jurella*[10] *and Microplastics* (Nuñez and Thiel, 2011) was used for an ocean plastic educational activity with children, and the 28-page picture story was about the

[10] A local Chilean fish.

fish facing plastic pollution in the ocean (Hidalgo-Ruz and Thiel, 2013). The positive result demonstrated that a great percentage of students actively engaged in the activity and obtained a new understanding of ocean plastic (Hidalgo-Ruz and Thiel, 2013). The environmental education activity designed for children by Vones et al. (2018) similarly confirms the positive impact of participants' active engagement in the remanufacturing process on improving the adverse effects of ocean plastic. After knowing the potential of turning plastic into 3D printing filaments, one of the participants asked: "*So if I bring my rubbish, like old plastic bottles, can we use that to make new filament?"* (Vones et al., 2018: 58) The children involved in the project indicated that they would tend to dispose of their litter more responsibly in the future and pick it up when they notice (Vones et al., 2018). It presents a change in the attitudes of those who have participated in such events about ocean plastic, and post-participation action may be taken to address the problem. Research by Hartley, Thompson and Pahl (2015) also indicated that British children showed more concerns and intentions after the marine waste educational intervention. The TeachWild program in Australia engages students in a series of citizen science activities, including scientific methodology, marine waste data collection and analysis, and the data is uploaded to a national database, which scientists used to better understand the origins and distribution of marine waste as well as the impact on wildlife in Australia (Fletcher, Salter and Longnecker, 2015). This project actively supports environmental education, community participation and awareness-raising of ocean plastic, and the increased engagement between scientists and the public can permeate the broader population and lead to behaviour change in plastic use and removal in marine and coastal environment (Vince and Hardesty, 2017).

However, some scientists argue that formal education programmes only make a small contribution about environmental issues to public understanding, even though they are undoubtedly important (Falk 2001; Falk and Dierking 2002; Falk and Storksdieck 2005). Biasutti (2015) suggests that a theory-based approach may only increase students' knowledge, whereas an integrated approach that combines theory, practice and field work may have more effect on shaping attitudes and behaviours. For instance, beach clean-up and waste survey activities can raise public awareness of environmental problems, leading to potential positive behaviour and attitude change, which reflect the educational value (Wyles et al., 2016). To refine and update the public's understanding and knowledge of the challenges, individuals need access to a variety of sources of information throughout their lives, such as *free-choice* learning experience (Ballantyne and Packer, 2011). According to Falk, Heimlich and Foutz (2009), *free-choice learning* is the learning that occurs largely under the learner's choice and control. Free-choice environmental learning activities are perceived to have the potential to contribute positively to addressing environmental issues (Ballantyne and Packer, 2011). For instance, environmental learning experiences can be applied in tourism industry (Ballantyne and Packer, 2011) where visitors have the opportunity to choose their preferable activities to address local or global environmental issues. Tourism not only has the responsibility to minimise the negative environmental effects but also has the potential to solve environmental issues by sharing environmental education experience and promote fundamental changes in public behaviours and lifestyles (Ballantyne and Packer, 2011). Places such as environmental centres, aquariums, museum and science centres are potential to educate, enhance and inspire the environmental behaviour of large numbers of visitors (Ballantyne and Packer, 2011). It is estimated that over 700 million people pay visits to zoos and aquariums around the world that are members of World Association of Zoos and Aquariums, and such facilities provide an unrivalled platform for public participation in environmental conservation (WAZA, 2015).

An ideal outcome of an education experience, according to Ballantyne, Packer and Sutherland (2011), is to conserve the environment by raising public awareness and motivating them to take measures to make their everyday behaviours more responsible and sustainable. Ballantyne et al. (2007) investigated studies on conservation learning in wildlife-based tourism sites and concluded that experiences in these places improve their understanding and perceptions of environmental problems. Many visitors are realising the potential impact of their daily behaviours, in combination with feelings of compassion and conservation, laying the foundation for behavioural change (Ballantyne, Packer and Sutherland, 2011). The behavioural changes reported by the respondents in their study include "changing household practices", "changing purchasing practices", "taking responsibility for the environment beyond the home", "seeking further information", "discussing environmental issues" and "volunteering for environmental causes" (Ballantyne, Packer and Sutherland, 2011: 775-776). Some respondents in Powell and Ham's (2008) study showed increased intention to write letters to the relevant authorities, join environmental organisations, make a donation, avoid using harmful products and attend environmental meetings.

## 3.2 Behaviour change is a consequence of many relevant factors

Environmental behaviour is a result of the interplay of various factors, which include individual characteristics, cognition, influence and evolution linked to the specific context and behaviour (Hungerford and Volk, 1990; Cottrell, 2003). In order to answer the question of how to operationalise responsible environmental behaviour, the 1977 Tbilisi Intergovernmental Conference on Environmental Education (1978) summarised five EE objectives, which were “awareness, sensitivity, attitudes, skills and participation”. Ballantyne and Packer (2011) believe that education process includes three stages, which are 1) participants’ learning tendencies, their own values and beliefs, and motivation brought to the experiences, 2) the emotional and value engagement, interaction and construction throughout the experiences, and 3) the environmental impact and behaviour enhancement after the experiences. As Williams Jr (1979: 20) puts it: “actual selections of behaviour result from concrete motivations in specific situations, […which] are partly determined by prior beliefs and values of the actor”. Therefore, beliefs and values regarding ocean plastic issues must first be formed in order to guide behaviours and actions, and education is a vital approach to create such values. Individuals should understand the nature of the environmental problem and the related ecological and human impacts before they engage in responsible citizenship behaviour since they are more inclined to take actions when a deep understanding of problems is achieved (Hungerford and Volk, 1990). Besides, there are four stages of participants’ response to an experience, including sensory impression (what they see and hear), emotional affinity (what they feel), reflective response (what they reflect) and behavioural response (what they do; Ballantyne, Packer and Sutherland, 2011). Simply put, it is “a cycle of experiencing, reflecting, thinking and acting” (Ballantyne, Packer and Sutherland, 2011: 777).

Plastic-related behaviour is special because of its diversity, including re-use, recycling, avoidance, and consumption of alternatives (Heidbreder et al., 2019), and it is difficult to assess the real change. Moreover, the experiences most likely influence those initially with the weakest pro-environmental attitudes and the lowest knowledge on their environmental conservation perceptions and future behaviours; whereas the impact on those with highest prior knowledge is the smallest (Lee and Moscardo, 2005). Studies by Packer (2004) and Ballantyne, Parker and Falk (2011) confirm that first-time participants have different intentions from experienced ones in terms of environmental actions; repeat visitors show more motivation to act on environmental behaviours whereas first-time visitors scored higher on learning intention. Ballantyne and Packer (2011) perceive that little is known about the effect of the experience on participants' environmentally responsible behaviour adoption after the participation. Budeanu (2000) and Weiler and Ham (2001) add that the effects of these experiences enhancing participants' supports for the community, environmental and economic sustainability as well as industrywide assumptions are still largely unexplored, and the connections between the environmental knowledge, attitudes and behaviours of participants and operational characteristics are not thoroughly tested. Dickinson and Bonney (2012) also agree that the potential impact of citizen science programs on participants' attitudes towards environmental issues has not been thoroughly studied.

Therefore, how environmental education experiences maximise change in participant behaviour is a challenge facing all environmental education operators. Forestell (1993: 277) believes that the possibility to have a significant positive influence on the environment depends on the ability to mobilise individuals' actions in cooperation with "an environmentally sensitive philosophy". In response to this theory, organised beach clean-ups have been proving effective in promoting environmental awareness and responsibility (Kiessling et al., 2017) because when people immerse themselves in the environment they have damaged, they are more inclined to react. Therefore, guilt can be seen as part of the theory, which Muralidharan and Sheehan (2017) believe affects plastic avoidance. Ballantyne and Packer (2011) also agree that, to influence behaviour, participants must be convinced that the planet is threatened by human influences on the environment and that individual behaviour can play a major role in preventing or reversing the damage. According to this theory, instead of being educated theoretically about environmental issues, participants need to witness or experience the damage done to the environment themselves (i.e., beach clean-up activity and documentary watching) and be provided with feasible solutions (i.e. recycle, re-use and reduce). Besides, extending the on-site educational experience to take-home information access, and continuously enhancing events will potentially optimise the effect of the experience on participants to adopt environmentally responsible behaviour at home and workplace (after the experience) and their ability to convert their intentions to behavioural actions (Ballantyne and Packer, 2011). Ballantyne, Parker and Falk (2011) suggest that in tourism settings for instance, tourism managers can encourage tourists to bond an emotional connection with the environment while visiting, respond to the threats facing the environment thoughtfully and reflect on the ideas and discuss them with the companions to optimise the long-time impact of environmental tourist experiences.

Locus of control is another theory that affects behaviour change, that is, when an individual believes that certain behaviours will be reinforced (Hungerford and Volk, 1990). When a person has an "internal locus of control", s/he expects to experience or to be reinforced for taking actions, and success, in turn, will enhance the internal locus of control; whereas when a person has an "external locus of control", s/he does not have belief in making change, and as a result, s/he probably will not act in an environmentally responsible manner (Hungerford and Volk, 1990: 12). Problem awareness-raising thus does not necessarily lead to environmental behaviours (Hungerford and Volk, 1990), and the key to the solution is to develop "beliefs, attitudes, behavioural intentions" as well as "overt behaviours that are consistent with them" (Powell and Ham, 2008: 473). An internal locus of control may not be developed in the classroom directly, but research shows that educating citizenship action skills can boost the locus of control (Hungerford and Volk, 1990). This theory indicates that environmental education should start with awareness-raising and also go beyond it, and the public should be shown and taught the effective ways in environment conservation and be encouraged their potential in reversing the current environmental situation. Ballantyne, Packer and Sutherland (2011) agree that citizens should be provided with achievable actions that can be taken in everyday life in this regard. Research has shown that behaviours can be activated automatically by the characteristics of the environment where one person's behaviour increases the possibility of another person or group to automatically engage in that behaviour (Bargh, Chen and Burrows, 1996; Chartrand and Bargh, 1999). What must be understood from the environmental learning experiences is, at the micro level, individual's behaviours and behavioural motivation are driven by that person's perception, but each person's behaviours, taken together, have the potential positive impact on the behaviour at the macro level change (Beeharry et al., 2017).

## 3.3 Authenticity, emotion and memory

This chapter has been discussing the relationship between environmental education and behaviour change. The definition of the term “education” in this study is not limited to the traditional education system, as it refers to wherever knowledge and information exchange occurs. It can take place in a classroom, or during a wildlife experience. The term “souvenir” in the research is not limited to the tourism industry either. It refers to any object that represents an experience or holds an intangible meaning. The function of experience-related products/service is to represent a memory element that allows the extension of life experience, such as a souvenir (de Andrade Matos and de Azevedo Barbosa, 2018). Wallendorf and Arnould (1988) and Rickly-Boyd (2012) agree that an experience is relational, and they believe that the authenticity feeling can be evoked from the relationship with a photograph or a souvenir, among other objects, reminding one of the experiences. Belk (1990) agrees with this opinion by pointing out that souvenirs gain meanings by awakening memories of another time and place. Gordon (1986: 135) also describes souvenirs as “reminders” of “special moments and events”. Therefore, the use of both terms in this study goes beyond their traditional contexts and gives them broader meanings.

A product (e.g. souvenir) made from recycled ocean plastics purchased from a shop or made during experience activities can be an educational tool that attracts people’s attention, and then they start to ask the question “what is this?” and acquire knowledge about the environmental issue. Since souvenirs carry the meaning of an experience, they become educational objects if the experience is related to environmental education. That is where the education part starts and why souvenirs and experiences are discussed in this chapter about EE and behaviour change.

Benjamin (1936: 147) believed that “the authenticity of a thing is the essence of all that is transmissible from its beginning, ranging from its substantive duration to its testimony to the history which it has experienced”. Therefore, an experience of environmental education, whether activities or product consumption, needs to leave a deep impression on consumers, which will influence their later life. They need to feel the authenticity of the experience from different aspects, including time, space and interactive objects.

### 3.3.1 Authentic souvenirs = mementoes

Lasusa (2007: 274) points out that a souvenir is "anything that acts as a token of one's experience, whether it is bought in a shop or not", and it can be any physical item taken away "from a place or experience that acts to represent that place or experience: a seashell from a beach, a photograph, or even a ticket stub". Souvenirs provides an opportunity for visitors to transform the intangible contact they experience into a tangible memory as well as expand the connection with the experience beyond the contact itself (Collins-Kreiner and Zins, 2011; Haldrup, 2017; Li and Ryan, 2018). According to Gordon (1986), the physical presence of a souvenir is able to locate, define and freeze a transient experience in time and bring something of extraordinary experiential quality back to the ordinary experience. The concept of "aura" can also be used to explain this phenomenon of the magical relationship between past experiences and the resulting objects. Benjamin (1936: 146) argued that "even the most perfect reproduction of a work of art is lacking in one element, its presence in time and space, its unique existence at the place where it happens to be", and he referred the uniqueness of the past time and space as *aura*. Jeffrey (2015: 147) also interprets the relationship between objects and past experiences from the perspective of *aura*:

> A key aspect of the aura is that sensation of being close to the past. This sensation, the thrill of proximity, is not essentially about the physical object itself, it is about the people who have been close to it in the past and the connection to them.

Therefore, there is "aura" of past experiences in souvenirs, which carry the irreproducible history of the experiencer in that particular time and space. As Wallendorf and Arnould (1988: 537) point out, "attachments based on personal memories" make an object important. One of the respondents in Peters (2011: 242)'s study stated that *"the ones that mean the most are the ones with specific memories rather than the object"* but the "object" serves as the carrier of such memories. Proust, one of the greatest novelists with extraordinary skill in the analysis of "forms and psychological mechanisms memory" (Bogousslavsky and Walusinski, 2009: 1), recognised the phenomenon of connection between objects and memories in his life, such as the taste of madeleine cake soaked in tea reminding him of his childhood (Proust, 2006). Souvenirs have links to numerous places: where they are from, where they are placed at home, and the “intangible place” as objects of importance or not (Peters, 2011: 236). Haldrup (2017) adds that souvenirs within the home setting, whether practical or decorative, have the ability to store the narrative and emotion of the experience in which they were purchased into a more ordinary, everyday environment.

According to Sthapit and Björk (2019), consumers now seek “high-quality craftsmanship” when they purchase products, and it “can be closely linked to uniqueness” (Littrell, 1990: 18). In tourism settings, for example, it is agreed in other research that locally made high-quality souvenirs and handicrafts demonstrate superb craftsmanship which represents the visited sites and are often more popular with tourists than those cheaper souvenirs made overseas as they are perceived as more authentic (Timothy and Boyd, 2003; Timothy, 2005; Xie, Wu and Hsieh, 2012). Elomba and Yun (2018) stated that, in order to be considered authentic and meaningful, souvenir features must truly reflect the heritage, destination, or values of the area, and the souvenir materials should be derived from the heritage area. Moreover, as Baudrillard (1966) put it, people were attracted to what had been uniquely created as the moments of creation that could not be duplicated. Consumers associate the authenticity of a craft with its uniqueness and originality, craftsmanship, cultural and historical integrity, use and functions (Littrell, Anderson and Brown, 1993). Anastasiadou and Vettese (2018: 169) believe that “the characteristics of artisans, the interaction with them, and the shopping experience” are important factors in determining the authenticity of crafts.

Creating memorable, compelling and personalised souvenir products is becoming increasingly valuable (Pine and Gilmore, 1998; Neuhofer, Buhalis and Ladkin, 2013). Research by Franke, Keinz and Steger (2009) indicates that consumers are more attracted to the customised products and willing to pay more than traditional, mass-produced ones as they are more in line with consumers’ preferences and needs. Since the sacredness of a souvenir is associated with the possessor’s connection with the item, which is unique to each individual (Goss, 2004; Decrop and Masset, 2014), customised souvenirs stand out to better meet the personal needs of consumers. Walters (1994) argue that personalisation adds a sense of exclusivity that increases the value of the souvenir as consumers may tend to believe that the objects they are purchasing are the original local art (Anastasiadou and Vettese, 2018), and special value is assigned to smaller numbers in limited editions (Jeffrey, 2015). Personalising souvenirs through methods such as inscriptions or engraving of words/patterns chosen by consumers can increase their value and make it unique (Anastasiadou and Vettese, 2018) as well as enhancing the personal relevance to the holder (Blom, 2000).

### 3.3.2 Authentic experiences

Some participants in Anastasiadou and Vettese (2019)'s study stated that they would be willing to pay more if they could personalise or be part of the souvenir designing process at the time of purchase. Prahalad and Ramaswamy (2004a: 6) argue that customers are now reviewing, analysing, and evaluating the value creation process in the industry and noted that, "informed, connected, empowered, and active consumers are increasingly learning that they too can extract value at the traditional point of exchange." With new tools and dissatisfaction with existing options, consumers want to interact with companies and thus co-create value (Prahalad and Ramaswamy, 2004b). On the one hand, for the consumers, due to the higher level of personal involvement with the sacrifice of time and effort, the transition from a consumer to "a co-designer and prosumer" gives them a closer connection with the visited site (Anastasiadou and Vettese, 2019: 438). On the other hand, personalisation reflects the self-experience value (Mugge, Schoormans and Schifferstein, 2009) by turning the consumption from passive into interactive and performative (Urry,1995). Participants in Anastasiadou and Vettese (2019)'s study expressed the significance to see the actions of making souvenirs in front of them instead of being manufactured overseas.

Customers can create their own experiences through different tools which are provided by the hosts (Same, 2012). A representative case is, in 2013, the *Rijksstudio: Make your own Masterpiece* project at Rijksmuseum in Amsterdam opened up the museum's collection of 125,000 images of artworks, which would be used without copyright, encouraging the visitors to access the high-resolution images and even 3D print their own objects (Gorgels, 2013). According to Gorgels (2013), this project is seen as "marketing instrument, inspiring people to enjoy the works at first hand" and it is believed that these artefacts gain a new meaning, a "virtual aura" that strengthens the original artworks (Hazan, 2001: 3). The Rijksstudio project is an example of public spaces embracing and integrating maker culture in their domains to engage consumers. The rise of emergent maker culture has expanded the number of makerspaces (also referred as hacker spaces), thereby boosting the development of personalisation and co-creation in public life (Taylor, Hurley and Connolly, 2016). Sheridan et al. (2014: 529) suggest that educational makerspaces enable users to be involved in:

> participating in a space with diverse tools, materials, and processes; finding problems and projects to work on; iterating through designs; becoming a member of a community; taking on leadership and teaching roles as needed; and sharing creations and skills with a wider world.

Co-creation and personalisation are about "individuals construct their own experiences" and companies co-shaping consumer expectations (Prahalad and Ramaswamy, 2004a: 10). A higher level of consumer-orientation and interaction can be achieved by strengthening the collaboration between consumers and companies, thus creating a higher level of value (Neuhofer, Buhalis and Ladkin, 2013). Lončarić, Dlačić and Kos Kavran (2018) suggest that co-creation with consumers' participation does affect satisfaction with general experiences and, in turn, perceptions of value and life quality. Value is based on co-created experience and is co-created at multiple interaction points (Prahalad and Ramaswamy, 2004a). Consumers act as value co-creator when they participate in the process of experience definition and creation, therefore a process of co-creating value begins (Prahald and Ramaswamy, 2004a; Prebensen and Foss, 2011; Chathoth et al. 2013). Experience marketing should provide something extraordinary, personally relevant and novel in order for consumers to be involved in the co-creating value process (Poulsson and Kale, 2004; Schmitt, 2010). Collaborative creative experiences must be approached from the individual participant's perspective as they participate in an activity at an emotional, physical, mental or intellectual level (Pine and Gilmore, 1998) and consist of what consumers know, feel and want (Same and Larimo, 2012). Participants can also create value through interaction with others (i.e., friends and family), through a collective consumption experience (Tynan and McKechnie, 2009).

Wang (1999) argues that things appear authentic in constructive authenticity because they are constructed in terms of opinions, beliefs and issues and therefore, ideal for raising awareness. Apart from the previous personal experiences (Alegre and Cladera, 2006), overall experience satisfaction and enjoyment (Jarvis, Stoeckl and Liu, 2016) also influence people's perception about and attitude towards marine waste (Krelling, Williams and Turra, 2017). Powell and Ham (2008: 472) propose four key elements of "successful environmental interpretation", which are "enjoyable, relevant, organised and thematic (EROT)"; and enjoyment is one of the main factors for successful interpretation and is considered as an intermediary that affects the effectiveness of possibility of behavioural outcomes. Schmitt (1999) suggest that when designing experience modules, they should encompass emotional experience, sensory experience, physical experience, creative cognitive experience, behaviours and lifestyles, as well as social identity experience related to reference group and culture. De Andrade Matos and de Azevedo Barbosa (2018) also believe that this communication to authenticity is significant. In this way, consumers, in turn, become a valuable source for experience organisers to gain innovation and ideas by adding value to the travel programs (Lončarić, Dlačić and Kos Kavran, 2018).

Hirschman and Holbrook (1982) first put forward the concept of experience-seeking customers, then the idea of experience marketing was popularised in theory and in practice (Lončarić, Dlačić and Kos Kavran, 2018). Carù and Cova (2003) conducted a study linking consumer experience with experiential marketing, raising the possibility of creating an extraordinary experience that consumers can fully immerse themselves in (Souza et al., 2013). People find themselves more authentic and feel freer to express themselves than in daily life because they engage in non-ordinary activities and are not subject to the constraints of daily life (Wang, 1999). A service experience takes into account "the individual, relational, emotional, and contextual attributes" to provide "interesting selections on authenticity" because "it is also multi focused and complex, and its perception by the consumer involves aspects of the whole experience" (de Andrade Matos and de Azevedo Barbosa, 2018: 59). According to Dewey (1971), participation in service experience involves progress in time, anticipated emotional engagement, uniqueness, and contemplation. It is very important of all the details for the experience authenticity since they contribute to creating a stage for a place's story to be told (Rickly-Boyd and Metro-Roland, 2010).

The experience becomes part of the past when it is lived, and consumers can seek to obtain material traces sometimes, which enables the memory of what they have experienced to be activated (Wallendorf and Arnould, 1988).

### 3.3.3 Experience and emotion

The emotional component is another essential part of the experience in experiential marketing (Carù and Cova, 2003; Verhoef et al., 2009). Emotions are an indispensable part of life (Khalid and Helander, 2006). Zeppel and Muloin (2008) refer that the emotional aspect is one of the fundamental responses of visitors to a marine wildlife experience. Emotion plays a key role in dual-processing thinking, cognition and information processing theories (Epstein, 1994). As a result, it can influence how customers interact with products and feelings, actions and perceptions (Khalid and Helander, 2006). Khalid and Helander (2006: 198) also noted, "an explicit requirement of emotional design is that it should be theoretically driven and empirically grounded, with valid and reliable measures of pleasure". This has to do with what consumers can see and use, and the other is about the environment, which "depends on the people and how feelings and sensations be shared by producers and consumers of the experience" (de Andrade Matos and de Azevedo Barbosa, 2018: 66). Krippendorff (2005) argues that humans respond to the cultural and individual meanings of objects instead of the physical properties, such as the form, structure and function. Khalid and Helander (2006) added that culture is linked not only to the visible aspects of a certain group but to a broader range of intangible factors, such as thoughts, values and behaviours. They also suggested that there are cultural differences in emotions, depending on people's traditions, needs, upbringing and expeditions (Khalid and Helander, 2006). This means when creating authentic experiences, personalised service should be provided to consumers coming from different cultural backgrounds to stimulate emotional response to the greatest extent.

Evidence proven by Anderson and Shimizu (2007) states that if memory episodes are linked to strong emotions at the time of its occurrence, long-term vivid memories may be therefore formed. Research about wildlife experience by Ballantyne, Packer and Sutherland (2011) concludes that visitors have longer memories about the dangers faced by the wildlife than the factual information about it; some visitors expressed a sense of empathy and an emotional connection with the wildlife, including understanding and recognising the feelings of the wildlife and leading them to care for its well-being. Normative pleasure is associated with social values, including caring for the environment and moral judgments, and these make people feel better about themselves when they act on other people's expectations and own beliefs (Khalid and Helander, 2006).

Gupta and Vajic (2000) believe that a service experience occurs when a customer interacts with different components in the context provided by the organiser to a certain extent, thus generating a learning sensation (Moore, 2014). Participants may be particularly receptive to information that has a continued and influential effect on their life (Ballantyne and Packer, 2011). These experiences can well "influence, encourage and support" consumers' environmental awareness and environmentally responsible behaviours (Ballantyne and Packer, 2011: 202). Thus, ocean plastic educational experience activities have the potential to create social norms and symbolic attributes that will be comprehended and shared by people (Solomon, 1983) in their everyday life. However, Ballantyne and Packer (2011) believe that it is unrealistic to expect the entire experience cycle to be completed during the participation only. Participants need time to process their experiences "cognitively and affectively, to develop new concepts, ideas and identities and to actively experiment with these in their everyday lives" (Ballantyne and Packer, 2011: 208). Ideally, participants should be supported and encouraged after the experience to continue the cycle in daily life (Ballantyne and Packer, 2011). They add that experience and post-experience resources (i.e., newsletter) can play a synergistic role together, the former attracting consumers' attention to the environmental problems and offering them reasons to concern, and the latter encouraging them to take action through offering strategies and reminder prompts (Ballantyne and Packer, 2011).

Discussing the experience with other people after participation is an aspect of social facilitation, with more than 90% of participants reporting they have done so (Ballantyne, Packer and Sutherland, 2011). Participants stated: *"Although I don't have a boat I remind friends that do to check that the paint that they are using on the keels is environmentally friendly",* and *"Recycling, composting – my daughter has been really big into ensuring we are not wasting and we talk a lot about what may be in the ocean that can hurt all the sea creatures."* (Ballantyne, Packer and Sutherland, 2011:

776) Kals, Schumacher and Montada (1999: 182) stated, “the sharing of experiences with significant others may function as an amplifier of the impact of stays in nature”.

This chapter investigated the role of environmental education in awareness raising and behaviour changing. Children and young people are more likely to adopt environmental behaviours. Therefore, incorporating ocean plastic education in teaching environments plays a significant role in raising and enhancing awareness. This approach will be practiced in Chapter 8. As discussed in the chapter, environmental education about ocean plastic should not be limited to traditional educational environment but should be open to all possible sectors. The author identified experience-related environment and its resulting tokens are an ideal tool for promoting environmental awareness and behaviours as the special emotional connection built during the experience may lead to consumers’ environmentally sustainable action. This chapter therefore discussed and analysed the role of authentic experiences of environmental education in awareness raising and behaviour change. Based on the arguments discussed in this chapter, different public engagement experiences are designed and conducted to answer the research questions in this study and will be discussed in Chapters 8 and 9.

***Author’s reflection***

*This is a chapter that includes research with different focuses, such as education and experiential marketing, which seems random and unrelated, but I see the connection between these areas and behaviour intervention. When I first researched environmental education, I reflected on my entire education and social journey and realised that most of my sustainable environmental knowledge was acquired outside of the education system. There is a need for environmental education on sustainability issues wherever possible, within and outside of the education system. Tourism and experiential marking are also the places where information and knowledge exchange takes place, making it a perfect sector for environmental behaviour intervention.*

*I appreciate being able to travel, see and learn new things. Sharing past holiday stories with people is always a rewarding process, and souvenirs make the intangible experience tangible when telling stories. I think it is the same with most people. When* *souvenirs are associated with ocean plastics, they serve as a great conversation starter and educational tool to spread the message and raise awareness.*

*Both the literature and the reality tell me that awareness raising is not challenging because people tend to believe the new information, but behaviour intervention and real behaviour change are difficult as it is a long process to intervene, monitor and evaluate. However, there is an increasing number of people who are aware of environmental issues and taking action towards them, proving the effectiveness of environmental education. People acquire this type of knowledge and information via different sources, such as news and social media, which also verifies the necessity of the implementation of environmental education wherever possible. It is challenging to assess people's behaviour responses, but it does not mean that the action is not taken. Combining the literature and reality, I believe that it is more important to engage the public in environmental issues than worrying about the testing the effectiveness of the intervention as it is still a success to influence one person to take action toward a more sustainable world. In addition, the more we research and engage the public, the more valuable data we receive to reflect on and learn.*

# Chapter 4. Plastic Processing Technologies

As the research is practice-based, after gaining the comprehension of ocean plastic pollution, laboratory experiments and designs will be conducted to explore the possibilities and potential of recycling ocean plastics. Before the hands-on experiments begin, it is crucial to understand plastic as a material and the processing methods. This chapter will first investigate the differences between different types of plastics. Plastic recycling methods including both traditional and emerging plastic processing technologies will then be analysed.

## 4.1 Differences between plastics

In order to work with plastic, it is essential to understand the material first. Plastic is made up of long chains of molecules, called polymers, that are formed by connecting "the same repeated building elements (monomers)" (Plastic Garbage Project, n.d.). Thermoplastic and thermosets are the two major plastic categories, and the differences between them affect the processing and recovery routes (Goodship, 2007). Thermoplastics account for about 80% of the total plastic consumption (Dewil, Everaert and Baeyens, 2006). The characteristics of these plastics are that they melt and flow when heated and solidify when cooled, and this heating and cooling process can be repeated multiple times (Goodship, 2007), providing plastic products with repeatable recycling opportunities. Thermosetting plastics, on the other hand, can no longer be melted (heated) once formed without permanent chemical degradation (Behseta, 2013). In the 1980s, Plastics Industry Association (n.d.) introduced a plastic coding system, called Resin Identification Code (see Table 1), to distinguish plastic types and aid recycling. Different plastic types have different qualities and properties, such as melting points, so they should be recycled separately.

When a plastic sample does not contain a code due to various reasons, the Differential Scanning Calorimeter (DSC[11]; see section 6.2) is often used to detect the type of plastic. The principle of this process is to determine the type of plastic being tested by comparing the line diagram generated by changing the temperature with the existing line diagram of known plastics in the database.

[11] Differential scanning calorimetry (DSC) is a thermoanalytical technique in which the difference in the amount of heat required to increase the temperature of a sample and reference is measured as a function of temperature. Both the sample and reference are maintained at nearly the same temperature throughout the experiment.

All types of ocean plastic samples in this experiment, PE, PP, PS and PET, are thermoplastics.

**Table 1**

Resin Identification Code[12]

| SYMBOL | ABBREVIATION | POLYMER NAME | MELTING POINT RANGE (°C) | USES |
|---|---|---|---|---|
|   | PET/PETE | polyethylene terephthalate | 260-280 | Water bottles, soft and fizzy drink bottles, pots, tubs, oven ready trays, jam jars |
|   | HDPE | high-density polyethylene | 210-270 | Chemical drums, jerricans, carboys, toys, picnic ware, household and kitchenware, cable insulation, carrier bags, food wrapping material. |
|   | PVC | polyvinyl chloride | 160-210 | Window frames, drainage pipe, water service pipe, medical devices, blood storage bags, cable and wire insulation, resilient flooring, roofing membranes, stationery, automotive interiors and seat coverings, fashion and footwear, packaging, cling film, credit cards, synthetic leather and other coated fabrics. |
|   | LDPE | low density polyethylene | 180-240 | Squeeze bottles, toys, carrier bags, high frequency insulation, chemical tank linings, heavy duty sacks, general packaging, gas and water pipes. |
|   | PP | polypropylene | 200-280 | Buckets, crates, toys, medical components, washing machine drums, bottle caps, and battery cases. |

[12] https://www.bpf.co.uk/sustainability/plastics_recycling.aspx
https://www.qualitylogoproducts.com/promo-university/different-types-of-plastic.htm
https://plasticranger.com/melting-point-of-plastics/

| | | | | |
|---|---|---|---|---|
|  | PS | polystyrene | 170-280 | Toys and novelties, rigid packaging, refrigerator trays and boxes, cosmetic packs and costume jewellery. |
|  | Other | Miscellaneous Plastics (polycarbonate, polyctide, acrylic, acrylonitrile butadiene, styrene, fiberglass, and nylon) | 160-390 | Plastic CDs and DVDs, baby bottles, large water bottles with multiple-gallon capacity, medical storage containers, eyeglasses, exterior lighting fixtures |

## 4.2 Plastic waste treatment

There are four main categories of plastic solid waste (PSW) treatment and recycling processes (Mastellone, 1999), and the processing methods used in this research are all mechanical recycling (known as secondary recycling; Al-Salem, Lettieri and Baeyens, 2009), which is the process of recovering PSW to re-use in manufacturing plastic products via mechanical methods (Mastellone, 1999). Material Economics (2018) estimates that mechanical recycling of plastic generates around 1.4 tonnes CO2/tonne plastics, which is believed to be less than 30% of the 5.1 tonnes CO2/tonne plastics emitted from manufacturing new plastic. Many of everyday products, such as grocery bags, window and door profiles, shutters and blinds, come from mechanical recycling processes (Al-Salem, Lettieri and Baeyens, 2009). Before being reclaimed, collected plastics are first decontaminated and then usually reduced to a more suitable and desirable size and shape, such as flakes and pellets, depending on the shape, sources and usability (Goodship, 2007; Al-Salem, Lettieri and Baeyens, 2009). The plastics then undergo heating and heat transfer, and deformation in all of these processes (Goodship, 2007) and are further treated differently in the machines as needed. The mechanical recycling process can be simplified into three stages: melting, forming and solidification (Al-Salem, Lettieri and Baeyens, 2009).

This section is written based on reviewing the literature, conversation with laboratory and workshop technicians who are experienced and knowledgeable in these fields and the researcher's own experience and practice.

## 4.3 Conventional processing methods

*Compression moulding*

Compression moulding is one of the most common methods in mechanical recycling. This method is commonly used to produce plastic products such as handles and panels (Swift and Booker, 2013). Many designers and makers choose this method because it is the most efficient and simple approach to recycle thermoplastics waste while achieving aesthetic goals. The method is very straightforward that can be mastered after a simple induction. A measured amount of plastic material is placed into a heated mould, which is then closed under pressure, forcing the plastic into all areas in the cavity as it melts (Swift and Booker, 2013). Then it is followed by cooling and solidifying. Advantages of using the compression moulding method include good surface detail in the final product and minimal mould maintenance (Swift and Booker, 2013). However, Swift and Booker (2013) argue that air entrapments are possible to occur during the process, which means that the finished product's strength may be unsatisfactory. Besides, this process can only manufacture simple-shaped products such as plates and open containers for the possibility of demoulding.

*Extrusion*

Plastic waste granules are fed from a hopper (Swift and Booker, 2013), melted and extruded through single or twin screws (Al-Salem, Lettieri and Baeyens, 2009). Then the melt is forced through a die and cooled upon leaving the mould (Swift and Booker, 2013). Extrusion is often used to mix the polymer with other additives, which is called compounding (Goodship, 2007). Material utilisation is good with low finishing costs (Swift and Booker, 2013). Different techniques including extrusion moulding, blow moulding and inflation moulding can be used in extrusion processes to produce different products (Al-Salem, Lettieri and Baeyens, 2009).

*Injection moulding*

Heated plastic is injected into a mould and solidifies to form the desired product (Al-Salem, Lettieri and Baeyens, 2009). Injection moulding can produce more complex products and quickly mass produce (Goodship, 2007). Mostly thermoplastics are used for injection moulding, and material utilisation is good with low finishing costs (Swift and Booker, 2013).

## 4.4 Emerging processing methods

*Laser technology*

Because of the high cost of mould manufacturing and the low complexity of the compression moulding shapes, laser cutting technology steps in and solves the problems to varying degrees. Design can be done on the design software and sent to the machine. A specific driver comes with the cutter to convert the design into the format that the machine can read. The laser is directed to the surface and moved around to cut or engrave material into the desired shape (Choudhury and Shirley, 2010).

Compared with conventional cutting methods, advantages including fewer leftovers of materials, high production, flexibility, easier cutting of customised parts and the possibility of cutting complex geometries lead to a significant increase in the use of laser technology in recent years (Stepanov et al., 2015). Moreover, laser technology uses a non-contact method when performing on the material. Hence, the wear and tear caused by conventional cutting methods are not present, thus preventing damages and deformation of the end product and offering a more delicate finish, which has brought a revolution to the manufacturing industry (Choudhury and Shirley, 2010).

A laser cutter is capable of performing on a variety of materials and widely used in a great number of industries, especially in design. According to Stepanov et al. (2015), art, design, and prototyping are areas where laser technology can be exploited to its full advantage. Laser cutting is more advantageous in a variety of products that require a small batch of cutting because it can change the production from products to products by only changing the geometry without changing the cutting tool (Stepanov et al., 2015). The beam's power and intensity can be easily controlled and changed to cut different thicknesses (Choudhury and Shirley, 2010; Stepanov et al., 2015). Laser technology previously was only accessible to designers and other professionals due to the complexity of using design software; and the industry now has made it more accessible. For instance, Sketch It, Make It (SIMI) is a modelling tool designed to allows non-professionals to design projects for fabrication with laser cutters (Johnson et al., 2012). The application of laser cutting in an educational project conducted by Jones, Tyrer and Zanker (2013) demonstrates that laser technology as an educational tool can impact school students to understand relevant knowledge.

*CNC milling*

CNC[13] milling is another widely used technology in many areas of production. High-density foam and wood are the main materials used in the Digital Design Workshop at Edinburgh Napier University. An image can be encoded on a computer-aided manufacturing (CAM) software, such as Vectric Aspire, into a GCODE file, which drives a CNC to drill and cut, reproducing the image pattern on the material.

[13] A computer numerical control (CNC) router is a computer-controlled cutting machine which typically mounts a hand-held router as a spindle which is used for cutting various materials, such as wood, composites, aluminium, steel, plastics, glass, and foams.

*3D printing*

Rayna and Striukova (2016) argue that even though many products have been digitised today, the goods that are essential in their physical expression (i.e., a spoon) cannot be utterly intangible. The emergence of 3D printing technology is the best example of digitisation and manufacturing cooperation. 3D printers allow people to make things that would otherwise be too time-consuming or difficult (Johnson et al., 2012). The advantages of 3D printing include the ability to manufacture custom products economically in limited production runs and the speed and ease of designing and modifying products (Berman, 2012). Just like the spoon mentioned earlier, in the past, consumers could only choose the styles in stores or online, whereas 3D printing enables them to create and make their own spoons. It also allows objects to be scanned, processed into files, then shared and printed worldwide (Anastasiadoua and Vettese, 2019).

There is a growing consensus about 3D printing being one of the next leading technological revolutions (Rayna and Striukova, 2016). Kietzmann, Pitt and Berthon (2015) predict that 3D printing will become a regular part of everyday life, just like laser and inkjet printers. Most manufacturing processes have been "subtractive", in which materials are removed from the substance to manufacture the product (Kietzmann, Pitt and Berthon, 2015). According to Wagner (2010), up to 96% of raw materials can be removed by subtractive technology during products production. On the contrary, 3D printing uses additive manufacturing to create a product layer by layer through a series of cross-sectional slices (Berman, 2012; Rayna and Striukova, 2016). Additive manufacturing in 3D printing can be interpreted as a computer-controlled hot glue gun filled with polymer (or other materials) filament, using a precisely calculated and measured combination of essential elements formulated together, adding the molten filament to each previous layer (Brown, 2012). 3D printing produces little waste compared to subtractive technologies because there is no milling or sanding (Berman, 2012). Moreover, even if the printing fails, up to 98% of the waste material can be recycled (Petrovic et al., 2011). Therefore, the failed parts do not cost much money or time anymore but become "a creative part of experimentation and research development" (Kietzmann, Pitt, and Berthon, 2015: 212). Besides, 3D printing has the potential to make a great contribution to addressing today's growing pollution problems by reducing the ecological footprint of current manufacturing systems and bringing printing objects closer to the point of consumption, thereby reducing transportation and unnecessary packaging (Kietzmann, Pitt, and Berthon, 2015).

As an increasingly accessible technology for individuals and SMEs (small and medium-size enterprise), 3D printing offers many unique “print-on-demand” or “print-as-a-service” opportunities for localised product manufacturing (Hunt and Charter, 2016). Rayna and Striukova (2016: 217) identified four significant benefits of 3D printing: “rapid prototyping, rapid tooling, direct manufacturing and home fabrication”. It allows small quantities of customised objects to be produced at a relatively low cost compared to the expensive moulds required by moulding processes (Berman, 2012). “3D printing has been compared to disruptive technologies such as digital books and music downloads, that enable consumers to order their choices online” and enable businesses to operate with little or no inventory of unsold finished goods (Berman, 2012: 155). CEO of 3D Systems Inc., a 3D printer maker, described this technology, “All you have to do is load a file, and you can replicate shapes that are not manufacturable through traditional methods… I call it a flexible factory in a box” (Alpern, 2010).

Another reason for the growing use of 3D printing is the materials it uses. PLA is the most commonly used material for 3D printing, and today, there are a variety of PLA options available on the market. Users can print wood, metallic, rainbow, flexible, even colour changing effects to meet their needs. PLA is a type of compostable, biodegradable eco-polymer that is based on renewable sources, including agricultural (corn cultivation), biological (fermentation), and chemical (polymerisation) science and technology (Jamshidian et al., 2010). One of the advantages of PLA production compared to other hydrocarbon-based polymers is reducing CO2 emission, which is considered the most significant contributor to global climate change and warming (Jamshidian et al., 2010). It is suggested that the CO2 consumed from cradle to factory is greater than its emission to the environment because corn absorbs more CO2 out of the air as it grows (Bogaert and Coszach 2000; Jamshidian et al., 2010). In addition to PLA, other materials are becoming increasingly widely used in 3D printing, such as acrylonitrile butadiene styrene (ABS), acrylonitrile-styrene-acrylate (ASA), high impact polystyrene (HIPS) and polyethylene terephthalate glycol (PETG). Because different materials have different characteristics, users can choose them based on their need.

Hunt and Charter (2016) agree that the ubiquity of plastic waste today provides potentially attractive business opportunities; where there is a steady and sustained stream of plastic waste, there is an excellent opportunity to convert the previously discarded waste into valuable products using 3D printing technology. Waste plastic can be broken down into small granules and fed into an extruder to form recycled filament for 3D printing (Peels, 2014). However, contaminants in the filament, including foreign substances and polymers with different melting points, can cause blockage and damage to 3D printers (Hunt and Charter, 2016). Plastic waste from the ocean, in particular, may pose challenges to obtain clean and high-quality results due to potential degradation and contamination from algae, salt and adsorption/absorption of chemical pollutants (Hunt and Charter, 2016).

This chapter is the cornerstone of the experimental aspect of the research. It discussed different types of plastic and both traditional and emerging processing methods that will be employed in later experiments. As the author approaches the ocean plastic problem from a designer-research perspective, the recycling methods in this research is a combination with making/crafting and engineering rather than material science alone. The experiments will be discussed in chapter 6.

***Author's reflection***

*Being completely new to polymer and plastic experiments, the literature on plastic processing methods and conversations with the technician ensured that the experimentation aspect of this research went smoothly and precisely. My engineering background and experiences of experiments in chemistry and physics made it much easier to understand the processes that are not related to design at all.*

# Chapter 5. Methodology

Based on the research questions and objectives stated in Chapter 1, this chapter will discuss the methodological choices adopted throughout the research. As a practice-based transdisciplinary study, the research design adopts a mixed-method approach, and the primary research stems from reviewing the literature. Although this study consists of two research directions: laboratory experiments and social investigations, these two are inseparable and interconnected in the timeline and research process in this study. This study uses science and design to explore the qualities and properties of ocean plastic, with the results shared through public engagement activities to raise awareness of the research and the wider issue of ocean plastic waste. The process of relating the researcher's experiences with those of others and developing that relationship into a more systematic form of enquiry (Behseta, 2013) guides the research methodology. This research adopts a mix of quantitative and qualitative design research approaches that do not only rely solely on collecting, calibrating or analysing and evaluating numerical data (Behseta, 2013) but also on insights gained from interacting and exchanging knowledge with the public. The methodology map that summarises the methodological choices and explains the relationship between research methods is presented at the end of the chapter (Figures 3a & 3b).

This research has been severely affected by the ongoing Covid-19 pandemic, so the methodological choices are not exactly the same as those proposed at the beginning of the research but have instead been adapted in response to the pandemic in line with continually developing research conditions. The literature reviews of Chapters 2, 3 and 4 are the theoretical research of this thesis, which assists in forming experimental and social investigation methods and is cross-referenced with the primary research in the Findings and Discussion of Chapter 9. The practical components of this research first take place in sequence and then intersect to be conducted simultaneously. Specifically, field trips and material collection were carried out first to prepare for subsequent practice, and the first half of the laboratory experiments took place after. The second half of the experiments were conducted simultaneously with the social survey as the results of each method inspired one another. Case studies and interviews play a novel and multi-functional role in this research, rather than in the traditional sense, which is explained in detail in section 5.4.

## 5.1 Research philosophy and approach

As mentioned in the introduction chapter, this research is transdisciplinary and aims to integrate material science and engineering, art and design, and social investigation to answer research questions and achieve research objectives. It involves systematic scientific material experiments and art and design skills to discover the possibilities of ocean plastics, as well as engaging the public to address the environmental issue together, making this study both objective and subjective. In this study, these disciplines sometimes work independently and sometimes interwind together, forming a complex research philosophy.

Positivism focuses on the scientific testing of hypotheses and finding logical or mathematical proofs from statistical analyses as well as producing precise and objective data (Collis and Hussey, 2014), while interpretivism or constructivism is concerned with exploring the complexities of social phenomena through achieving an empathic understanding of how the research subjects view the world (Bryman and Bell, 2011; Saunders, Lewis and Thornhill, 2012). This research is underpinned by the combination of both research philosophies – pragmatism, as one alone does not cover the nature of this study. Pragmatism claims to "bridge the gap between the scientific method and structuralist orientation of older approaches and the naturalistic methods and freewheeling orientation of newer approaches" (Creswell and Clark; Creswell, cited in Kaushik and Walsh, 2019: 255). Rather than believing in extreme objectivity or subjectivity, pragmatists argue that the process of acquiring knowledge is a continuum rather than two opposing and mutually exclusive poles of objectivity and subjectivity (Goles and Hirschheim 2000). Pragmatism is based on the proposition that the researcher should employ the philosophical and/or methodological approach that best fits the particular research question being inquired (Tashakkori and Teddlie, 1998), as the focus is on the results of the research and the research questions (Kaushik and Walsh, 2019).

For this study, various research methods can be used to investigate the research questions and achieve the research objectives, but the research adopts research strategies that can achieve the desired research outcome under the circumstances at that time. Morgan (2007) argues that in pragmatism, as a research paradigm, it is the researcher who makes the choice and decides what question is important and what methodology is appropriate, and these choices are influenced by many aspects, such as the socio-political location of the researcher, his/her personal experience and belief system. At the beginning of the thesis, the author introduces his background, experiences, research interests and so forth, where this study is derived from. These aspects lead and influence the research questions and methodological choices of this study. Thus, the author's background, how she perceives the world through the combined lens of an engineer and designer, and the nature of this study determined by these aspects align with the philosophy of pragmatic research.

Pragmatism supports theory based on experience, experimentation, and action (Ormerod, 2006), which are the three focuses of this research. Therefore, in line with the pragmatism research philosophy, the research approach adopted for this study is both quantitative (deductive) and qualitative (inductive).

Goertzen (2017: 12) argues that "quantitative research focuses on data that can be measured" and allows for statistical analysis. In other words, Kaushik and Walsh, (2019) believe that quantitative methods focus on precision, generalisability, reliability, and replicability. Therefore, the inherent approaches of quantitative research and deductive analysis methods make the most appropriate approach for the material experiments and investigating the possibilities of ocean plastic recycling as the experiments follow strict guidelines and produce precise results that are reliable and can be replicated following the same procedure.

Qualitative methods are found useful in understanding the nature, quality and context of the intervention (Hausman, 2002; Bower and Rowland, 2006), which is appropriate to achieve the research objectives and questions of understanding design's role in recycling ocean plastics, public perceptions, determining psychological factors and intervening public awareness and behaviours. Research methods including interviews, making-as-research, reflective journals, case studies and workshops are ideal to answer these research questions because they can uncover "why people think, feel, or act in certain ways" (Goertzen, 2017: 12). An inductive-based approach to analysis allows for a flexible data collection process as it can take place in multiple stages rather than one and enables meaning to generate from the collected data to identify patterns, relationships (Ramsberg, 2018) and social phenomenon of the problem being investigated. Data collected in this part of the research consists of words and visual images through observation, the author's own experience and interaction with participants (Denscombe, 2014), which fits the pattern of qualitative research.

It is worth noting that although this study adopts both research approaches, the proportion of qualitative research is larger. The quantitative approach serves as a foundation for "yielding" data and conclusions that are used throughout the qualitative research process.

## 5.2 See, smell and touch – field trips and material collection

When studying an environmental problem, field trips can be fundamental for subsequent research. Lonergan and Andresen (1988) define field trips as any arena or area within a discipline where supervised learning through first-hand experience can take place outside the limits set by a four-wall classroom. Dewey (1997: 43) recognised the significant transaction arising from exposure to the environment, that is, "an experience is always what it is because of a transaction taking place between the individual and what at the time, constitute his environment." Stoddart and Adams (2004) argue that the field exposes the complexity of geographical problems, which also becomes amenable to comprehension when in the field. Fieldwork provides "a better sense of real-world environments and processes and an enhanced understanding of the subject" (Fuller, 2006: 220). Ord and Leather (2011: 19) emphasise the importance of outdoor experience, arguing that "human beings are immersed in the world and the thoughts about it are not separate and removed but products of it. The experience of the outdoors cannot be removed from the thoughts, ideas and ultimately the 'meanings' we make of it".

Previous studies related to ocean plastic lay the foundation and background for this research. However, this only helps to understand the situation as a general phenomenon but does not help to understand ocean plastic as a material. The use of field trips allows the author to see the situation first-hand so as to restore the contextual research to the "real" environment. As the study seeks to not only experiment with the ocean plastic material but also understand public perceptions and raise awareness, it is essential for the author to have a thorough understanding of the issue and its surrounding environment before engaging others. Field trips enable the author to establish a special bond with the environment and the ocean plastic material. It provides the author with extremely vivid images and unforgettable personal experiences that no amount of literature or online sources can provide. “Real-world” visits also become an emotional trigger and driving force that makes the author eager to address the ocean plastic problem because it is effective to see what is happening in the environment. The intangible experience combined with the tangible touch of plastics on the beach set the stage for further development of this research practice.

There are other ways to obtain ocean plastic material to experiment with, such as from beach clean-up groups, but the second-hand material collection would not have allowed the author to work with ocean plastics the same way she did in this study. The sample collection process can be perceived as “treasure hunting” or “ingredient seeking”, as the author holds the power to select colours, shapes and other forms of ocean plastics for the design process rather than passively receiving them from elsewhere. Seeing, smelling and touching plastic in the marine environment offers a preliminary and conducive insight into the material for the author to address this issue from a design and research perspective. Seeing how the material exists in the environment, touching the texture, and then transforming it from waste to something of value, provides a much more real and rewarding feeling and experience than purely working with the material. It enables a completed storyline of recycled ocean plastic objects from the location of material collection to where the experience takes place that can be presented when engaging the public to inspire responses. This feeling and experience is then introduced to the participants to achieve resonance and to allow participants to fully engage with the study and subject at hand.

As part of the field trip component, the author paid visits to five beaches in Scotland (Figure 1), including both touristic and remote ones, giving diversity to the research. Portobello and Milsey Bay Beach are two of the most popular beaches with tourists and residents in the Lothian area. Visits to these two places took place first due to their proximity to the author, who could witness the plastic situation in busy coastal areas and collect samples for further laboratory experiments. Sample collection provides authenticity to the following practices, and the authenticity enhances the emotional connection between participants and the activities, and the excitement and engagement level in the participatory workshop (see Chapter 8), which helps distinguish this study from a material science one, as the author takes the *experience* and *situation* aspects into consideration at every stage throughout the research to achieve the research objectives. The other three sites chosen are on the Isle of Harris, off the west coast of Scotland, where there is an enormous amount of ocean plastic. Two of them are remote beaches where neither tourists nor locals pay visits, namely Gobhaig and Rodel, while Horgabost is a popular spot. Therefore, the author is able to compare the ocean plastic problem in different regions with different visitor situations and collect samples.

The author used the observation method during field trips, and the samples collected are based on the author's colour, size and shape preferences. The collection process can be understood as an artist picking up painting supply or a designer choosing material for design creation rather than a scientific material collection. These were documented using photography and reflective journal. Samples were analysed through observation, classification and conversation with a polymer technician.

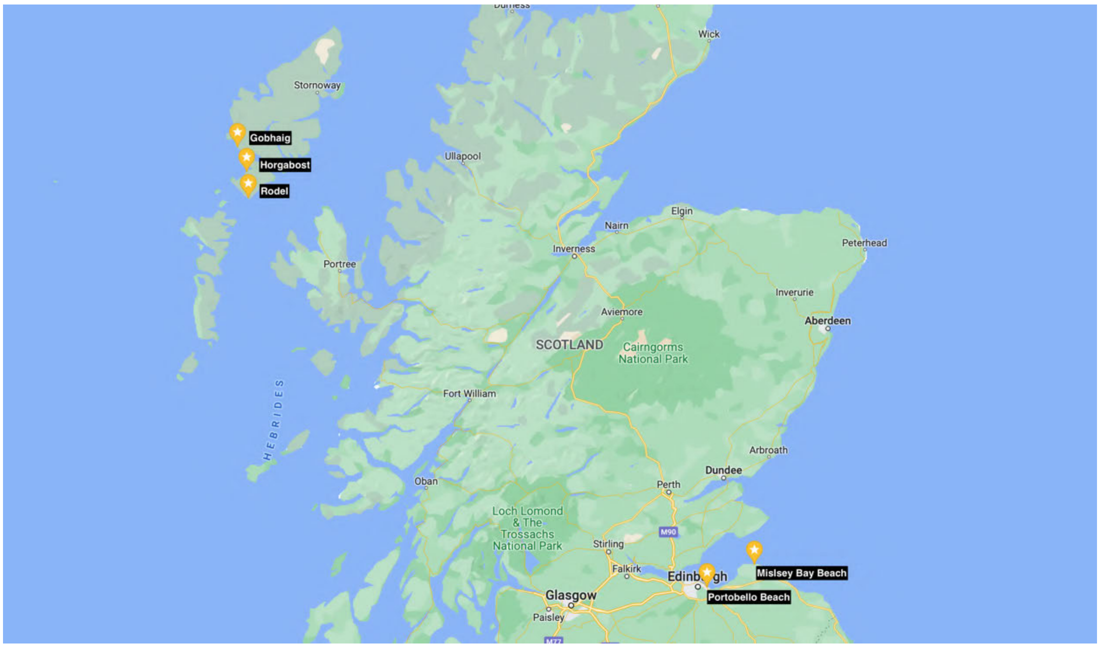


*Figure 1. Five beaches visited in Scotland, Google Map, 2019.*

## 5.3 Making-as-research

According to Candy (2006), practice-based research is a kind of original investigation for acquiring new knowledge, partly through practice and the outcome of the practice. Drucker (1990: 242) define knowledge as "information that changes something or somebody – either by becoming grounds for action or by making an individual (or an institution) capable of different and more effective action.” Therefore, in this study, the approach of repurposing ocean plastic into something else through making is the grounds for action, as well as making the researcher capable of more effective action. To generate knowledge through making, reflecting is an essential element throughout the process as Schön (1983: 7) stated, “[a]lthough reflection-in-action is an extraordinary process, it is not a rare event. Indeed, for some practitioners, it is the core of practice”. In reflective practice, reflection takes the form of transforming unconscious patterns and tacit understanding into conscious understanding through articulation (Friedman, 2000).

Johansson and Porko-Hudd (2013: 1) define making as “the process of creating something, an intentional activity” of people actively involved in developing and changing something, such as a material, into something else. Tin (2013)’s description of making precisely conforms to the purpose of this research: “It transforms matter, and it articulates meaning (p.1)”, and “Making is a form of research, in as far as it pursues a goal that is sufficiently clear to be perceived, but sufficiently unclear still to deserve to be pursued in and through making (p.3)”.

In this research, the making process came logically and naturally after field trips and the sample collection. To investigate the possibility of recycling ocean plastics, there are two approaches to conducting the research – first-hand making and reviewing secondary data. However, as stated in the introduction chapter, the research attention paid to ocean plastic recycling, especially from a designer/maker perspective was relatively low compared to regular plastic waste, leaving the research gap to be filled. Making is the leading method employed for the author to understand and explore the ocean plastic material and its possibilities, and secondary data on recycling regular plastic waste is used to fill experimentation gaps and as comparison criteria (see section 5.4 and Chapter 7). In the making process, the author is a polymer engineer, a designer, an artist and a researcher, bringing all of these identities together to give ocean plastics a new life.

The author defines ocean plastic *making* in this research as an iterative and innovative process that uses engineering experiments and material science as the foundation, with the addition of design and artistic vision, creating new knowledge about ocean plastic recycling. The definition of “successful” and “failed” results is both subjective and objective in this study compared to a completely objective scientific experiment. For instance, a complete coaster from a compression moulding could be considered unsatisfactory as the pattern did not achieve the author's expectation. On the contrary, an incomplete coaster with a corner missing could be attractive and unique. Therefore, the making process is iterative is also to meet the author's aesthetic expectations. Johansson and Porko-Hudd (2013) believe that making is an exploratory and reflective process, in the experience of materials and materiality. The *exploratory* and *reflective* process does not only occur in the laboratory and design workshop but also during public engagement activities as *making* is also informed by public's responses (Figure 3a).

The making process mainly includes laboratory experimentation (scientific) in the Polymer Lab and product design explorations (aesthetic) in the Design Workshop at Edinburgh Napier University, largely employing the methods of shredding, compression moulding, extruding and laser cutting to process the collected ocean plastic samples. 3D printing mostly took place at the author's home during the lockdown period. The author used a systematic recycling approach to classify and recover different types and colours of ocean plastic to understand their performance and properties.

The entire making process was documented in detail in a reflective journal (physical & visual; Appendix 10), comprising photographs, notes, observations and analysis. One of the advantages of journaling as a data collection tool is that it does not require oral-to-text transcriptions, saving a great deal of time and effort (Pedgley, 2007). The journal is a valuable tool to capture the "real-time" making practice (Seitamaa-Hakkarainen et al., 2013: 9; Lambert, 2019). It recorded the "raw data" generated during the experiments – due to the fact that sometimes the experiments occur very fast, and the author uses keywords and drawings instead of complete sentences which are then used to inform later phases of research. Brett (cited in Pedgley, 2007: 471) suggested, "A diary entry should glow with the immediacy of reaction (even if the diarist subsequently revises his opinion of what he has written)." The author holds the same opinion that without recording the immediate reactions in the journal, the experience cannot be fully recovered after the making process. This journal thus may be comprehensible only to the author herself, but it provides evidence for the subsequent experiments and reduces the chances of repeating useless experiments. It also helps the author reflect on past successes and undesired results to adjust the making approach. The journal can be regarded as an archive or evidence book because it is recorded chronologically, clearly shows the progress of the production process and facilitates quick access to past records. The journal then was processed and analysed, and the critical data and knowledge obtained in the experiments are summarised and discussed in Chapter 6. The real-time data collection also includes video recording, which aims to assist the author to find omissions in personal memories and the journal.

## 5.4 Using the experience of others – a combination of case studies and interviews to investigate public perceptions

*Case studies*

Case studies facilitate exploratory research to understand existing phenomena for inspiration, comparison or information as well as to study the effects of change, innovation or new programs (Martin and Hanington, 2012). It requires researchers to identify a problem, make preliminary hypotheses, conduct research through information gathering approach, such as interviews, modify hypotheses and theories, and then tell a story (Breslin and Buchanan, 2008).

The research aims to investigate the impact of public engagement in educational activities on people's awareness of ocean plastic, and the most desirable and effective way to do this is through direct contact with the public, such as through workshops. Unfortunately, due to the pandemic, the viability and effectiveness of participatory workshops were limited. As public engagement via workshops could not be carried out directly, cases studies were employed to access public perceptions indirectly and gain insights through individuals and organisations that have already had close contact with the public, and the results were used to inform public engagement research that took place at a later stage in the research process. The author seeks to study the impact of their work in order to predict the outcome of public engagement in ocean plastic activities during "the *anthropause*[14] time". Therefore, the function of case studies in this research is expanded from understanding existing cases and obtaining inspiration

[14] See section 2.6.

to also studying the effects of change, and the impact and effectiveness of public engagement. “Through the study of typical cases, the status quo of a phenomenon can be revealed and understood (Mabry, 2008: 216).”

It can be the case that workshops in Edinburgh limit the audience to mostly British and other Europeans who view the world differently through their cultural and economic lens from people from other continents, economic conditions or cultures. Case studies offer the research a bigger scope of understanding public perception on environmental issues geographically and demographically, compared to conducting workshops alone, reducing bias and improving reliability and validity. Moreover, these cases spend years engaging the public through different approaches so as to understand their perceptions and conduct behavioural interventions, providing useful insights into this study that would not have been possible through the workshop alone in the limited time of this study.

Case studies also help fill the experimentation gaps in the making process. Not all plastic processing methods can be completed within the scope of this study, due to limited equipment, time and funds. Most of the cases available so far only recycle ordinary plastic waste but cover methods that are not used in this study. Since both ocean plastics and ordinary plastics are essentially plastic materials, the author can compare the performance of ocean plastics in this study and ordinary plastics in these cases under the same processing methods to speculate on the performance of ocean plastics with the methods not used in this research, discovering more possibilities of the material.

Precious Plastic is the most representative case for this research because of its worldwide scale and influence. Not only can it provide countless inspirations for recycling plastic, but it also offers valuable experience in raising public awareness. In addition, it has formed a global community inside which many small cases are also worth analysing. Most cases studied in this research are related to Precious Plastic, covering various types of businesses and organisations in and beyond the education system, from developed and developing countries on different continents.

*Semi-structured Interviews*

Interviews are a fundamental research method for collecting first-hand experiences, attitudes and perceptions (Martin and Hanington, 2012). Moreover, according to Jain (2021: 541), interviews are considered useful in “getting a broader understanding of how and why certain things happen and what are the opinions, motivations, interests, feelings of the people involved”, and these elements are the answers the researcher seeks to explore. According to Depraz, Varela and Vermersch (2003: 2), one’s experience is the core of relational knowledge production, and “experience is always that which a singular subject is subjected to at any given time and place, that to which she has access ‘in the first person’”. Therefore, more comprehensive and authoritative knowledge can be obtained through the acquisition and analysis of experiences formed by different individuals at different times and places.

Case studies answer the question of *what happened*, interviews explain *why* and *how*. As a practice- and experience-based study, when evaluating the experience of others, it is critical to understand in more depth how the experience of investigated individuals/groups influence their practices and vice versa. Interviews also facilitate the author to query the story or logic behind certain actions related to this research topic.

As shown in Figure 3b, interviews are used for a number of purposes, including the indirect understanding of public awareness, gaining insights into public perception and engagement, confirming the importance of designers’ role in plastic recycling and identifying emotional changes in waste recycling practices.

Through case studies and analysis, suitable candidates were chosen for interviews to “access their knowledge” (Lambert, 2019: 75) and obtain further insights. Cases that are selected for interviews engage in different business, but due to the purpose of each interview being similar, a semi-structured interview is employed because of its versatility and flexibility (Kallio et al., 2016). The author can ask additional questions when an interesting or new line of inquiry arises during the semi-structured interview (Young et al., 2018), and the flexibility of asking questions enables the author to discuss in depth about the research topic (Mannan and AFNI, 2020).

*The cases investigated in this research and purposes*

- Precious Plastic - inspiration and public engagement investigation
- Precious Plastic related projects
    - Recycle Rebuild (Charity) - social investigation
    - Still Life Workshop (Design Studio) - inspiration and social investigation
    - DOBA Studio (Design Studio) - inspiration and social investigation
    - Bambú Living Sustainably (Zero-waste shop) - social investigation
    - Norwegian Trash (Design Studio) - inspiration
- Smile Plastics - inspiration
- WRAP - public engagement investigation

General problems were planned ahead for all interviewees. Interviews seek to investigate the following aspects of the interviewees:

- The relationship between their previous experiences/background and their current business and practice.
- Their goals in terms of plastic recycling and the zero-waste movement.
- How they perceive plastic and plastic waste as a material.
- Their emotional attachment to their recycled products and recycling experiences.
- Their experiences on influencing friends/families/customers' plastic-related behaviours.
- Their recommendation on intervening public awareness and behaviours.

*Interview questions – Recycle Rebuild (see Appendix 3 for questions for the other three cases).* Some of the following questions specifically about the charity were improvised during the interview rather than planned in advance.

- Can you tell me about yourself and your organisation? Apart from being the funder of Recycle Rebuild, you also work for other positions, how do these different roles benefit/ balance with Recycle Rebuild?

- What is the biggest challenge you have faced in your organisation?

- I see in your team there are different roles, but mostly designers with different specialities, what role do you think designers play in addressing waste and climate challenges?
- What the ultimate goal that you want Recycle Rebuild to achieve? How are you planning to do it?
- How do you view plastic as a material, and plastic waste? Do you think it's evil and we are in a war against it?
- You have worked with people in developing countries, have you observed a lot of change in their attitude towards plastic waste? For example, it was only rubbish before but it is precious now?
- You are from a first-world country but have worked in third-world or developing countries, what is the difference in people's perspectives about plastic waste in developing and developed countries? And why?
- What people need, based on the different situations and environments in developing countries and developing countries are different, for people in developing countries, they need more functional products like shelters. Compared to that, what do you think that recycled plastic can do to have an impact on people in developed countries?
- Based on your experience, what are the more effective and efficient approaches to involve the public in terms of awareness raising and behavioural change?
- Have you followed up on people's plastic related behaviours after they were involved in your project?
- This is not a question about your project, but what is your opinion of bringing waste plastic recycling technologies into education and tourism settings?
- Your office based in North Berwick. I know there are beach clean-up volunteers collecting rubbish on the beach regularly, have you thought about including places like this in your project?

All the above cases were reviewed and analysed in-depth, and the founders of the underlined cases were also interviewed for a period of thirty minutes to one hour each. All interviewees were selected because they have been engaged with the public about plastic recycling or zero waste at various levels in their respective fields. Their experience in influencing public awareness and behaviour regarding plastics provides valuable insights for this study, which cannot be achieved by case studies and public engagement only. The interviews were carried out online via Webex during the pandemic, and all interviews were audio/video recorded.

## 5.5 Public engagement as a research method

As stated in previous chapters, environmental education has the potential to positively influence people's awareness and behaviour, and educational activities can be carried out in many settings, such as tourism and teaching environments. The public engagement method is ideal for this study to achieve its research objectives in awareness raising. According to National Co-ordinating Centre for Public Engagement (NCCPE; n.d.):

> Public engagement describes the myriad of ways in which the activity and benefits of higher education and research can be shared with the public. Engagement is by definition a two-way process, involving interaction and listening, with the goal of generating mutual benefit.

The author chose the public engagement approach to raise public awareness of ocean plastics in this research because research activities taking place in this study including design lectures, student projects and workshops are all *two-way process*, *interactive*, with *listening* involved and *the goal of generating mutual benefit*. The engagement contributes to the public's positive perceptions and behaviours in relating to plastic consumption while providing the author with valuable research data for both this and future studies.

Purpose, people, process and evaluation are the four principles of high-quality engagement (NCCPE, n.d.). All three public engagement methods in this research have one goal, which is to raise public awareness about ocean plastic and influence their plastic-related behaviours, but through engaging different public groups, different processes and evaluation approach, maximising the impact of the engagement. Details will be discussed later in this section and Chapter 8.

Under the public engagement method, there is a sub-method, the participatory research approach that includes student projects and the workshop. Cornwall and Jewkes (1995: 1667) argue that “the key difference between participatory and conventional methodologies lies in the location of power in the research process”. These two approaches are more interactive with more power and contribution from the participants’ side compared to lectures which involve more listening as the researcher holds more “power” even though it is a two-way process and interactive.

Participatory methodologies aim to “reflect, explore and disseminate the views, concerns, feelings and experiences of research participants from their own perspectives” (French and Swain, 2004: 317). This method also involves the co-creation process. Most participatory research focuses on *knowledge for action* (Scott and Shore, 1979). People are invited to take part in the co-creation of knowledge about themselves (Reason and Heron, 1986) as well as positive behaviour intentions for the environment. Chambers (1997) identifies that participatory research ensures the problems researched are perceived as problems by the participants, and it helps to develop self-confidence, self-reliance and skills within the participants. Thus, on the basis of public engagement as defined by NCCPE, participatory is defined in this paper as participants who, as the engagement centre, spend time and energy participating in co-creating physical or research outcomes with the researcher under the guidance and interaction. The method is ideal to achieve the research objectives as it ensures the participants perceive ocean plastic as a problem and helps to develop their self-confidence, self-reliance and skills of positive plastic-related behaviours (French and Swain, 2004).

Since the 1990s, the word *workshop* has often been associated with the word *participation* (Cornwall and Jewkes, 1995; Kensing and Blomberg, 1998). A workshop is “an arrangement whereby a group of people learn, acquire new knowledge, perform creative problem-solving, or innovate in relation to a domain-specific issue” (Ørngreen and Levinsen, 2017: 71), and this definition applies to all three activities in this section, not just the festival workshop. When the *workshop* is the selected research method, the researcher chooses an "immersive and collaborative environment" in which meaning is "negotiated", so it offers an opportunity to identify new factors that the researcher and the participants may not be aware of before the workshop and their relationships with one another (Ørngreen and Levinsen, 2017: 79).

The research methods in this section would have been implemented differently if the Covid-19 pandemic had not occurred. The author had planned a variety of activities involving different stakeholders, such as university design students, tourists in Edinburgh, beach clean-up volunteers and tourism professionals. Five to ten people from mixed backgrounds would have formed one group, and five or more groups should be created to increase the diversity and reliability of the result. The activities would have taken place in the university's classrooms for the participants to access the tools and equipment. In the beginning, the participants would have been required to talk about their experience or knowledge of ocean plastic and then listen to a short lecture about ocean plastic and the author's research. The presentations would vary depending on the previous discussion. They would also be provided with 3D printing pens, 3D printers, jewellery-making kits, tools, recycled ocean plastic filaments and premade recycled ocean plastic objects. They would have also been given time to interact with the materials and experience the making process from recycled ocean plastic and then interviewed with a few questions about the experience and perception change. To further comprehend the actual change in behaviour, participants would have been asked to be interviewed again in a few months voluntarily and discuss any actions/changes they witnessed in that period time. These activities were designed to take place throughout 2020 but got cancelled.

In May 2020, a follow-up field trip was also planned and booked to allow the author to return to the Isle of Harris, from where most of the samples used in the experimental research were collected, for follow-up research. The original plan was that several postgraduate design students would come along and participated in an activity similar to the proposed ones above. The activity would have also invited locals interested in recycling and those who attended the public lectures organised by Dr Katharina Vones and Dr Ian Lambert (see next paragraph) in 2019. These activities and trips did not take place because of the pandemic restrictions at the time; instead, they will become the author's future research focus.

The methodology was informed by a participatory project in which the author was involved in March 2019. The project was led by researchers Dr Katharina Vones and Dr Ian Lambert, with the assistance of the author. The team visited two secondary schools in Scotland and delivered two workshops to students (13-15 years old) in groups of eight to ten, introducing the idea that ocean plastic washed ashore locally could be repurposed to make something new (Vones and Lambert, 2019). In the later public lectures, local people contributed knowledge and insights about the ocean plastic problem, with many using personal evidence to blame the marine industry, particularly fish farms (Vones and Lambert, 2019). Drawing on this as inspiration, and after changing plans in response to the pandemic, the author carried out seven participatory activities, including five design lectures, a design project within the university setting and a festival workshop in a public setting.

Lectures delivered to design students and staff enable the author to comprehend the audience's perceptions and emotions about ocean plastics, discover design's role in recycling ocean plastics and potentially intervene in their awareness and behaviours. Moreover, the student design projects seek to explore these aspects in more depth, because this method lasts longer and allows the researcher more time and space to observe and analyse the participants and their responses. Since both take place at the university where the author works, they have added the advantage of allowing the author to observe and have conversations with participants after the participation to analyse its impact and effectiveness. The use of these two research methods echoes one of the research objectives, which is to implement environmental education within the education system to intervene in plastic-related behaviours. The workshop at the festival targets outside the education system, with participants from all walks of life and a wider age range. As seen in Figure 3b, this method is designed to directly act on all the research objectives.

All of the participants involved were locals, students studying in Edinburgh, or people visiting Edinburgh. Previous research has shown that the participation of residents in research increases effectiveness and is vital for the sustainability and appropriateness of interventions (Cornwall and Jewkes, 1995).

*Timeline for workshops*

- November 2019 - Edinburgh Napier University, Bdes Design students, Design Lecture
- November 2019 - Edinburgh Napier University, Bdes Design students, Design Lecture
- September 2020 - Edinburgh Napier University, Bdes Design students, Design Lecture
- February and March 2021 - Edinburgh Napier University, Bdes Design students, Student design project “A World without New Plastic”
- March 2021 - Edinburgh Napier University, Bdes Design students, Design Lecture
- March 2021 - College for Creative Studies (USA), BA and MA Design students and staff, Design Lecture
- August 2021 - Edinburgh Climate Festival 2021, Participatory Workshop

Some of the participants had the opportunity to interact with the recycled objects produced in Chapter 6 so that they could see, touch and understand the potential of ocean plastic. However, half of the workshops took place online due to the pandemic, so participants could only view photographs and videos of the making. To encourage engagement, interactive presentation software and social media platforms were used together with visual aids. The observation was carried out to capture participants’ reactions and behaviours. Photographs were taken to document participants’ “making” results. Discussions with the participants took place during and at the end of the workshops. Participants of the last workshop were asked to fill out a post-participation questionnaire about the impact of the participation after they left the site to increase the veracity of their responses.

## 5.6 The scientific method as an ongoing process

The scientific method (Figure 2) is a holistic approach that runs throughout the entire research. It is a summary of all the methodological aspects of this thesis, rather than an approach specific to a particular chapter or practice. At the most basic level, the scientific method is a simple, three-step process, including observing, proposing an explanation and testing the explanation (Carey, 2004). However, it is more complex than that in practice because when practised correctly, the method is an “ongoing, iterative, self-correcting process” (Garland Jr, 2016:11). The scientific method is based on the concept that "every idea about the workings of nature has consequences and that these consequences provide a basis for testing the idea in question" (Carey, 2004: viii). The scientific method is similar to the "practice as research" method as it is also an iterative process of "doing-reflecting-reading-articulating-doing" (Nelson, 2013: 32). However, the author believes that the "making process" of this research conforms to the "practice as research" method, but the overall study is more in line with the principle of the scientific method.

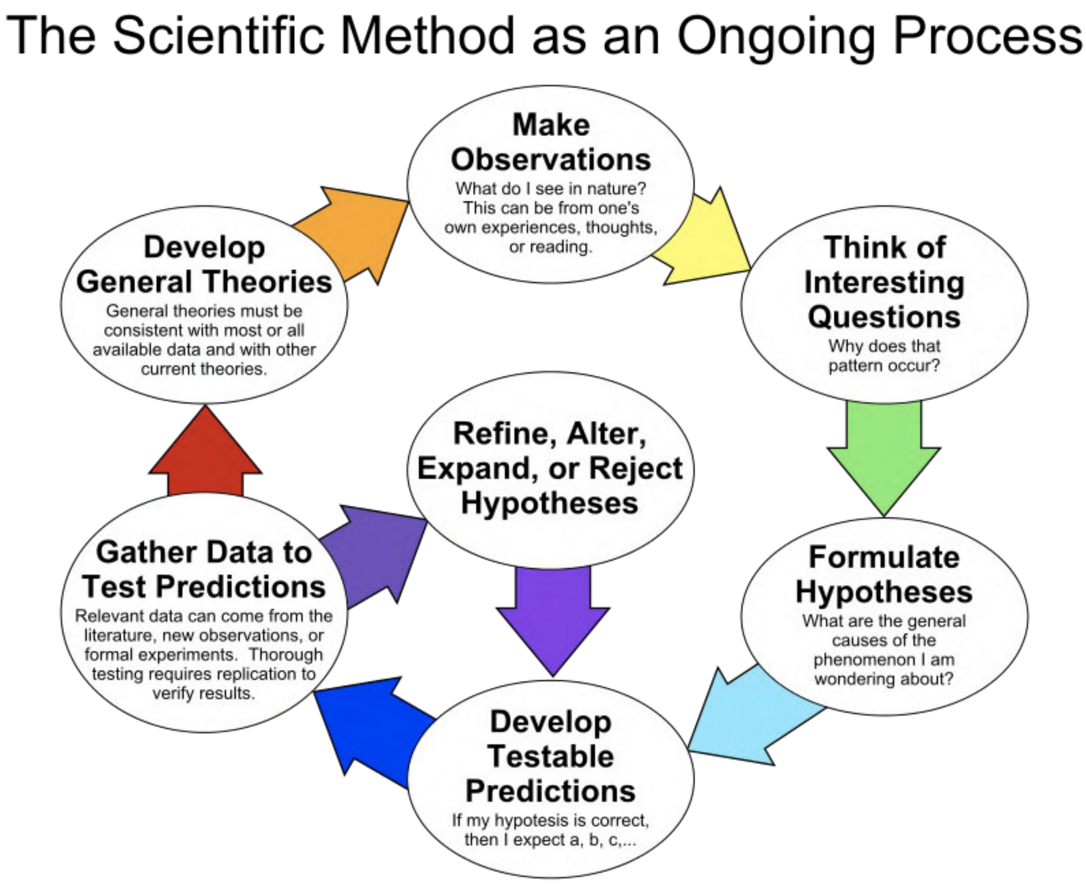


*Figure 2. The scientific method as an ongoing process, Garland, 2016.*

The following is the process of how the author employs the scientific method in this research.

1. *Make observations* consists of field trips, documentary watching and literature reviews. The author uses experiences and literature to answer the question: "What do I see in nature?"
2. *Think of Interesting Questions*

a. What are the possibilities of integrating a designer's vision and subjectivity into ocean plastic recycling?
b. After personal interaction with recycled ocean plastics, will there be a difference in public perceptions?
c. What psychological factors can influence behavioural intentions?

3. *Formulate Hypotheses*

   a. Ocean plastic can be recycled in a variety of relatively simple ways that are not necessarily limited to scientists or engineers. Designer can make ocean plastic recycling more "attractive" and acceptable by the public.

   b. Environmental education activities can raise public awareness about ocean plastic to varying degrees.

   c. Recycled ocean plastic objects will have a positive impact/response from the public. Some emotions can be triggered to lead to action taken.

4. *Develop Testable Predictions*

   If the hypotheses are correct, then the following are expected.

   a. Methods such as compression moulding, extruding can be used to recycle ocean plastic.

   b. Ocean plastic can be 3D printed, but significant adjustments and alterations may be needed due to contamination.

   c. Environmental education activities on ocean plastic are effective in raising/enhancing public awareness and can potentially lead to behaviour change.

   d. Designers' perspectives on recycling ocean plastics are beneficial in many ways.

   e. Different people react to emotion triggers differently, but at a similar level mostly.

5. *Gather Data to Test Predictions*

   Methods used to gather data

   a. Experiments

   b. Case studies and interviews

   c. Public engagement

6. *Refine, Alter, Expand, or Reject*

   The process of refinement, alteration, expansion or rejection not only exists in each research method individually but also runs through multiple research methods as a whole. “The cycle of predict, test, refine can repeat many times, even indefinitely (Garland Jr, 2016:11).” For example, replicated experiments are carried out to verify the validation of a result in the making process. Meanwhile, experiments are also refined, altered and expanded based on the results of the social investigation, such as lectures, and then the refined experimental results are tested in the new social events. It can be summed up that each research method reflects on its own results, but they also reflect on each other, generating new knowledge and general theories in the process. It is a reflective iteration process of steps 4, 5 and 6 until step 7 is reached.

7. *Develop General Theories*

   The developed general theories will be discussed in the Conclusion of Chapter 10.

## 5.7 Ethical Considerations

All research was designed in line with the Code of Practice on Research Integrity and passed the University’s ethics review processes. All participants remain anonymous during their involvement unless consent was given. All of these activities are completely safe for people of any age. Student representatives have given written consent on behalf of their classes for the data generated during the design lectures at Edinburgh Napier University to be used in the author’s publication. Participants at College for Creative Studies have given video recorded verbal informed consent at the beginning of the design lecture for any insights from the participation to be used. All the students from the design project at Edinburgh Napier University have given written informed consent. The final workshop at the Edinburgh Climate Festival took place during the Covid-19 pandemic, and strict precautions and measures were taken in accordance with the requirements of the Scottish government and the festival. All adult participants have given informed consent through Microsoft Forms, and all children were given consent by their parents in the same way. All faces in the photographs are blurred or cut out. Interviewees have given video recorded verbal consent for any verbal insights from the interviews to be used.

## 5.8 Methodological issues and limitations

There are limitations in the methodological choices of this research to some extent. The limitations of different aspects of this research are listed below.

*Experimentation*

Most of the experiments were carried out in the Polymer Laboratory and Design Workshop at Edinburgh Napier University, with a small number taking place at the author's home. The equipment, tools and moulds available in both settings were limited, and there were few opportunities to purchase new ones due to lack of funds and space, reducing the diversity of possibilities for recycling ocean plastic. This research, though, has experimented with four types of plastics in the marine environment, making it the most extensive study to date. However, due to inconvenient transportation and limited working space, there are still many types that have not been collected to test. Another reason is that the sample collection took place in the early stage of the research, and the author did not have sufficient understanding of plastics. Therefore, possible bias might occur in the collection process as the author might be attracted by the interesting shapes and colours without considering the diversity of plastic types. The subsequent sample collection opportunity was cancelled due to the pandemic, so the researcher was unable to obtain more materials. Moreover, due to the limited time and material access, the experiment could only be carried out on ocean plastics but not compare their performance with those of domestic or commercial plastic wastes. Therefore, the study could only draw a conclusion on the recycling possibilities of ocean plastics, but not how they were different.

*Public engagement*

The sample size and sample profile were severely affected by the Covid-19 pandemic. This limitation was already discussed in Section 5.5 of this Chapter and Chapters 1, 8 and 9. In forming insights that resonated with the author's emerging perspectives, the outcomes of most workshops were subject to a degree of bias (Lambert, 2019). People tend to say "yes" to positive behaviour change when they participate in studies, but it is hard for the researcher to verify the actual action. In addition, those attracted to the workshop might have already been aware of or had taken action against ocean plastics, resulting in positive results that favoured the researcher's expectations. However, all participants were anonymous, which reduced bias to a great extent. This was evidenced by the different or opposite “voices” from the author in the participation results.

Limitations also come from the selection of participants. Most of the participants were current or former university design students from Scotland, which limited the diversity of the results as they were likely to think from their own cultural or academic backgrounds. However, the final workshop was more inclusive, with participants from different places, ages and backgrounds. The level of participation and data collection was also affected by the fact that half of the workshops took place online. Due to venue limitations, participants did not fully experience the entire ocean plastic recycling process. The authentic feeling of the experience might increase if they had an immersive opportunity in the recycling process, and this might increase the likelihood of action taken after participation. The study identified and implemented different approaches to engaging the public to raise awareness of ocean plastics, but there are limitations to assessing their effectiveness due to the uncertainty of research arrangements caused by the pandemic and the time constraints it caused.

This chapter articulated the methodological aspects of this thesis. Due to the pandemic, the research methodologies were adjusted significantly to fit the real situation and what was possible amid ongoing restrictions. Due to the closure of the university and restrictions during the lockdown, experiments at the Polymer Laboratory and Design Workshop were suspended for about a year, and the second field trip to the Isle of Harris and most of the offline participatory workshops were cancelled. The research faced more challenges and overcame more hurdles than usual. The author found alternative research methods that best fit the circumstances to complete the research and gained valuable research outcome but also identified limitations that could be addressed in future studies. The findings of this thesis are significant because they filled the gap in the existing literature, found innovative ways to recycle ocean plastic and built bridges between ocean plastic and the public, as well as engineering and design. The research methods discussed in this chapter will be elaborated in subsequent chapters and discussed in detail in Chapter 9.

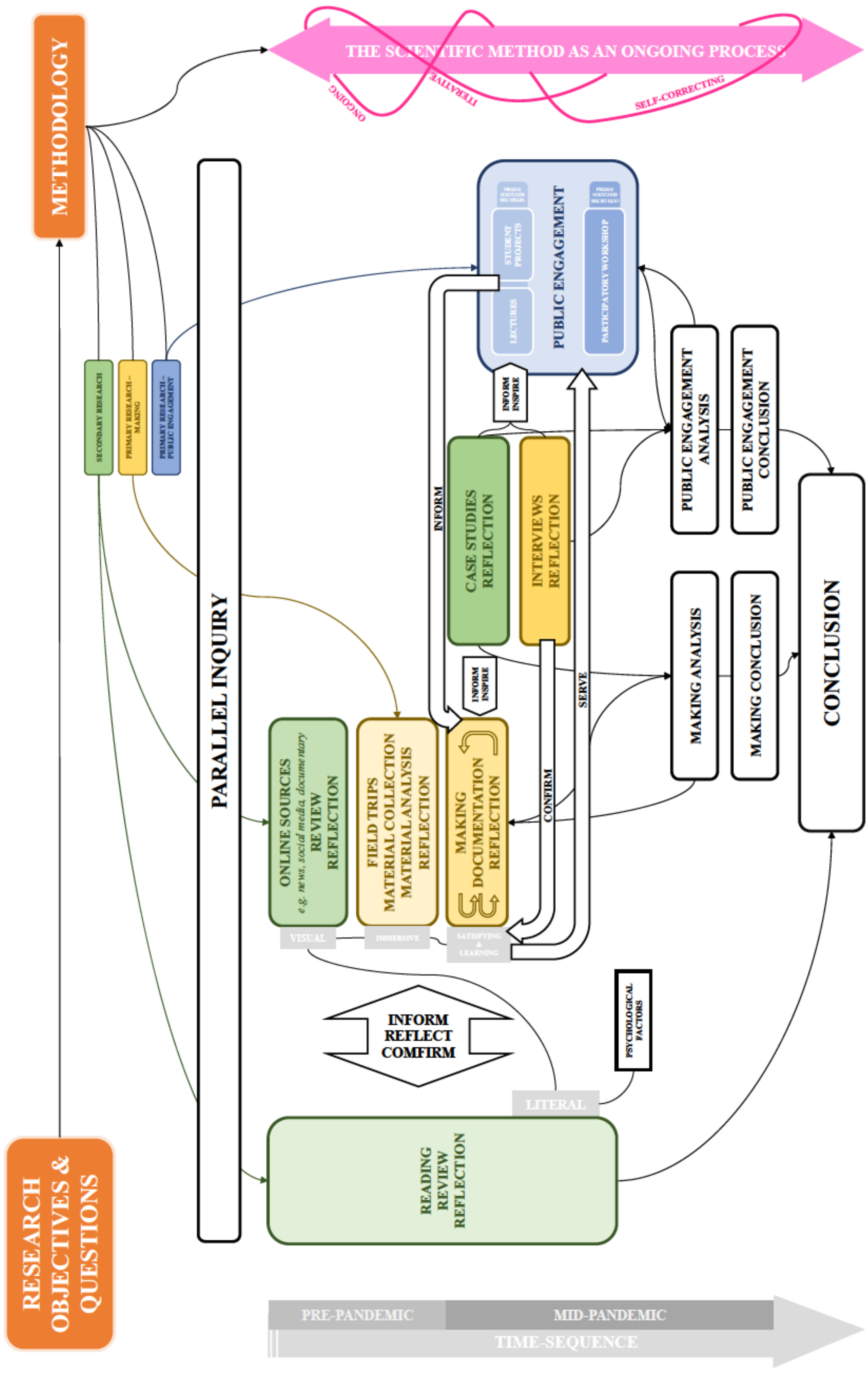


*Figure 3a. Methodology map, Tao, 2022.*

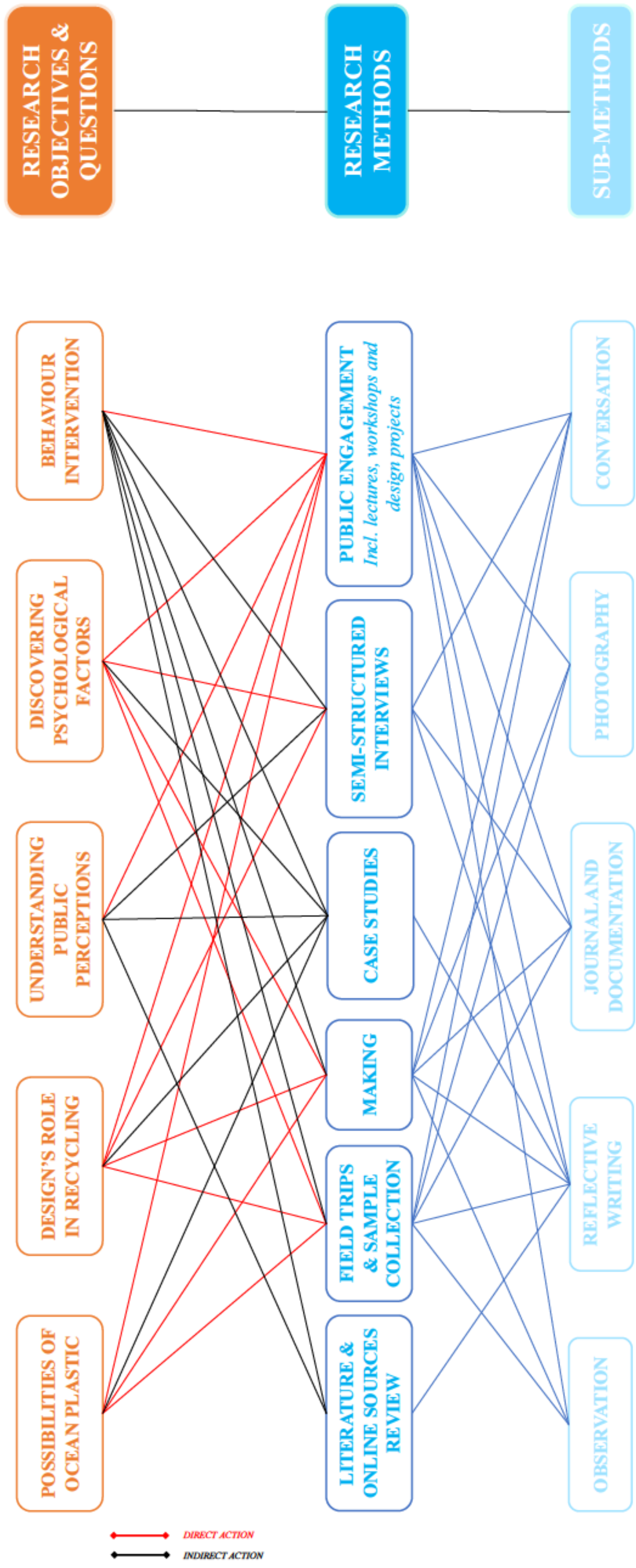


*Figure 3b. Methodology map, Tao, 2022.*

## Chapter 6. The Journey with Ocean Plastic – the making processes

The chapter will discuss the author's experiments and experiences with ocean plastic. The strategy adopted in this research is in line with Design *from* Recycling[15] (Ragaert et al., 2020: 2), including

> a thorough characterisation of the recycled polymer, adapted product (and mould) design to the recycled polymer's properties and identifying acceptable (cost-effective) strategies for the upgrading of the material quality (to product requirements) where necessary.

"A thorough characterisation" was carried out by processing the samples with various methods discussed in Chapter 4 and analysing the performance to summarise the characteristics. Products corresponding to "adapted product (and mould) design" will be proposed throughout this chapter, and more summative applications will be discussed in Chapter 9.

### 6.1 Field trips and sample collection

The researcher paid visits to five beaches in Scotland at the beginning of the study, including Portobello beach and Milsey Bay Beach in Lothian area in the winter of 2018 and the Isle of Harris off the west coast of Scotland in the spring of 2019, with the aim of having the first contact with ocean plastic and collecting samples for experiments. The "first contact" with ocean plastic may sound inaccurate, as the author had encountered plastic waste in the marine environment before starting the research, but here it refers to the contact for the first time with a research and investigating purpose, rather than in an ordinary leisure situation.

Prior to the beach visit, the author watched the documentary *Drowning in Plastic* (Drowning in Plastic, 2018) while reviewing the literature, which was the first time the author "saw" the dynamic state of plastic in the ocean rather than the static data and images in the literature and online, and realised how severe the situation was. The

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[15] "Design *for* recycling is a well know strategy in which new products are developed so that they can be recycled at their end-of-life. Design *from* Recycling is an altogether different approach, even though the two do not exclude one another. In Design *from* Recycling, the secondary raw material originating from the recycled polymer (r-polymer) waste of a previous product's end-of-life is starting point of new product development. … Design *from* Recycling involves identifying the r-polymer's strengths and weaknesses through extensive characterisation, as well as identifying acceptable strategies for possible upgrading of the material quality where necessary. During the stage of product design, these characteristics are taken into account and matches are found between (new) products and r-polymers suitable for producing them" (Ragaert, 2016: 163).

author first visited the Portobello beach in Edinburgh to investigate the situation of ocean plastic there. The walk took an hour, including along the beach and the estuary. Even on a chilly November afternoon in Scotland, the beach was busy. The amount of plastic seen during the visit was surprisingly small compared to the size of the crowds, not at all like the beaches looking like landfills in *Drowning in Plastic*. Little to no plastic waste was found on the beach near the water, while more was found near the road, mostly single-use packaging and cutlery. However, the bin by the beach was too full to hold any rubbish, filled with disposable coffee cups, takeaway packaging and cutlery (Figure 4). There was also rubbish lying around the bins on the ground. The rubbish was at high risk of being blown into the sea because of Scotland's often windy weather. In addition, more plastic waste was found in the estuary (Figure 5) than on the beach, and if it was not removed promptly, it would find its way into the ocean. Milsey Bay beach was not as busy as Portobello beach, but cleaner, and the author only found a single piece of plastic packaging during the one-hour walk (Figure 6). One of the reasons that both beaches were relatively clean is that local organisations and individuals organise regular voluntary beach clean-ups[16].


*Figure 4. A bin on Portobello beach, Tao, 2018.*

[16] Self-led beach cleans https://www.seabird.org/events/beach-clean-fridays

*Figure 5. Plastic in the estuary near Portobello beach, Tao, 2018.*

*Figure 6. Plastic waste found on Milsey Bay beach, Tao, 2018.*

The researcher visited three beaches during the other trip, and two of them were strewn with plastic waste, namely Rodel and Gobhaig, while Horgabost was clean and only a single piece of plastic was found under the sand (Figures 7 - 9). The scenes in *Drowning in Plastic* were actually displayed in front of the author – it was real and tangible. The researcher recorded her first impression in her reflective journal,

> *"I couldn't believe my eyes. I couldn't believe what I was seeing. I know I saw it on the internet and TV, but I just couldn't believe this was happening in reality. But IT IS REAL!!! When I stood on the plastics and saw them with my own eyes, the emotion kicked in harder. We have to do something."*

*Figure 7. Plastic waste on Rodel beach, Tao, 2019.*

*Figure 8. Plastic waste on Gobhaig beach, Tao, 2019.*

*Figure 9. Plastic waste found on Horgabost beach, Tao, 2019.*

The area around the two "plastic beaches" are surprisingly sparsely populated and rarely visited; and on the contrary, Horgabost, the clean beach is more popular. There is a campsite[17] in Horgabost that has a 4.5-star reviews on Google, with most comments describing it as an exceptional, beautiful white sand beach. It is not a rare situation – remote beaches in the oceanic current's pathway, such as these on the west coast of Scotland, become repositories for ocean plastic (Barnes and Milner, 2005; Vones et al., 2018). The enormous amount of waste has continuously been washed up and accumulated on the beach. Even if these beaches were cleaned up, millions of pieces of plastics were washed ashore the next second. Besides, how to properly deal with the collected plastic waste on a remote island is a challenge. Residents repurpose some collected ocean plastics to use at home or sell at Homemade Harris Craft market.

The following features of ocean plastics were observed during the beach visits:

- *They are from all over the world*. Even though most of the samples could not be identified the origins, various languages and country names were found on the surfaces, such as England, Spain (Espana) and Denmark (Figure 10).
- *They are colourful*.
- *They have rough surfaces*. The surfaces of these samples had some scratches and discolouration. Scratches are embedded with dirt and sand. Marine organisms even grew on some pieces (Figure 11).
- *They all smell like the ocean*.
- *They are mostly fragmented, with a few complete and recognisable* (Figure 12).
- *They do not have a plastic recycling code in most cases*, so it is impossible to determine the type of plastic without a laboratory examination.
- *They vary in size, from microplastics smaller than 5mm to large pieces measured in metres.*

[17] Horgabost Campsite https://goo.gl/maps/teGdBtdX7wPKjSSP9


*Figure 10. Ocean plastic with country names, Tao, 2019.*


*Figure 11. Ocean plastic with rough surfaces, Tao, 2019.*

*Figure 12. Fragmented plastics on the beach, Tao, 2019.*

In addition, the researcher observed that some plastics had sunk beneath the sand, and that some pieces had become so entrenched in the sand that it is almost impossible to remove without extensive labour and effort. Anecdotal evidence, based on conversations with residents, suggests that much of the plastic come from local fish farms and other maritime industries.

Plastic samples were taken during the beach visits, mainly from Gobhaig and Rodel where vast numbers of plastics were observed, and a small number were collected at three other beaches. Objects collected include barrels, bottles, toys, shotgun shells, a basket lid, a buoy, an ice cube mould and some unknown pieces. Figure 13 listed some of the sample collected (more in Appendix 1). The samples are predominantly blue, black and yellow, with a few red, orange, green and white ones. In terms of size, the smallest item (bottle caps) collected was around 3cm, while the largest was approximately 50cm. There were smaller and bigger pieces on the beaches that were not collected.

*Figure 13. Some of the samples collected from beach visits, Tao, 2019.*

## 6.2 Sample detection

Many plastics lose their “identity” (the recycling code) after “travelling” in the marine environment. It is necessary to understand what the material is and how it behaves before recycling (Goodship, 2007). This process was to determine the types of plastic samples to understand their properties and characteristics. It took place in the Polymer Laboratory at Edinburgh Napier University. A small piece of each sample was cut out, numbered and organised in preparation for differential scanning. Beverage bottles did not need differential scanning since there was the code 01 (PET) on the bottom; the lids were HDPE or PP (codes were marked inside). Same as the blue ice cube mould, the code 02 (HDPE) was marked on it with other information.

Samples were then cut into a micro size (approximately 2mm) and detected using DSC 7 (Differential Scanning Calorimeter; Figure 14). As mentioned in section 4.1, the principle of this process is to determine the type of plastic being tested by comparing the line diagram generated by changing the temperature with the existing line diagram of known plastics in the database. For instance, the buoy sample’s line graph matched that of polystyrene, so the buoy was made of polystyrene. The detection identified polyethylene (PE), polypropylene (PP), polystyrene (PS) and polyethylene terephthalate (PET) as the plastic types of the samples (Figure 15). PE included high-density polyethylene (HDPE), low-density polyethylene (LDPE) and other PE. Most of the samples had precise results; however, the line diagrams of a couple of samples fell between HDPE and LDPE. The results might have been affected by contaminants, or the samples were already made from recycled PE. The number of PE samples were the largest, with HDPE more than LDPE. Most rigid samples with unknown history or large size were PE. Many of the brightly coloured samples were made of PP. Only the orange buoy and the white foam were made of PS.

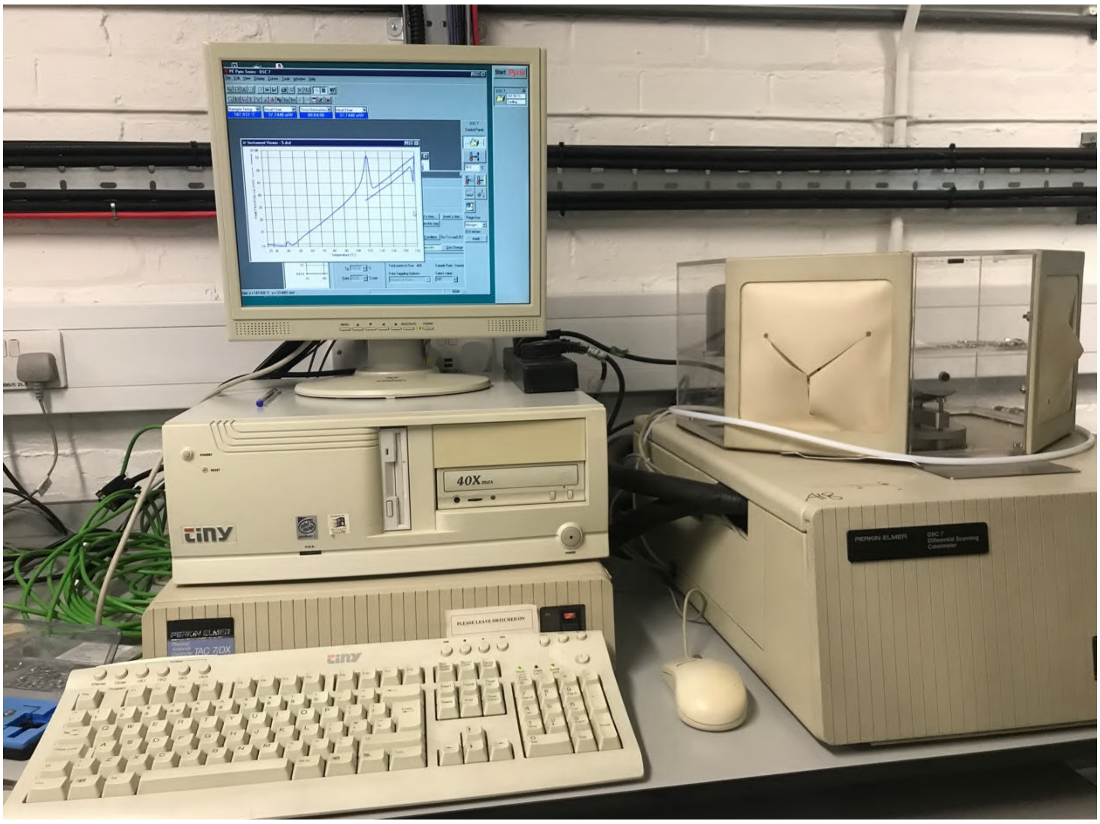


*Figure 14. Differential Scanning Calorimeter 7, Tao, 2019*

*Figure 15. List of samples and types, Tao, 2019.*

## 6.3 Sample pre-treatment

Pre-experimenting processes included decontamination, sorting and size-reduction (optional).

1. Decontamination

As mentioned above, dirt, sand and marine organisms are often attached to ocean plastic. Cleaning is the fundamental step of the whole process – it determines the quality of following experiments and results. Samples were immersed in water with washing-up liquid, and then decontaminated with a brush. Most of the contaminants (paper, dirt and other forms of impurities) were brushed off the samples, but marine organisms growing on some samples (Figure 11) and sand/dirt embedded deeply in scratches could not be entirely removed. Unwanted labelling was also removed. The cleaned samples were left to dry naturally afterwards.

2. Sorting

When recycling mixed thermoplastics, they do not bond well to each other due to the polymers' chemical composition, so individual families of thermoplastics need to be separated for reprocessing (Goodship, 2007). Sorting in this experiment, therefore, is the step of separating different plastic samples according to the detection result, and then putting the same type together in preparation for further processing. The separation by type was followed by colour classification. For example, black PE samples were separated from yellow PE.

3. Size reduction

Sawing and shredding are the two methods that were used in the size reduction process. From the perspective of processing temperature, energy and time consumption, whether raw or recycled, the smaller the size, the more convenient and efficient it is to process the plastic. Size reduction often provides more possibilities when the samples are cut into pieces. They are easier to process, and there would be more colour options for the finished products because different samples (same type) can be processed together. However, sometimes from a creative point of view, size reduction can be omitted if the original sample shape is used to achieve a more aesthetic result, so it is not necessary for every experiment.

- Sawing:

The samples were sawn into small cubes in the Design Workshop at Edinburgh Napier University using a hand saw and a stand machine saw.

The buoy is the most critical sample in this study as it represents ocean plastics – they are abundant, used directly in the marine environment and difficult to be reused by locals. It was challenging to repurpose it directly due to the size and spheroidal shape unless it was cut into small pieces. The buoy was designed seamless and difficult to be fixed on a worktop for sawing. It was so strong that it was unscathed even if thrown to the ground with great force. Eventually, it was drilled a hole and sawn through. Unlike the faded and scratched outer surface, the inner surface was shiny, smooth and untouched (Figure 16). During sawing, the heat generated by the friction melted the samples on both sides of the blade, creating an interesting "by-product" (Figure 17). Sawing is also the step before shredding, because to shred solid, rigid plastics, the objects put into the shredder must be in small pieces (Figure 18).

*Figure 16. The buoy, Tao, 2019.*

*Figure 17. The "by-product" from sawing the buoy, Tao, 2019.*

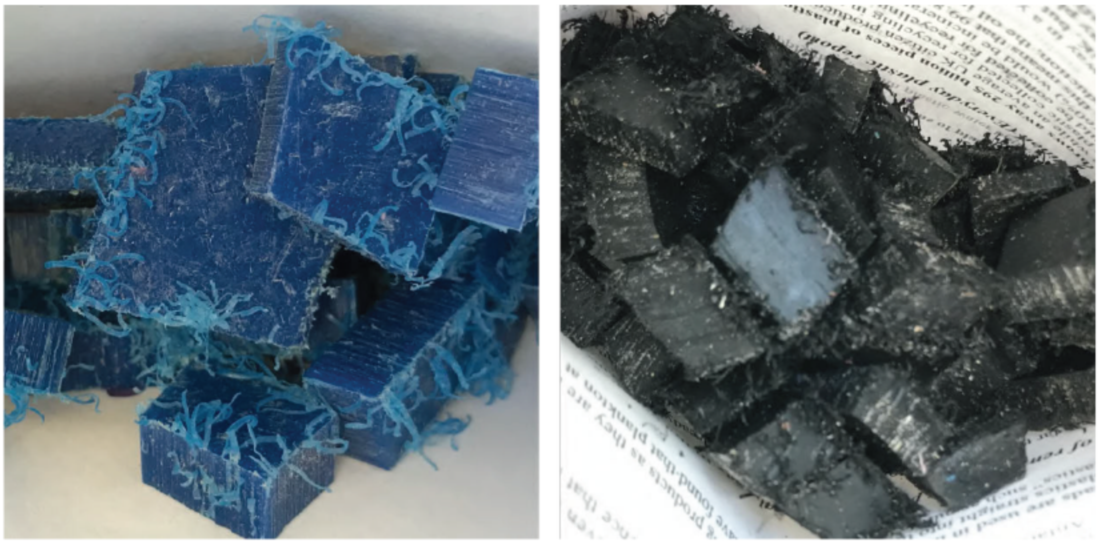


*Figure 18. Sawn samples, Tao, 2019.*

- Shredding:

Shredding is the step of breaking down the sawn samples into small granules or flakes. Due to limited experimental machinery, only one shredder was available and used in this process, leading to new contamination – the previous granules left in the shredder were mixed into the next samples. For example, a few blue PE granules were mixed into shredded red PP samples (Figure 19). Relatively large and prominent contaminants can be removed manually, but residual contaminants were unavoidable under this experimental condition. Samples made of thin layers of plastic, such as bottles and barrels, were easier to shred, but they generated static electricity and were more likely to stick to the inside of the shredder. As a result, they were more probable to contaminate the results of the next shredding. The granules were sieved to remove the dust and other small contaminants entered during the process. The “smell of the ocean” of most samples was more pungent after shredding, especially sample No. 20, the buoy, which appeared to have a distinct fishy smell. It may be explained that the ocean odour permeated the samples, and there were more surfaces to give off the smell when they are granulated.

*Figure 19. Shredded samples with contaminants, Tao, 2019.*

Shredded plastic is preferable for further processing, but not essential. Most of the subsequent experiments were done with shredded plastic samples, but a small number were processed directly from sawn or original samples to explore the effect of different shapes on the appearance of recycled products.

## 6.4 Compression moulding

Sawn, shredded and original samples were used for compression moulding, but sawn and original pieces took a longer time to compress because it was harder to heat through the thickness. The machine used in this step was Moore A78A Lab Press (Figure 20). Except for processing a variety of post-experimental scraps together, this experiment was designed to compress one type of plastic at a time, with the aim of making re-recycling possible. The procedure is listed below in Table 2.

**Table 2**

| **Compression moulding procedure** |
|---|
| 1. Preheat the compression machine with the plates to close to the used sample's melting point (i.e. 180°C for PP). |
| 2. Choose the right mould and place it on the heated plate with the weighed plastic samples laid evenly inside. Place the other plate on top and then put them on the heating bed inside of the machine. |
| 3. Run the machine and compress the mould. The duration depends on the thickness of the moulds and the samples – the thicker, the longer. |
| 4. Take them out and place them in the cooler. |
| 5. Take them out and demould. Remove the overflow around the edges and weigh the compressed sheet again. The data would be the sample weight required for the same material and mould in the future experiment. It was done to reduce waste (too much material) or avoid repeating experiments (not enough material). |


*Figure 20. Compression moulding machine and cooler, Tao, 2019.*

There are moulds of different sizes, thicknesses and shapes in the Polymer Laboratory. The researcher did single-colour compression first and then conducted multi-colours experiments, “designing” the pattern. All the compressed results still carry the “smell” of the ocean. The smell disappeared after some time, which may be related to the time the sample spent in the marine environment or the characteristics of the material itself. In addition to changing moulds, sheet/membrane materials can also be applied to achieve different surface textures, such as aluminium sheet (glossy surface) and baking sheet (textured surface). Some results were further processed to achieve an aesthetic effect, bringing potential for more personalised opportunities. Figures 21 - 34 list some of the compression moulding results for ocean plastics, and more results are listed in Appendix 1.

## Single colour

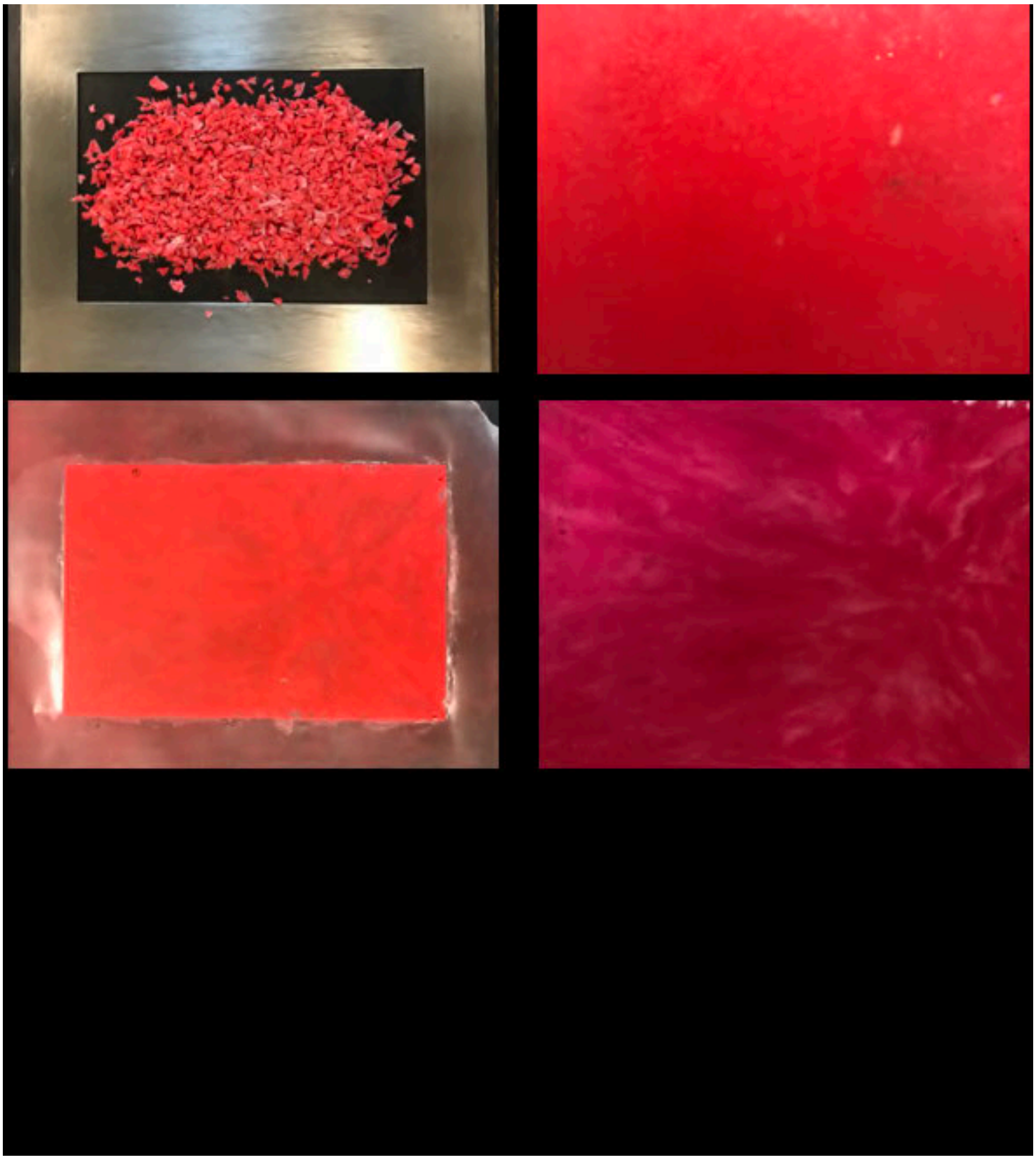


*Figure 21. Compression moulded single colour - PP, Tao, 2019.*

## Multicolour

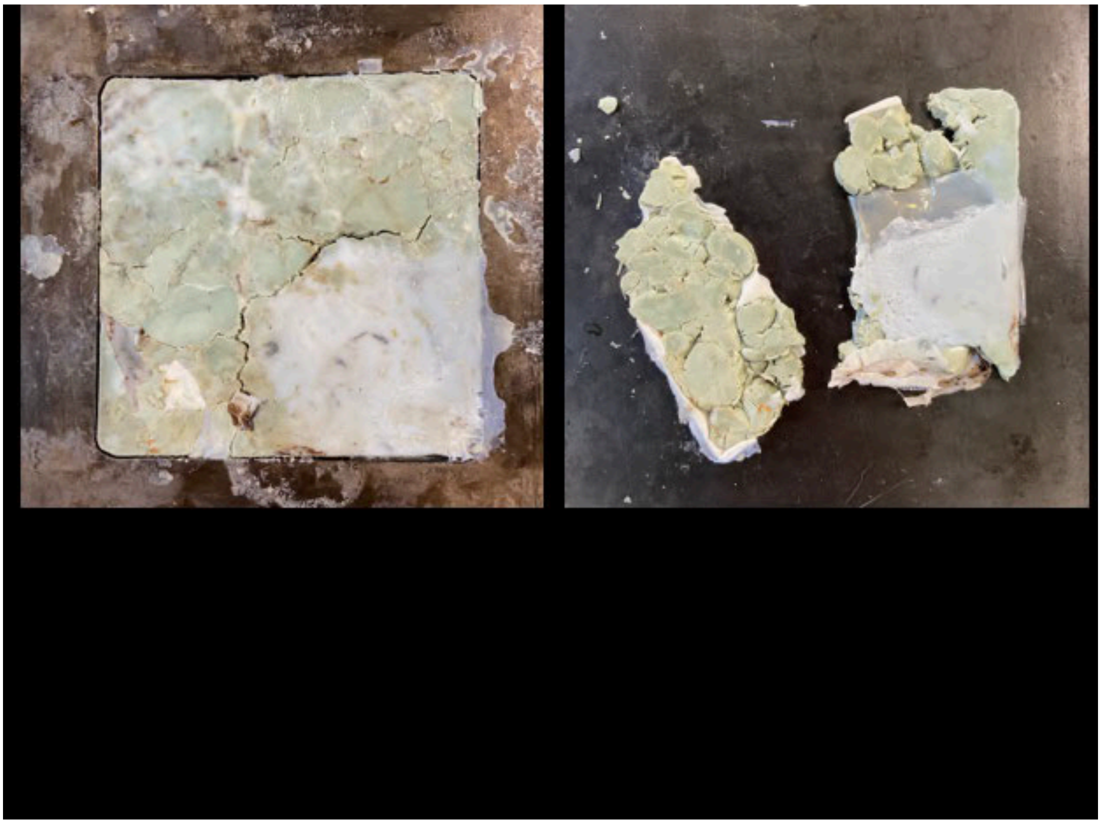


*Figure 22. Compression moulded multicolour - PET, Tao, 2019.*

## Multicolour and patterns

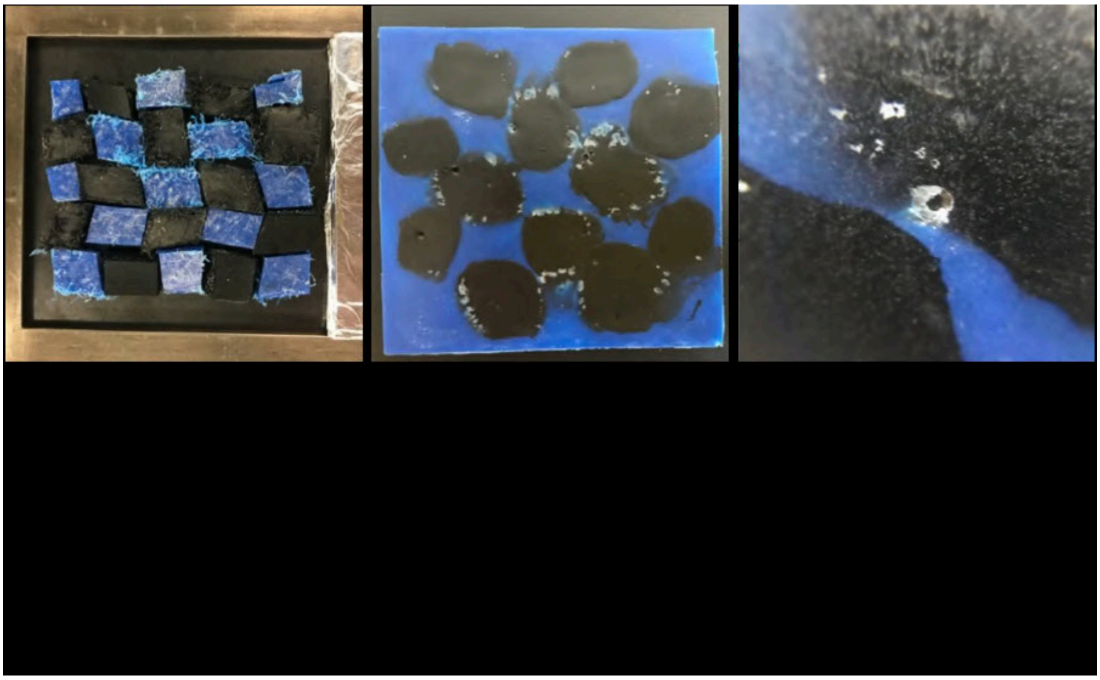
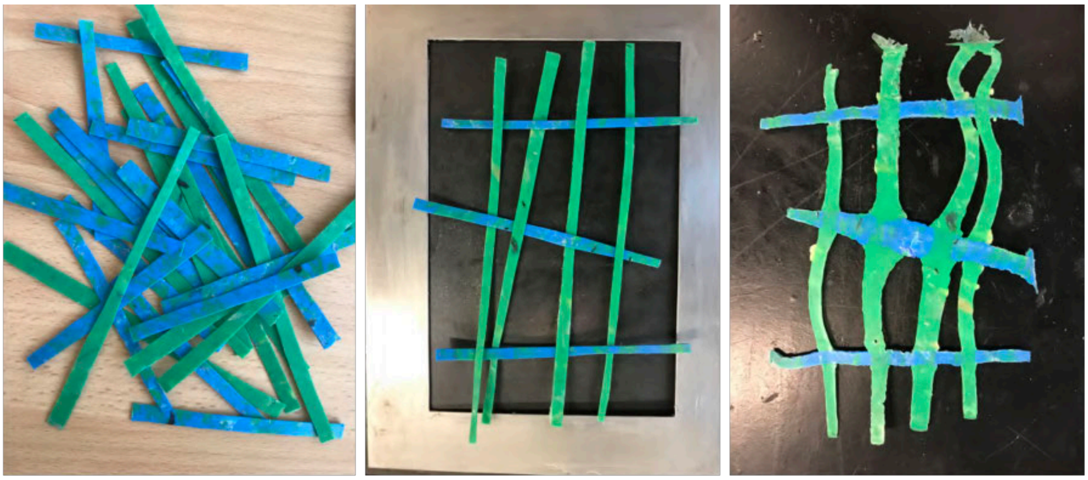


*Figure 23. Multicolour and check pattern, Tao, 2019.*

*Figure 24. Multicolour and stripe pattern, Tao, 2019.*



Pattern: Woven
Type: PE
Colour: Green and blue
Temperature (°C): 180
Method: Compressed blue and black sheets were cut to stripes, which were placed to a woven pattern and compressed.
Time (machine preheating excluded; minutes): 2 for compression, 1 for cooling
Observation: The stripes were too thick to be woven neatly. Due to the material overlap, the intersection points are bigger than the rest. The shape of the result changed in comparison to the shape before compression.

*Figure 25. Multicolour and woven pattern, Tao, 2019.*

*Figure 26. Scrap PET re-compressed, Tao, 2019.*

*Figure 27. Multicolour PE, Tao, 2019.*

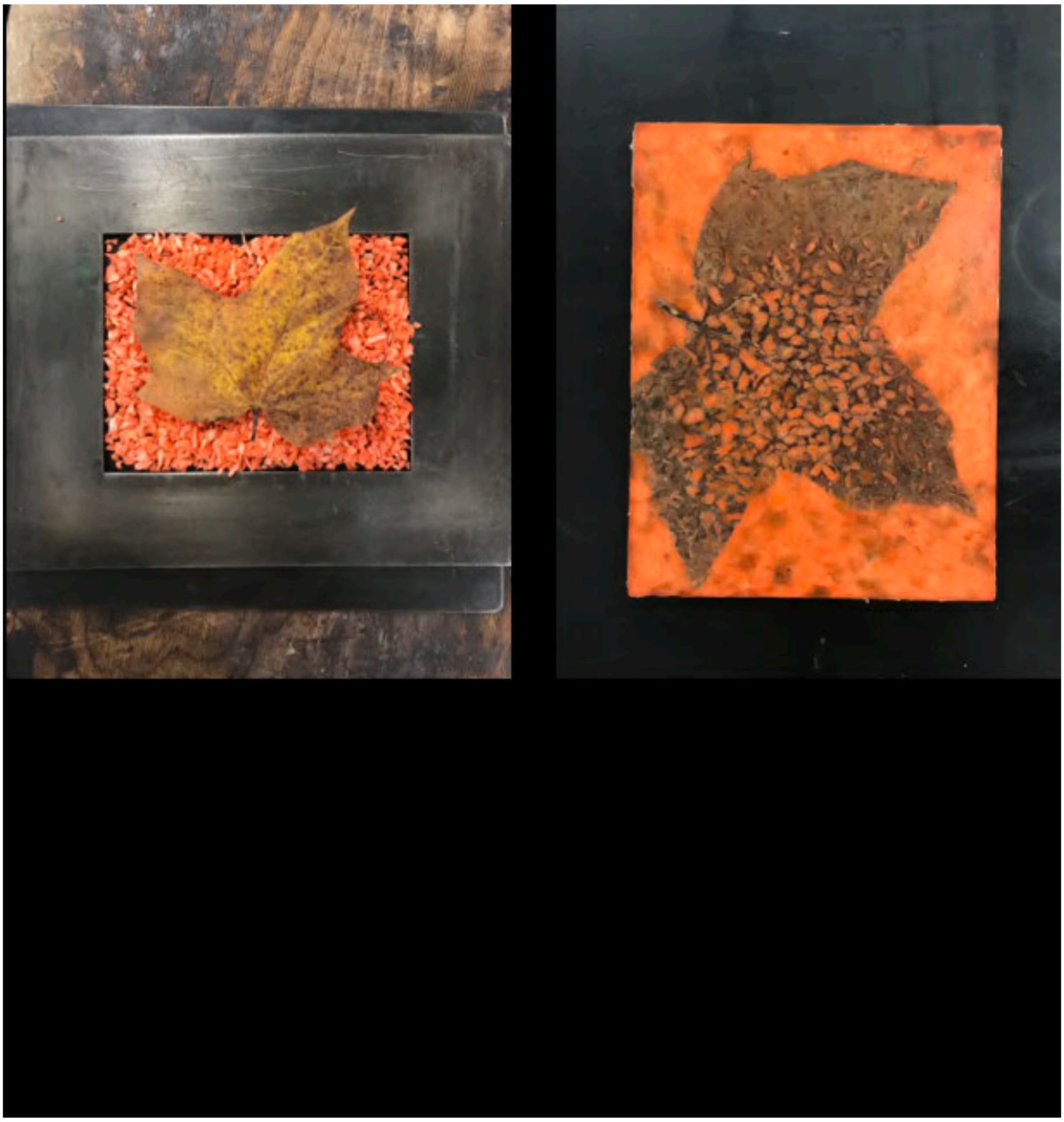


*Figure 28. Leafy pattern, Tao, 2019.*

## Textured surfaces

Pattern: Bottle caps
Type: PE
Colour: Multicoloured
Temperature (°C): 175
Size (mm): 80 x 80 x 4
Weight (g): 22.3
Method: Different colours and sizes of bottle caps were compressed together.
Time (machine preheating excluded; minutes): 10 for preheating the caps in the machine, 10 for compression, 5 for cooling
Observation: Logos and dirt on the caps are visible on the result, which make the coaster more characteristic. Colours match well with each other. Although this process took a longer time than other compressions. This method can be potentially used to lock holiday memories - the logos on the coaster can remind the tourist of the experience of collecting the caps on the specific beach.

*Figure 29. Matte bottle top coaster, Tao, 2020.*

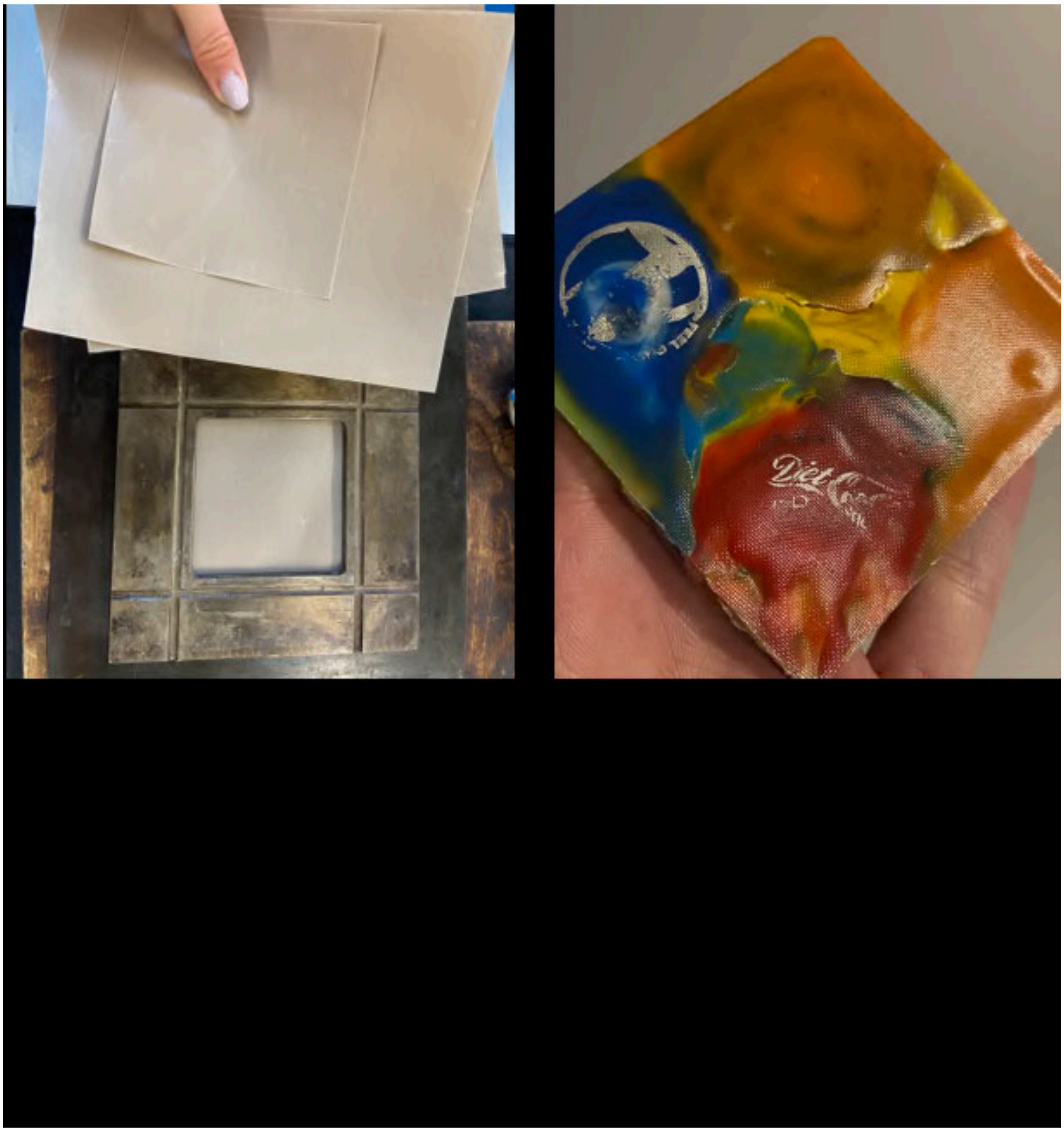


*Figure 30. A PE coaster with textured surfaces, Tao, 2021.*

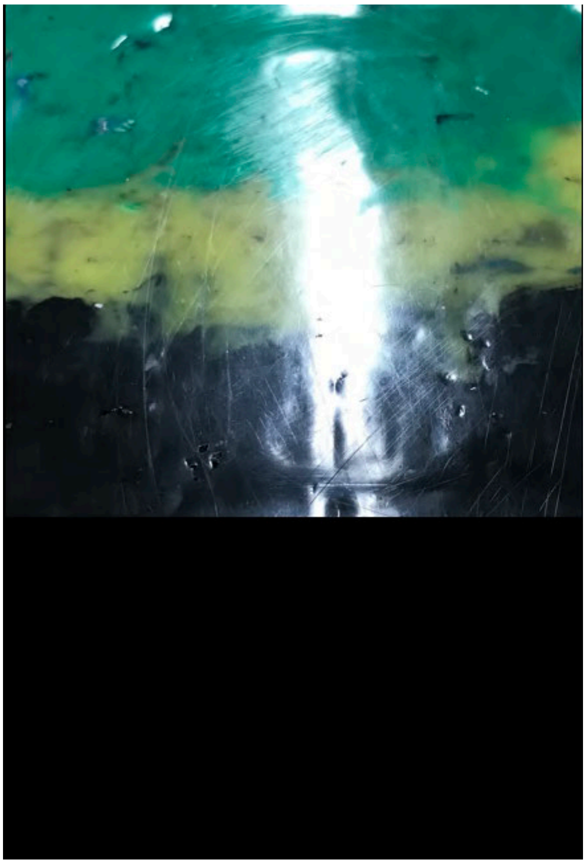


*Figure 31. A PE coaster with shiny surfaces, Tao, 2019.*

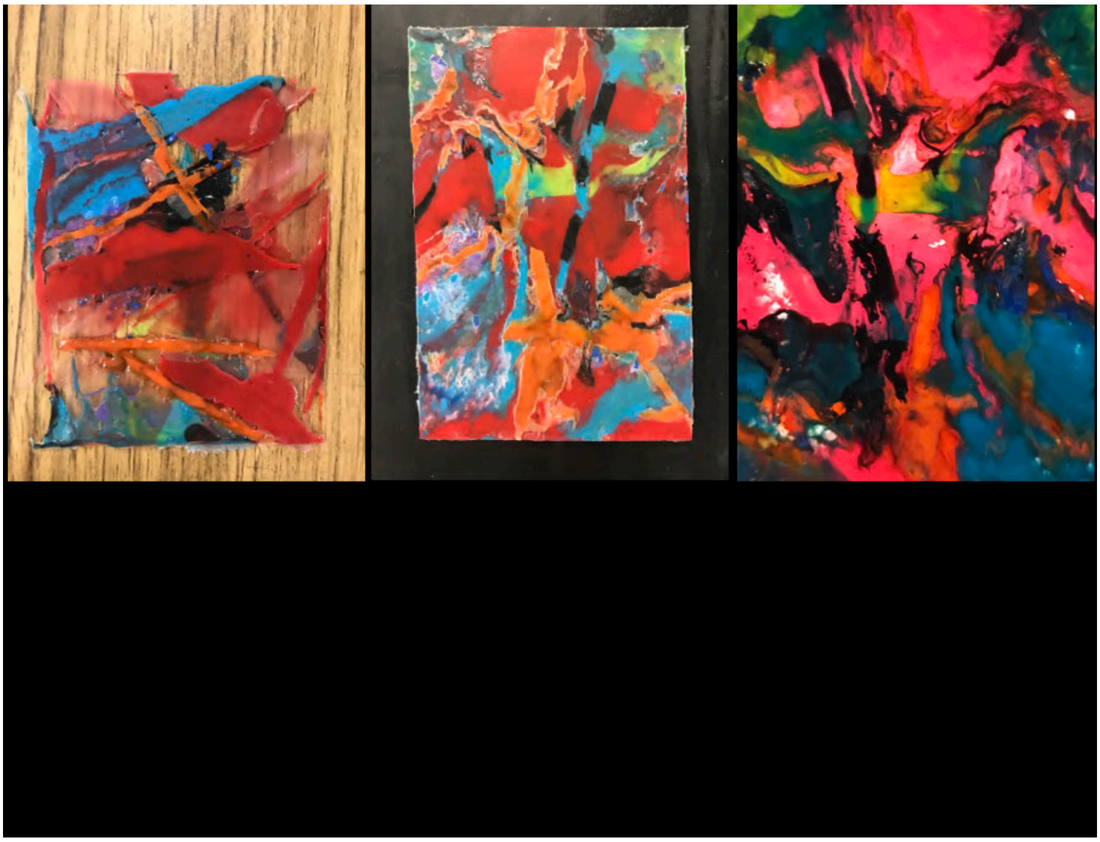


*Figure 32. Compressed scrap sheet, Tao, 2019.*

## Different moulds

*Figure 33. University coasters, Tao, 2020.*

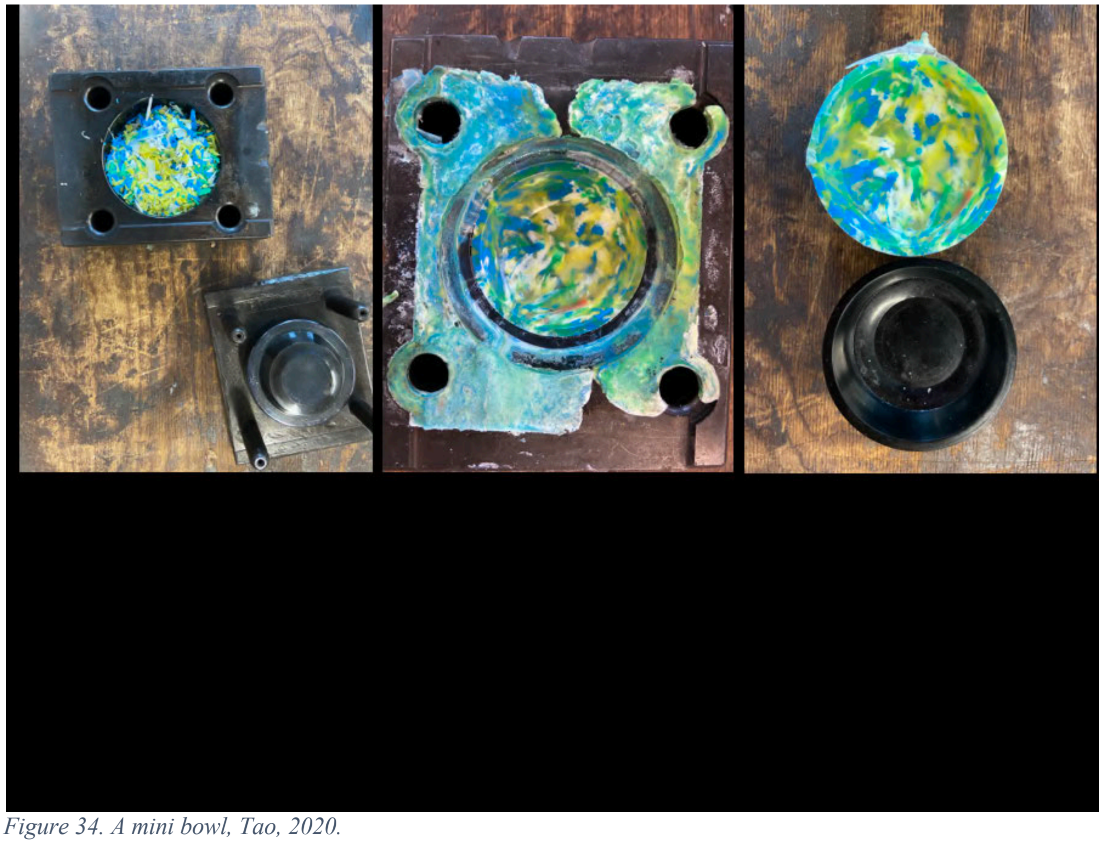


*Figure 34. A mini bowl, Tao, 2020.*

## 6.5 Laser cutting and CNC milling

The ocean plastic sheets produced from compression moulding were further processed into different shapes (designed by the researcher) through laser cutting (procedure see Table 3; results see Figures 35 - 39; see Appendix 1 for more results). Recycled ocean plastic sheets were made to keychains, 3D puzzles and jewellery.

**Table 3**

| **Laser cutting procedure** |
|---|
| 1. Create line patterns on Adobe Illustrator. Black lines are usually designed for cutting through, while red lines are for engraving. |
| 2. Import the file into the laser cutter software. Double-check the settings to confirm the colour of the line matches the command. |
| 3. Set up the desired size. Place the plastic plate in the cutter. |
| 4. Follow the instruction to run the machine. |
| 5. Wait until the machine vents out the fume, then take out the objects. |
| 6. Polish the edges if needed. |

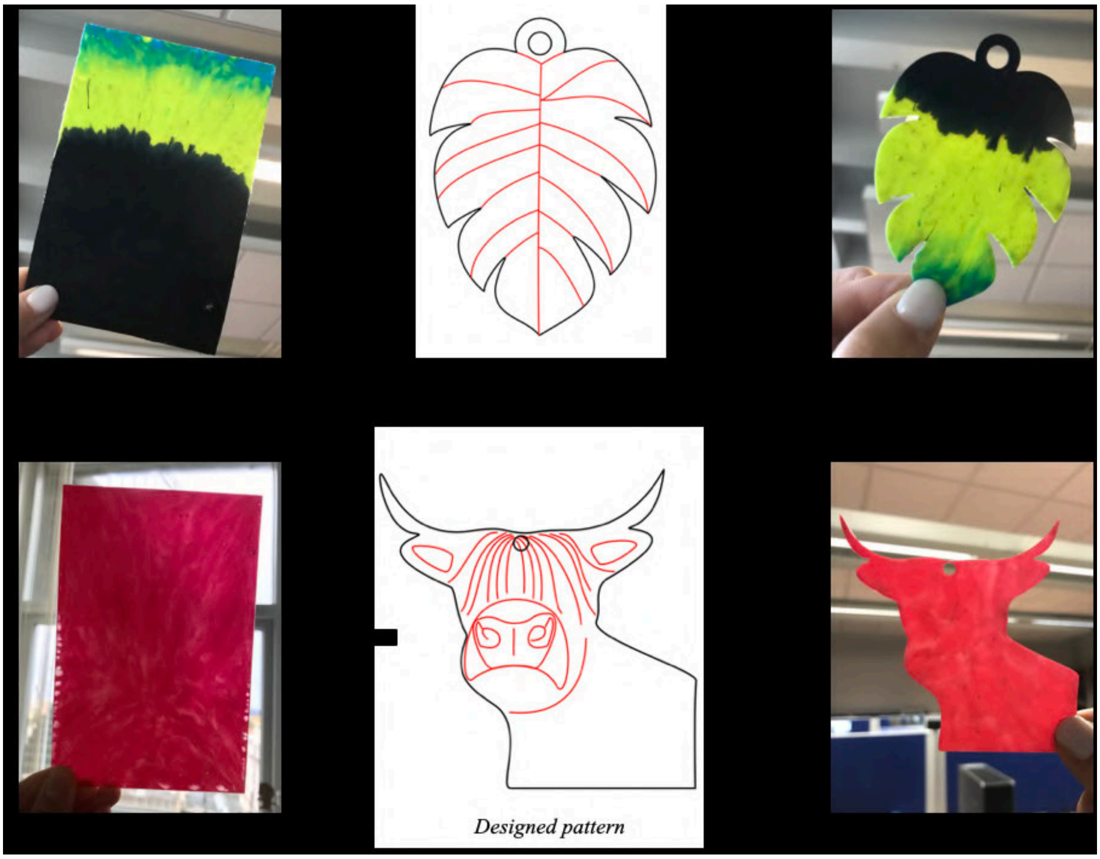



*Figure 35. Laser cutting demonstrations, Tao, 2019.*

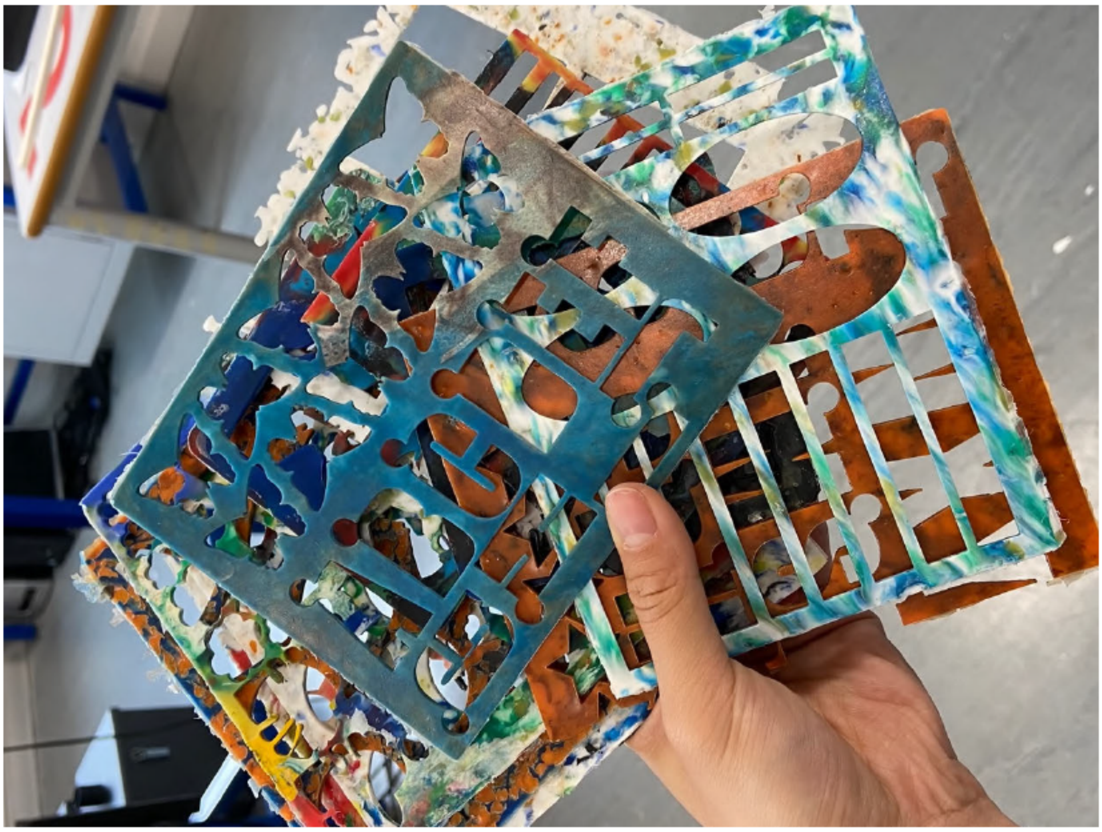


*Figure 36. Off-cut from laser cutting, Tao, 2021.*


*Figure 37. Laser cut initial keychains, Tao, 2021.*

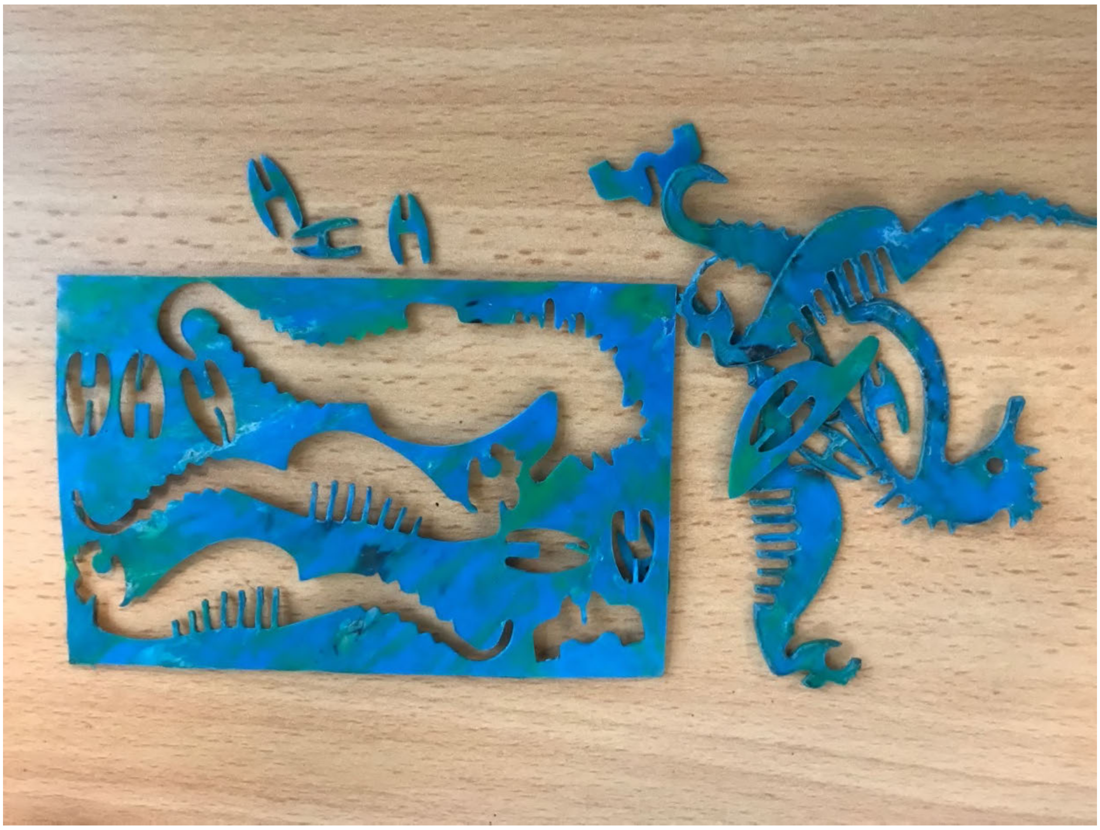


*Figure 38. Laser cut 3D puzzles, Tao, 2019.*

*Figure 39. Laser cut Necklace, Tao, 2021.*

As heat is generated by friction during the CNC milling process so the researcher used PS samples as they did not react to the heat as much as PP or PE during laser cutting. An image of Edinburgh Castle (Figure 40) was encoded for this process. This process was more complicated than the others and was operated by the technician, so the researcher is not familiar with the procedure or the machine. Due to the colour imbalance and air entrapment from compression, the result did not show a clear image (Figure 41), but the technology did work on the sample.

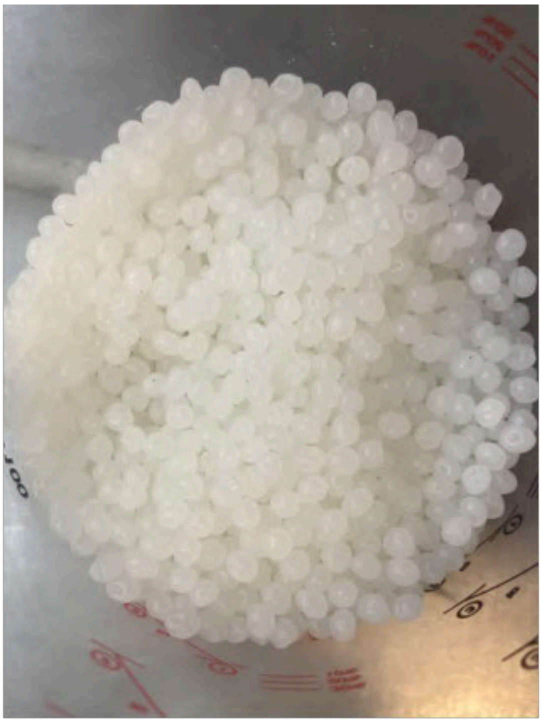
*Figure 40. Edinburgh Castle, Gunadi, n.d.*

*Figure 41. CNC-milled sample, Tao, 2019.*

## 6.6 Extrusion

This process was to produce ø1.75mm filaments for 3D printing. The extruder used was Betol 1820J (Figure 42). The extruder was connected to a Filabot Spooler, which can spool the extruded filaments mechanically. By adjusting the speed of the extruder and the reel rotation, the filament's diameter could achieve 1.75mm. This process extruded filaments including 100% ocean plastics and a mixture of ocean plastics and polylactic acid (PLA; Figure 43). The experiment aimed to produce filaments made from the highest proportion of ocean plastics possible; however, not all filaments made of 100% ocean plastic are printable in the 3D printing process, and the addition of PLA was to enhance the printing performance.

*Figure 42. The extruder, Tao. 2019.*



*Mixed PP and PLA* *PLA pellets*

*Figure 43. Mixed PP and PLA & PLA, Tao, 2020.*

The extruding process consists of a feeding hopper, adjusting panels, a water tank and a Filabot Spooler with a removable spool. The granular samples were fed through the hopper into a rotating screw whose spiral shape moves the granules forward through a heated chamber, and then heated gradually and turns into a homogeneous plastic melt as it approached the nozzle (Figure 44). The molten plastic extruded from the nozzle was manually passed through the water tank hole into the water to cool down and solidify and then through the reel inlet. The extruding and reel rotating speeds were adjusted until the filament diameter was close to 1.75mm. The filament was then attached to a removable spool and rolled up at a constant speed.

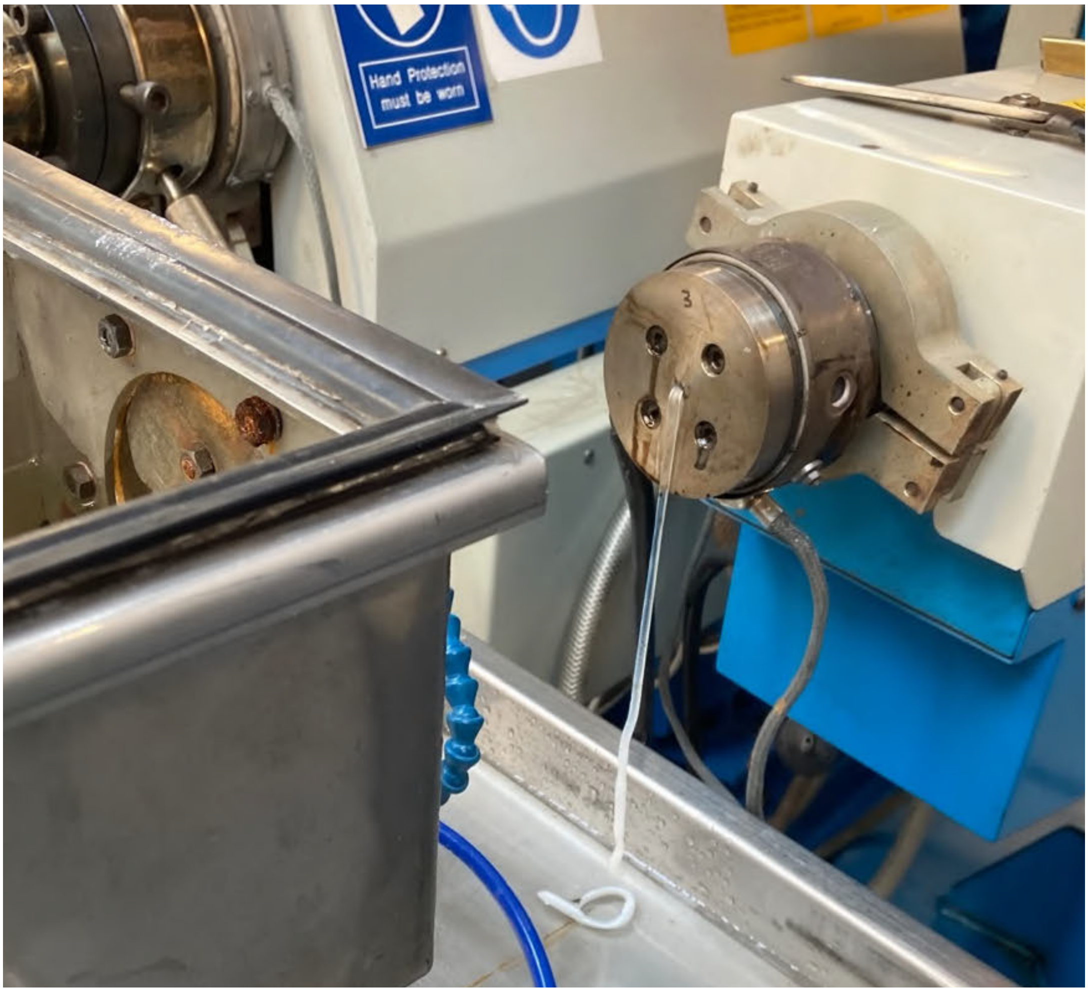



*Figure 44. Extruding, Tao, 2019.*

Filament A (1) was the first recycled ocean plastic filament in this research before systematic extrusions began (see Figure 45 for comparison with a commonly used PLA filament). It was made from 100% of ocean plastic PE (sample No.14). The surface is smooth and shiny. Impurities are present but few. The extrusion process was smooth. A (1) will be used as a trial material in this experiment. Table 4 lists all the filaments recycled from ocean plastics in this experiment. Figures 46 - 54 present the filaments produced.

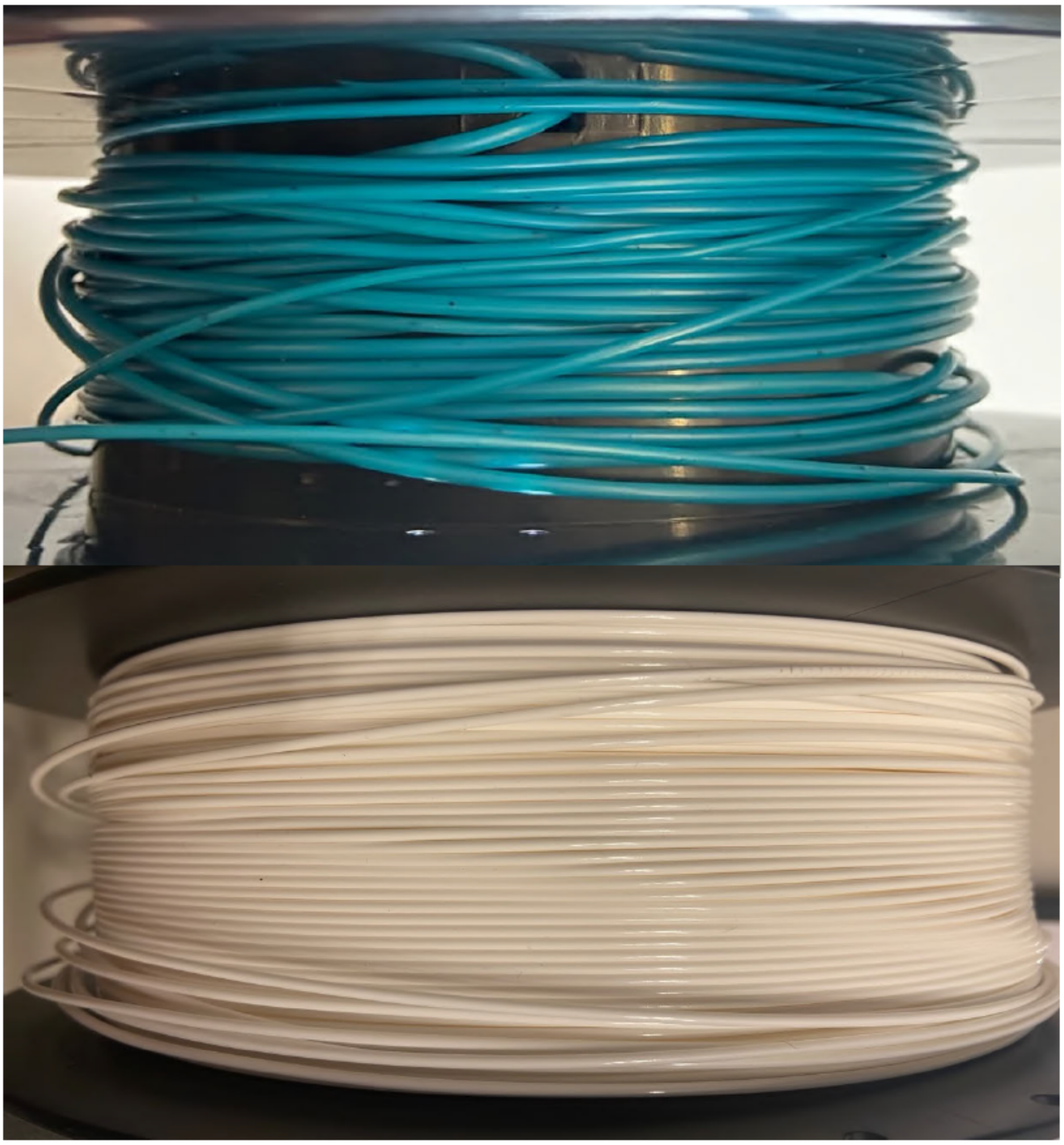


*Figure 45. Filament A (1) vs PLA, Tao, 2020.*

**Table 4**

Filaments recycled from ocean plastics

| Sample types | Filaments | | |
|---|---|---|---|
| PE | **A**. 100%PE | **B**. PE: PLA=1:1 | **C**. PE: PLA=2:3 |
| PP | **D**. 100%PP | **E**. PP: PLA=1:1 | **F**. PP: PLA=2:3 |
| PET | **G**. 100%PET | | |
| PS | **H**. 100%PS | **I**. PS: PLA=1:1 | |

*PE filaments*

A. 100% ocean plastic PE

There were different colours of PE samples used in this extrusion, including black, blue and yellow, but the result only shows black. This filament has the most pleasing surface compared to the other two. It is smooth and shiny. It is very flexible and difficult to snap, almost like a rubber thread. The extrusion process was smooth.

*Figure 46. Filament A - 100% PE, Tao, 2020.*

B. PE: PLA=1:1

This filament is extruded from a mixed equal amount of PE and PLA. PLA pellets were added to improve printing performance. The surface is not as smooth as A, and the flexibility decreased. It does not break easily, looking like an electric cable made up of many thin wires. This often happens when two different types of plastic are processed together. The extrusion process was smooth.

*Figure 47. Filament B - 50% PE, Tao, 2020.*

C. PE: PLA=2:3

This filament is very similar to B because the proportions are not much different. It has the coarsest surface of the three, which suggests that the smoothness of the filament surface is inversely proportional to the amount of PLA added. The extrusion process was smooth.

*Figure 48. Filament C - 40% PE, Tao, 2020.*

*PP filaments*

D. 100% ocean plastic PP

Sample No.17, the yellow sample looking like a brush with marine organisms growing on it, was used in this process. It turned greenish after extrusion. The surface looks fine and shiny; however, the blue contaminants are noticeable. All blue samples are PE in this experiment, so the impurities are more likely to be PE. This also suggests that filament A may not be as "perfect" as it looks, as imperfections are invisible in black colour. The extrusion process was smooth.

*Figure 49. Filament D - 100% PP, Tao, 2020.*

E. PP: PLA=1:1

The samples used in this process were transparent plastic cups collected on the beaches. Almost all the pollutants were removed, so this filament looks the finest without any visible impurities. The result of blending PP and PLA is surprisingly better than that of PE and PLA. The surface is matte but not rough. The extrusion process was smooth.

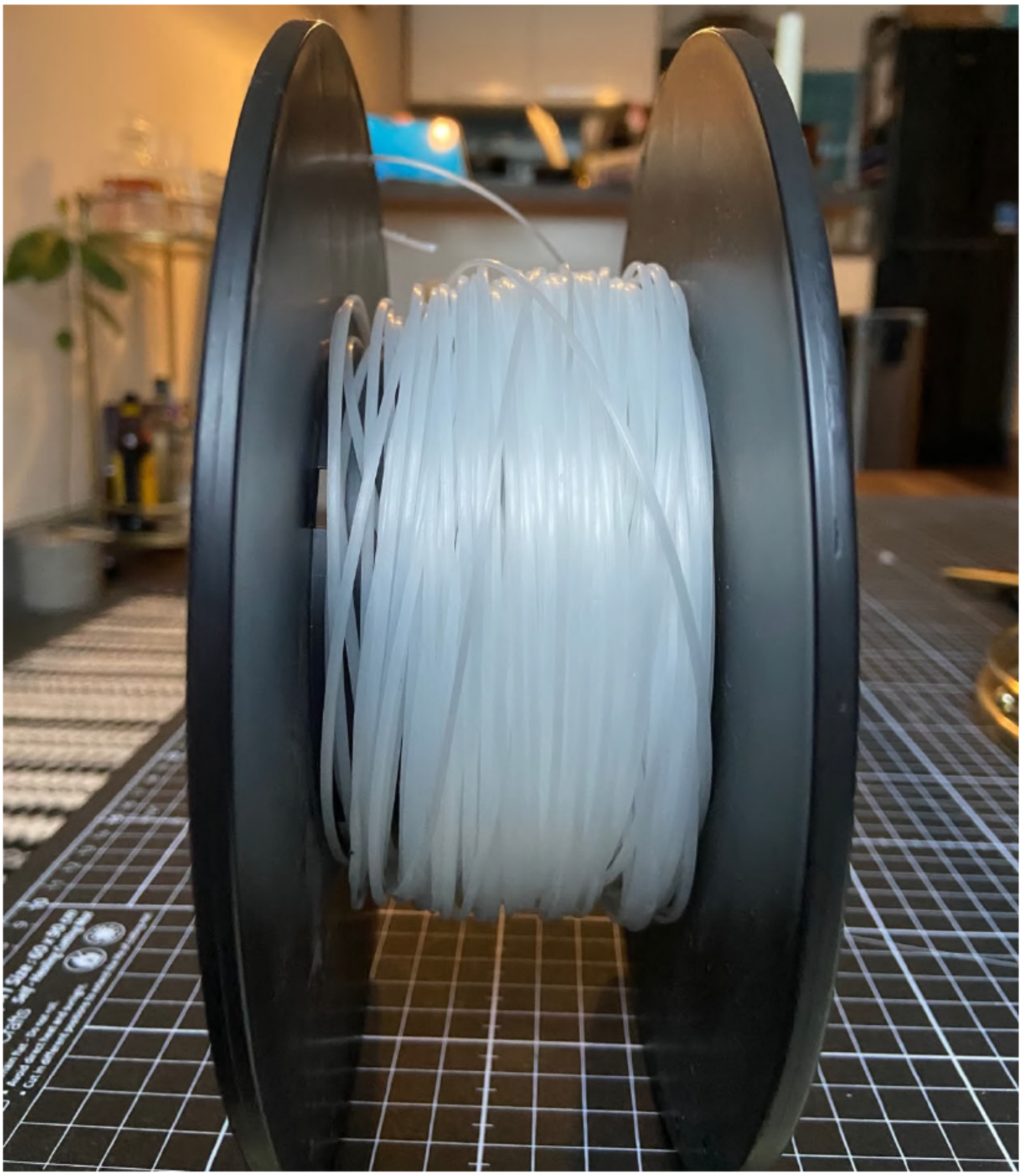


*Figure 50. Filament E - 50% PP, Tao, 2020.*

F. PP: PLA=2:3

Sample No.17 was also used in this extrusion. The result looks more yellow, and the impurities are less evident due to the addition of PLA. The extrusion process was smooth.

*Figure 51. Filament F - 40% PP, Tao, 2020.*

*PET filament*

G. 100% ocean plastic PET

The sample was preheated to remove the moisture prior to the extrusion. Only one type of PET filament was produced because the melting point of PET is much higher than PLA. If the two were mixed, the temperature needed to reach at least 250°C, which was likely to cause PLA degradation. Therefore, it would counteract the effect of adding the PLA on improving print performance.

In comparison to the other filaments, the extrusion process of filament G was the least smooth. It did not continuously produce long filament as the material often stopped coming out of the nozzle. The filament has many defects and is easy to snap. The scrap PET was extruded again, but the material behaved even more poorly due to the possibility of degradation.

*Figure 52. Filament G - 100% PET, Tao, 2020.*

*PS filaments*

H. 100% ocean plastic PS

The sample used was No. 20, the orange buoy. Its whole functioning life and beyond was spent in the marine environment, which explains the stronger ocean odour. The filament's colour is not even due to the pollutants and scratches on the buoy's surface. Impurities are visible but few and inconspicuous. The filament is crispy and easy to break. The extrusion process was surprisingly smooth.

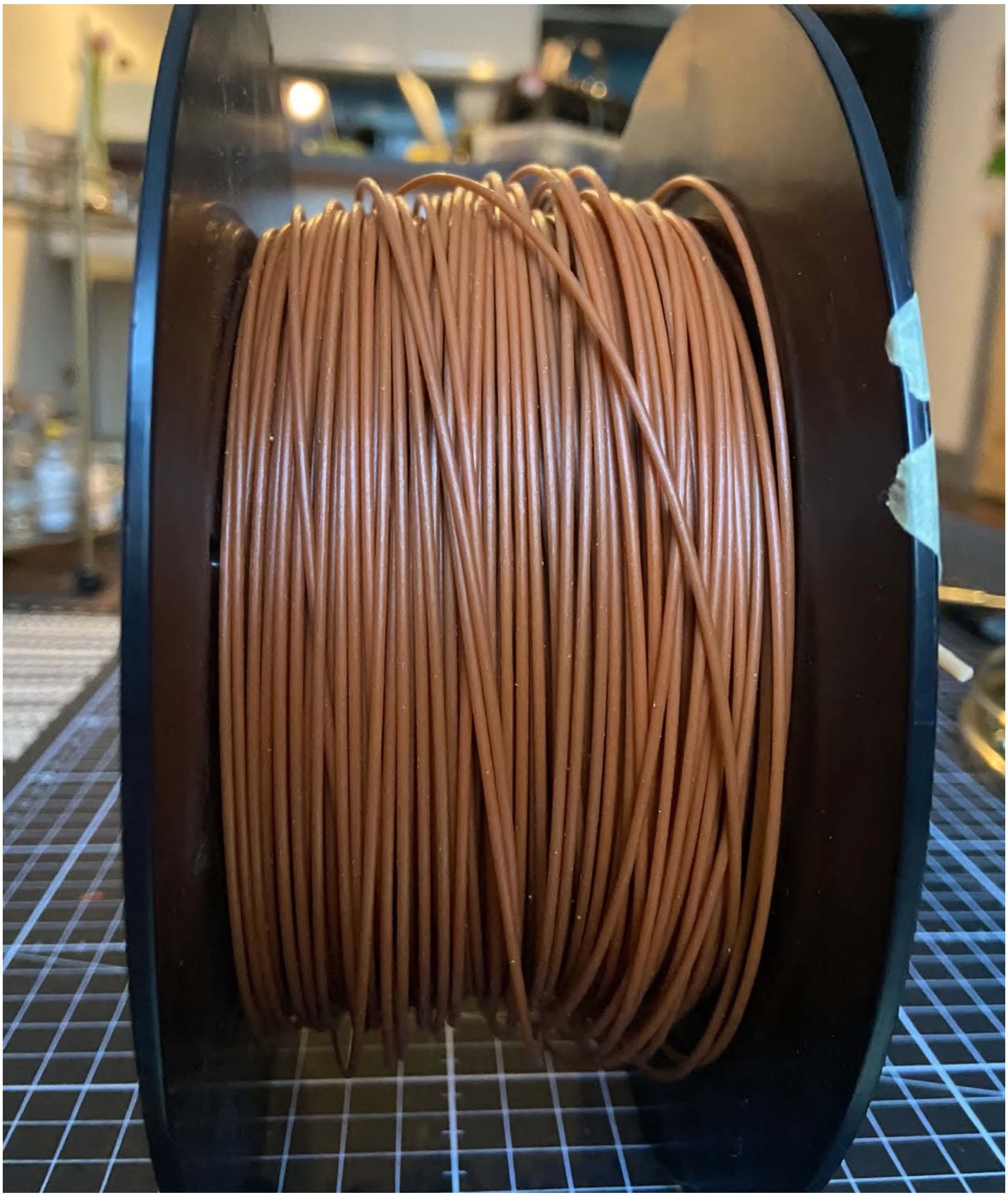


*Figure 53. Filament H - 100% PS, Tao, 2020.*

I. PS: PLA=1:1

The colour is much lighter compared to filament H. PS blended very well with PLA. There are no obvious defects on the filament except that the uneven colour is more prominent. The extrusion process was smooth.

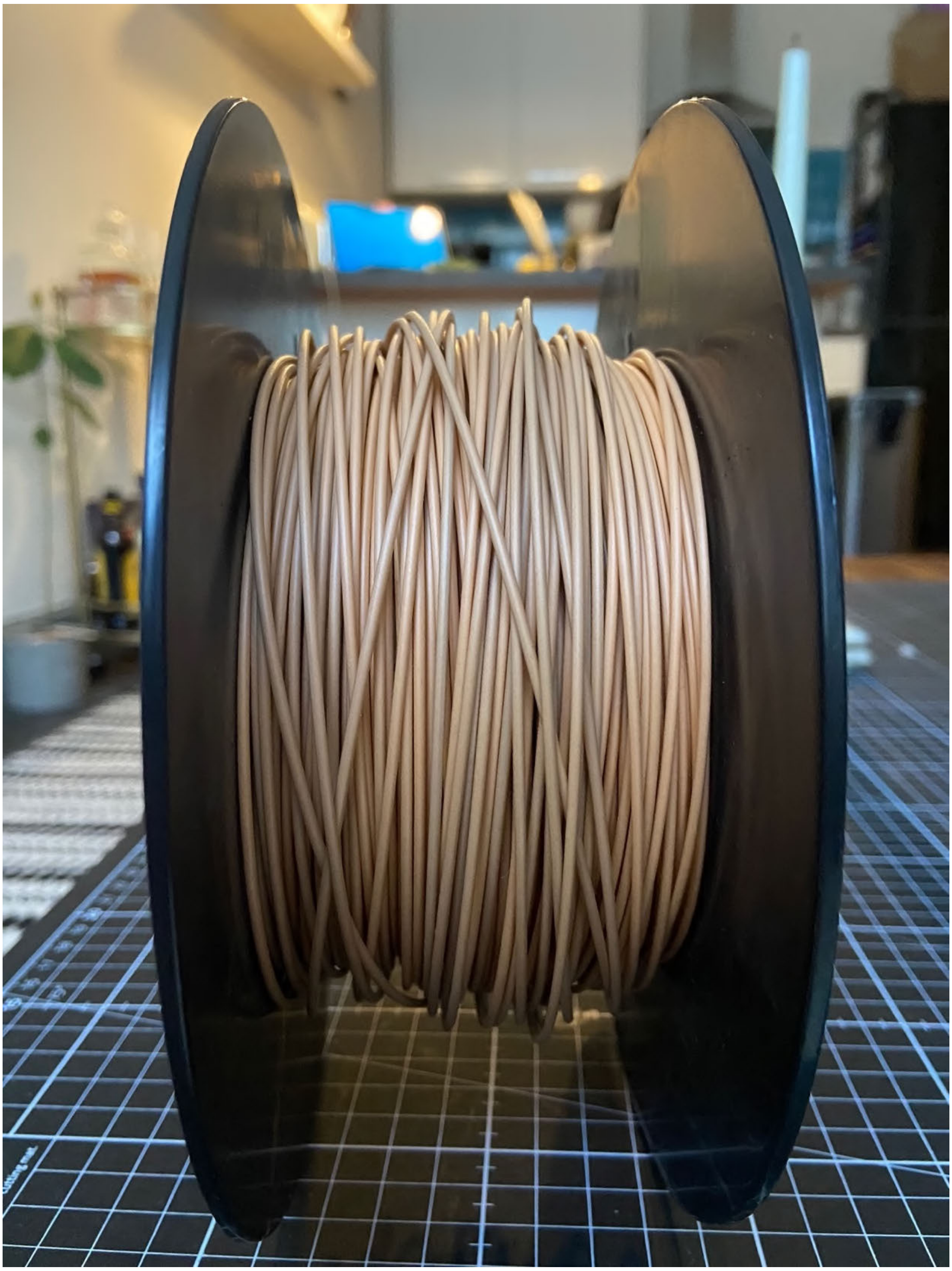


*Figure 54. Filament I - 50% PS, Tao, 2020.*

## 6.7 3D printing

The experiment involved using a 3D printer and a 3D printing pen. The 3D printer used in the experiment was a Prusa i3 MK3 (upgraded to i3 MK3S+ after; Figure 55), with the nozzle and printing bed temperature adjustable to print all the samples in this experiment. The 3D printing pen (Figure 56) was purchased on eBay. The 3D printing pen was advertised to accept a variety of materials, with an adjustable print temperature of 160-235°C, which covers the melting points of all types of plastic samples.

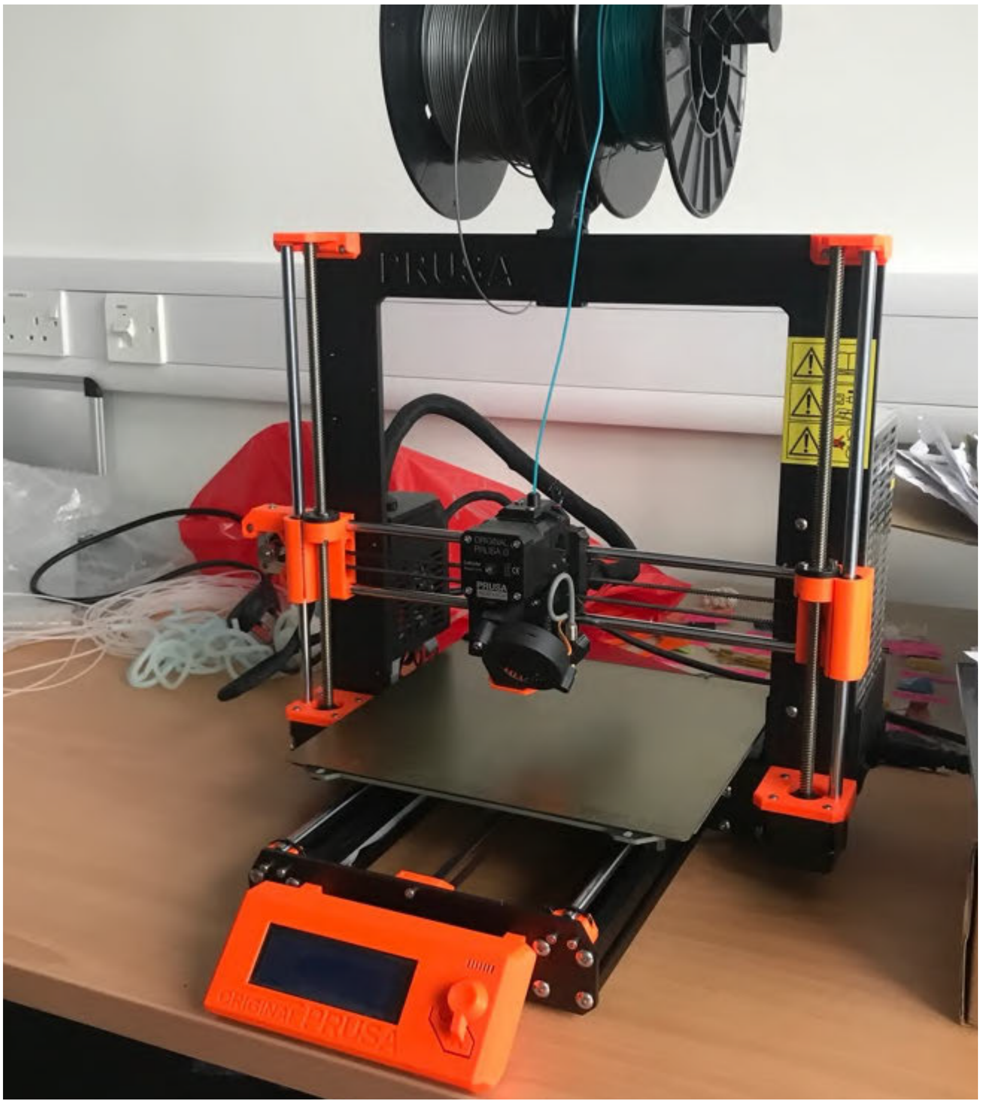



*Figure 55. The Prusa i3 MK3S+ 3D printer, Tao, 2020.*

*Figure 56. The 3D printing pen used in this experiment, Tao, 2019.*

The experiment on 3D printing pens was carried out before the 3D printer to reduce the potential damages (i.e., blockage) on the printer due to the more straightforward mechanism and lower price. Regular 3D printing nozzles range from ø0.1mm to ø0.8mm, which are easy to be clogged by contaminants. Figures 57 - 58 show the result of using 3D printing pen printing regular PLA and all filaments produced in this experiment.

*3D printing pen*

A (1)

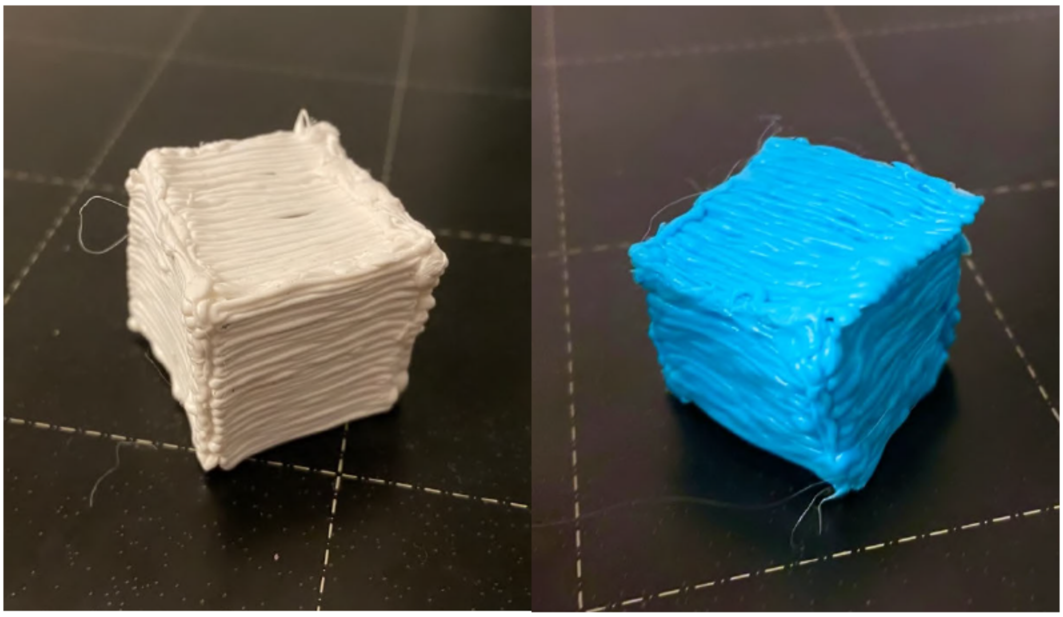


*Figure 57. Regular PLA vs filament A (1) printed from the pen, Tao, 2020.*

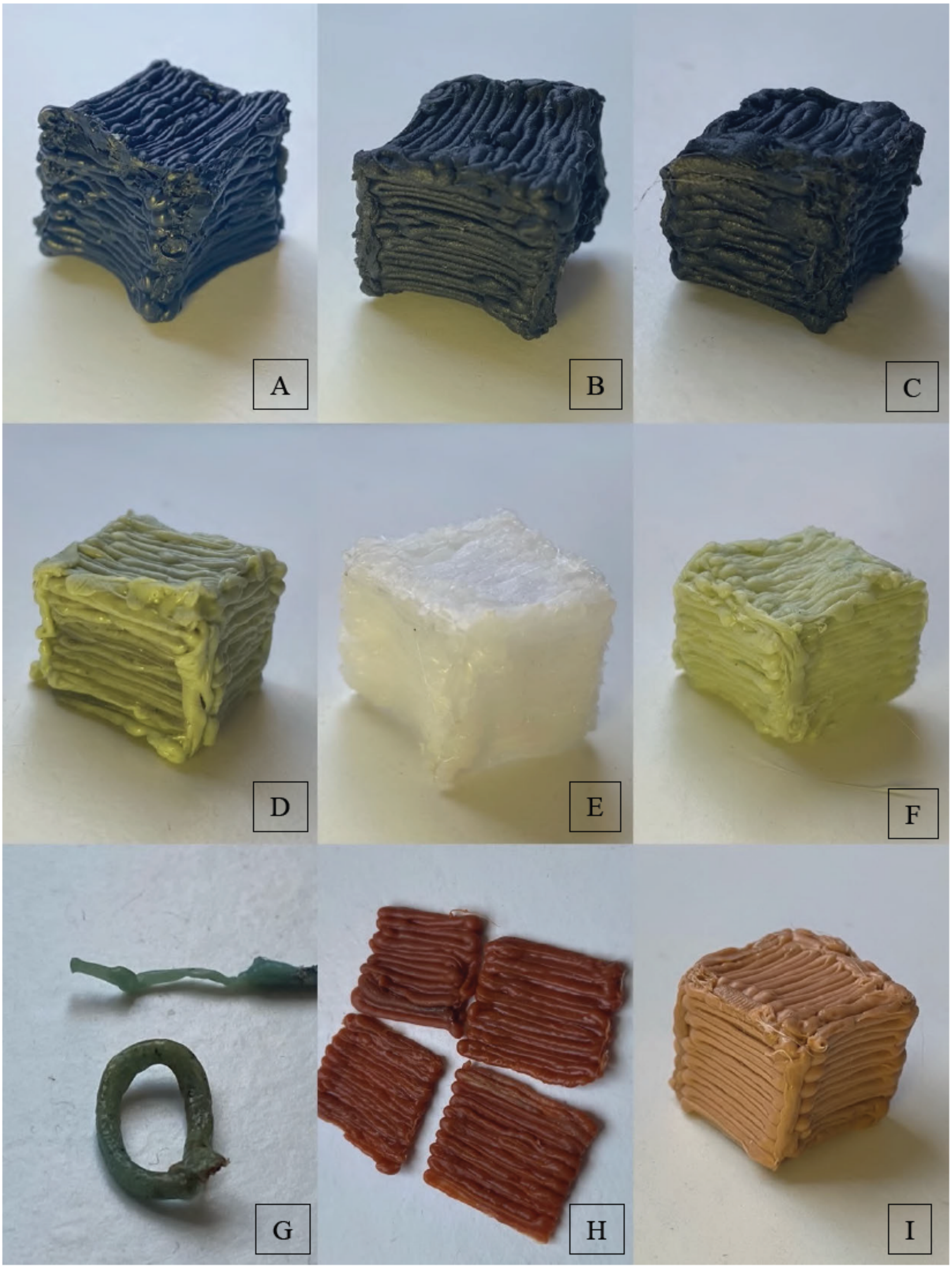



*Figure 58. Results from 3D printing pen, Tao, 2020.*

All filaments made in the extrusion process could feed through the pen and be extruded out of the nozzle, so they could all be tested on a 3D printer, although Filament G and H got jammed in the pen during printing, suggesting the researcher to pay more attention to these two filaments when using the 3D printer. The conclusion drawn from this experiment is that filaments made of 100% ocean plastics (PE and PP) have the potential to replace the PLA or ABS used on 3D printing pens. The performances of the 100% recycled ocean plastic filaments and the conventional filaments were not significantly different.

Once the filaments were "approved" by the pen, they were tested on the printer to print a small ring designed on Rhinoceros, a 3D modelling software. It was a small-sized, simple design, which only took about two minutes to print. 3D models of a kitten and a cookie-cutter (.stl files downloaded from thingiverse.com) were then printed (see Figure 59: top).

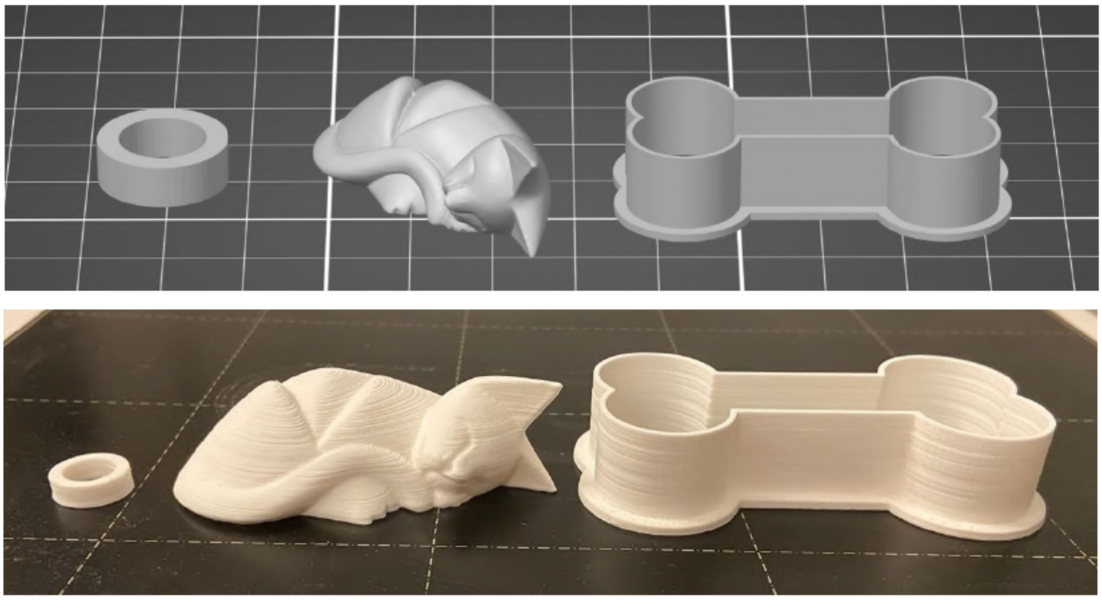


*Figure 59. Digital 3D models & reference prints, Tao, 2020.*

The experiment first printed the commonly used PLA filament as a reference (Figure 59: bottom). Filament A (1) was then used for trial printing. The filament was loaded and extruded out of the nozzle smoothly. However, the printer printed nothing out but small "blobs", even after adjusting the printing speed and temperatures several times (Figure 60). The problem was that the material did not stick to the printing bed when it came out of the nozzle. Instead, it stayed on the nozzle and built up into a blob during the entire printing process. After applying stick glue or hair spray onto the printing bed, the printed matter started to stick to the bed.

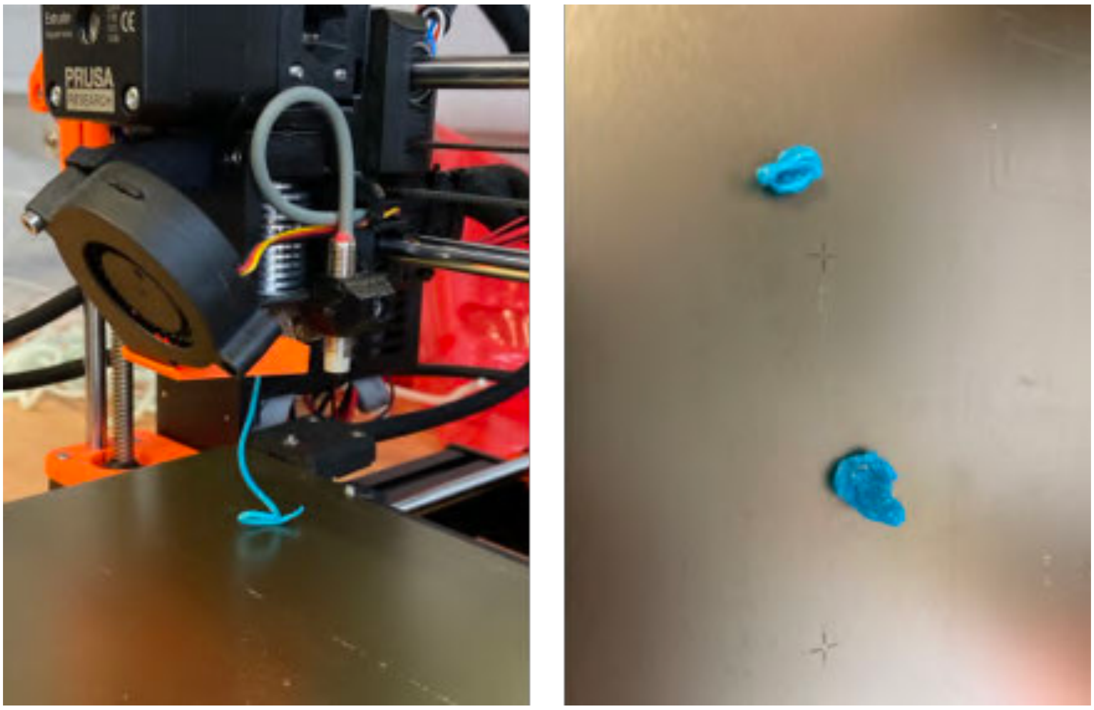



*Figure 60. "Blobs" printed out of filament A (1), Tao, 2020.*

After a series of adjustments on the printer, all the filaments were printable (Figures 61 - 69; more in Appendix 2).

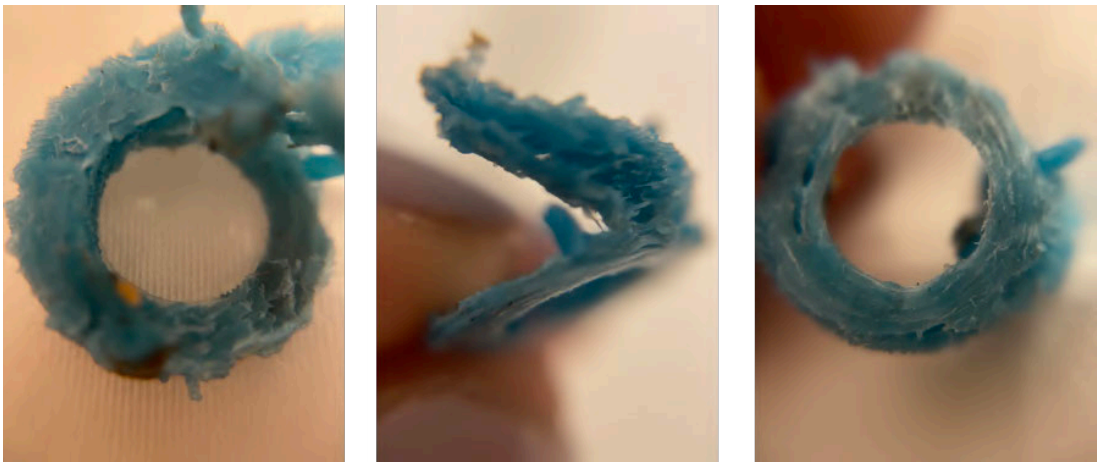


*Figure 61. Printing result - A (1), Tao, 2020.*

*PE results*

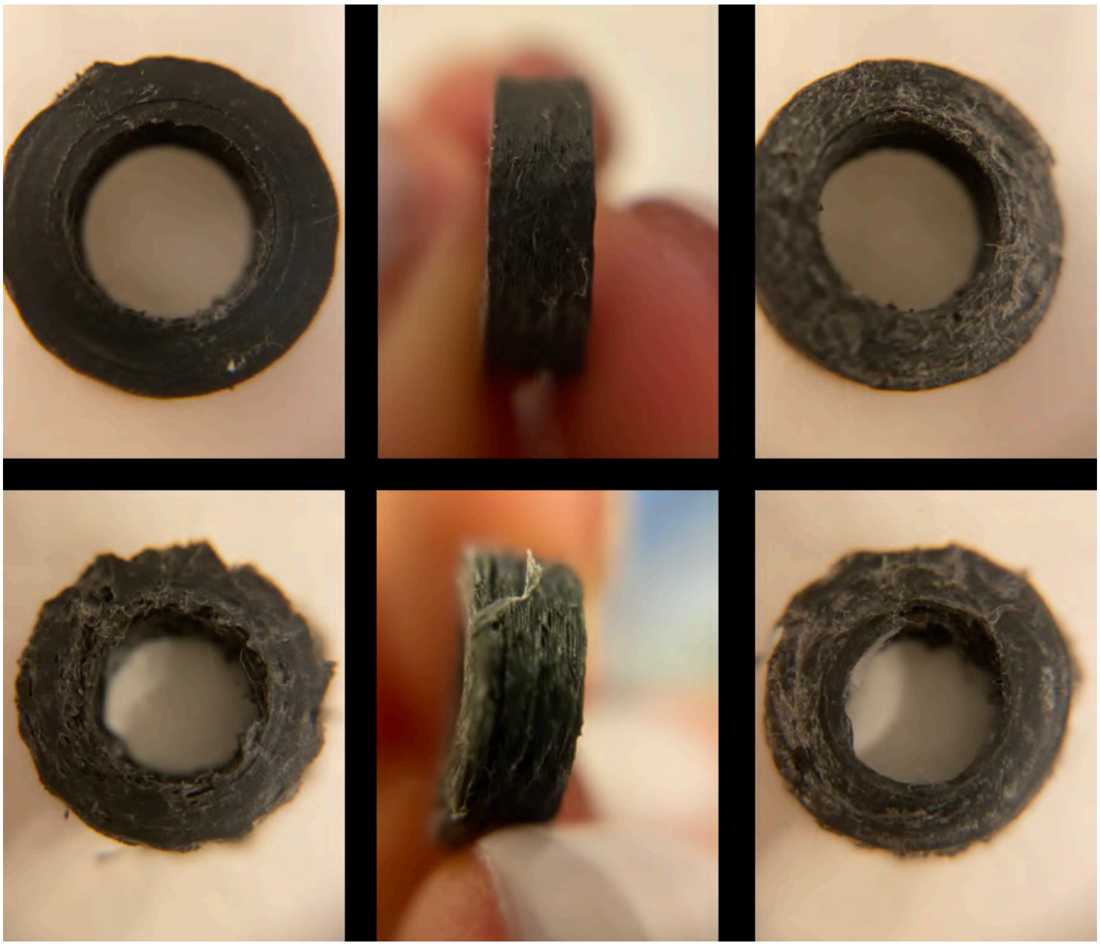


*Figure 62. Printing results - B&C, Tao, 2020.*

* The 3D printer could not extrude continuous filament A (black), so no ring was printed.

*PP results*

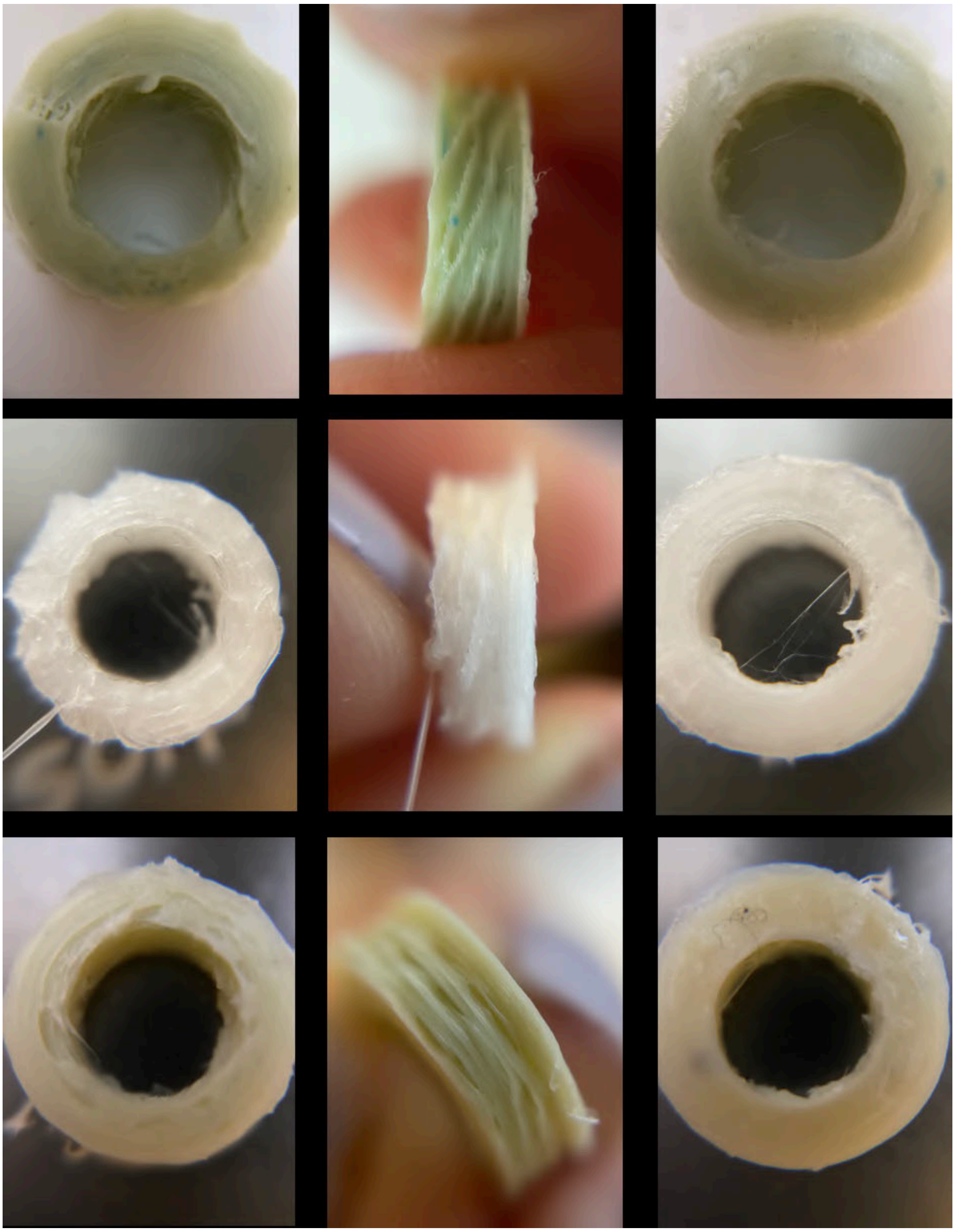


*Figure 63. Printing results - D, E &F, Tao, 2020.*

*PET result*

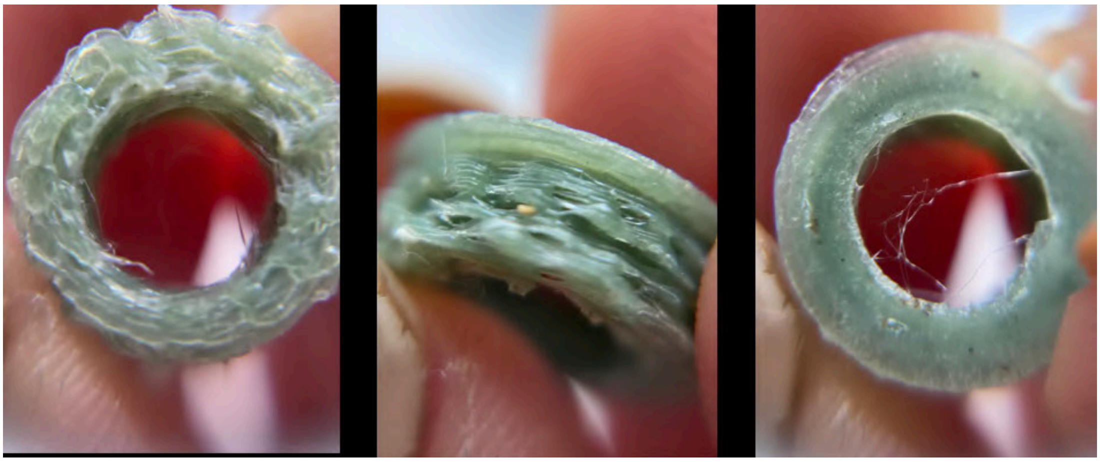


*Figure 64. Printing result - G, Tao, 2020.*

*PS results*

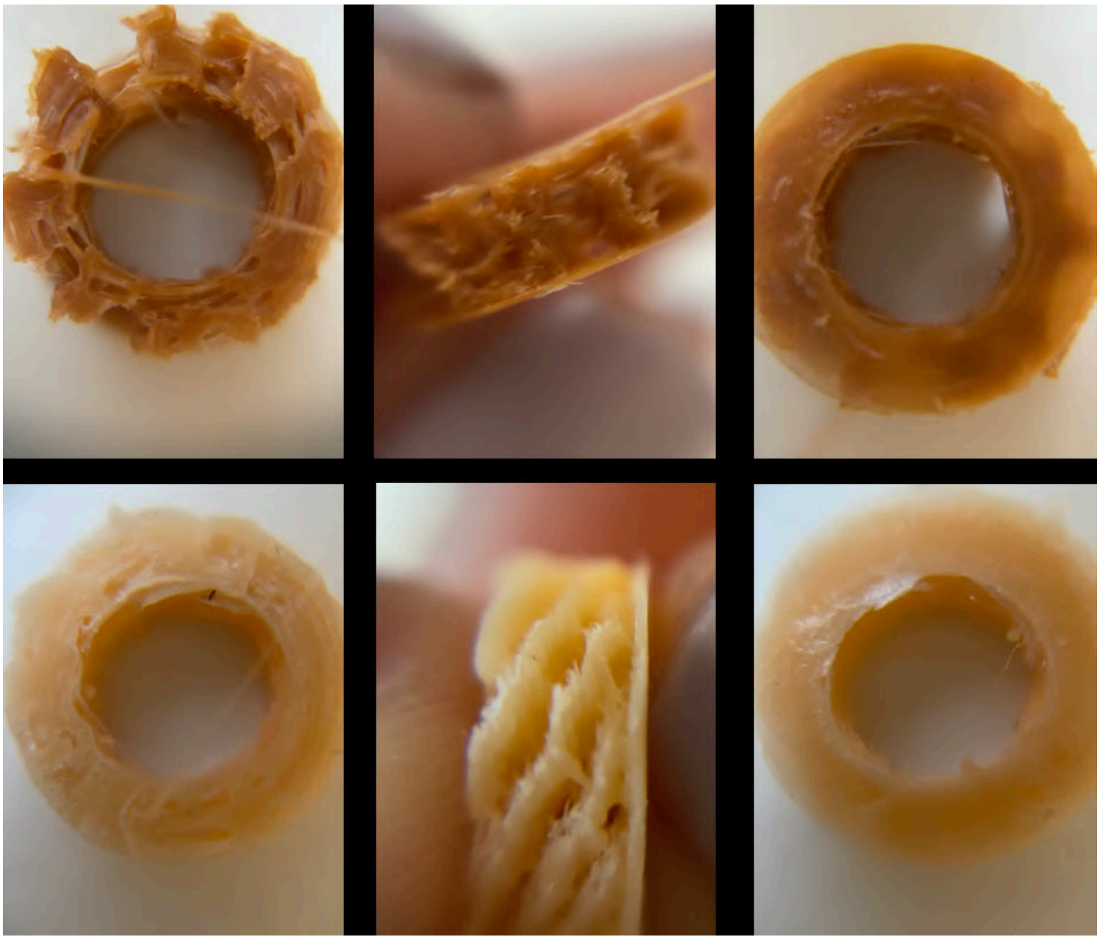


*Figure 65. Printing results - H & I, Tao, 2020.*

PP, in general, had the best performances. Filament D, which was made of 100% ocean plastic PP, achieved the best result compared to the other filaments made of 100% ocean plastic. A (1) produced the least satisfactory printed matter, with little to no completion, while A (black) did not get any printed result from 3D printer but performed very well on the 3D pen. The PET "jade" effect that could not be achieved in the compression moulding process was realised after printing filament G. The results of the kitten and cookie-cutter are shown below (Figures 66 - 69).

*Figure 66. Cookie cutters 1, Tao, 2020*

*Figure 67. Cookie cutters 2, Tao, 2020.*

*Figure 68. Kittens 1, Tao, 2020.*


*Figure 69. Kittens 2, Tao, 2020.*

Kittens and cookie cutters were not printed out of filaments A and A (1). Only the bottom of the cookie cutter was printed with G, and H jammed the printed while printing the kitten.

Some problems were observed during the printing process that might affect the printing process and even cause the printing failure. The bottom layer not sticking to the printing bed and warping are the common issues. Methods of applying an adhesive layer (hair spray and stick glue) to the printing bed and adjusting printing bed's temperatures were adopted. Another problem is that layers do not bond with each other even though the model was entirely printed. This is due to the different characteristics of different plastics. The reason for the failure to print filament G is suspected to be that PET degrades more severely than others. As one of the most abundant ocean plastic types, PP has the best potential for 3D printing so far.

## 6.8 The hands-on experience with surgical facemasks

During the Covid-19 pandemic, the researcher read many news and studies about PPE products polluting the marine environment and entangling animals. Many facemasks were not discarded properly and lying on the side of the road (Figure 70). After investigations, the author found that the main component of most disposable facemasks was made of PP (Figure 71), and PP performed well in this experiment. Thus, the researcher collected the disposable masks she wore (Figure 72) during the pandemic and conducted a series of experiments to prevent masks (Figures 73-79) from entering the ocean.

*Figure 70. Facemasks spotted on the street, Tao, 2020.*

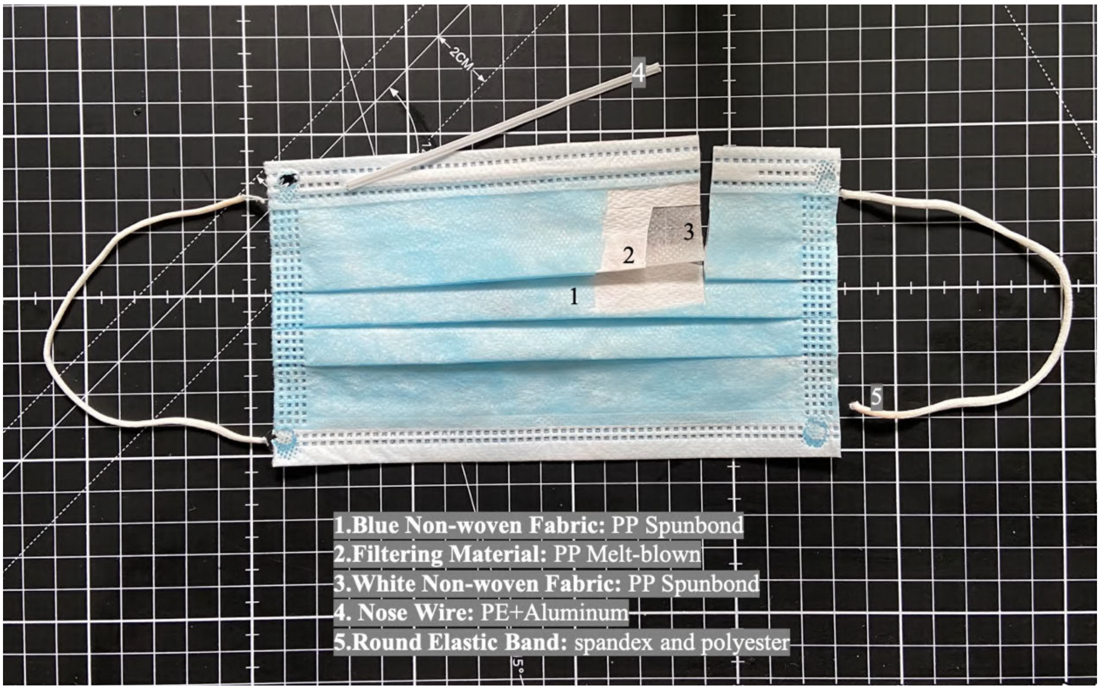



*Figure 71. Composition of a facemask, Tao, 2021.*

*Figure 72. Worn masks, Tao, 2021.*

*Compression moulding*

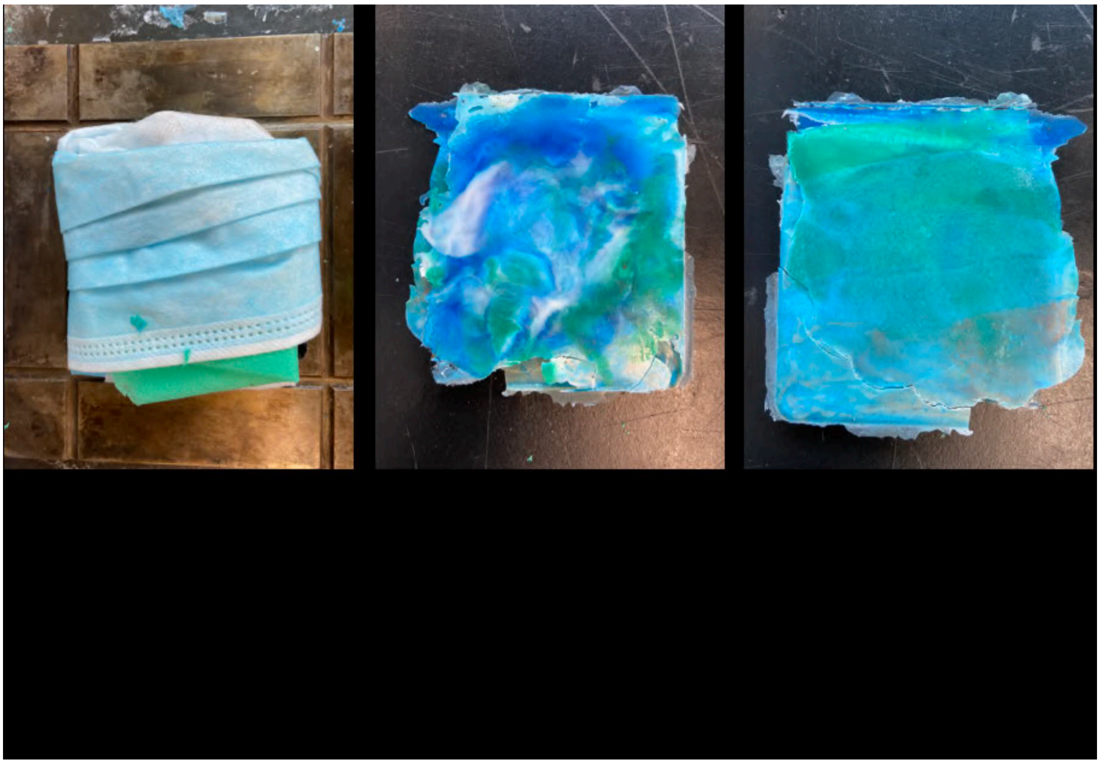


*Figure 73. Compression moulded facemasks, Tao, 2021.*

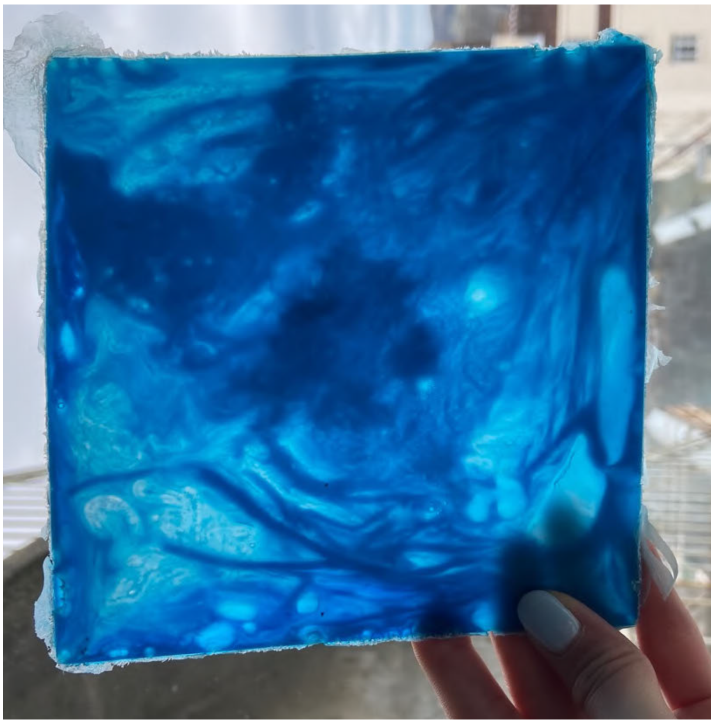


*Figure 74. Compression moulded facemasks achieving an ocean pattern, Tao, 2021.*

*Filament making*

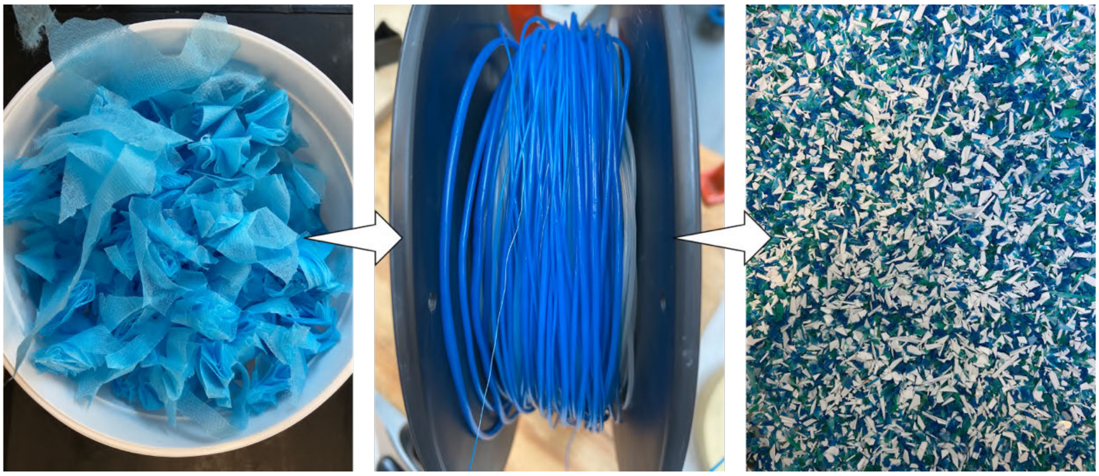


*Figure 75. Filament making 1 – 100% PP, Tao, 2021.*

Due to the lightweight, even when masks were cut into smaller size, they did not feed through the extrusion hopper easily and produce consistent filaments. As a result, the researcher shredded the facemask filaments, and the granules fed through smoothly, producing a better filament (Figure 76).

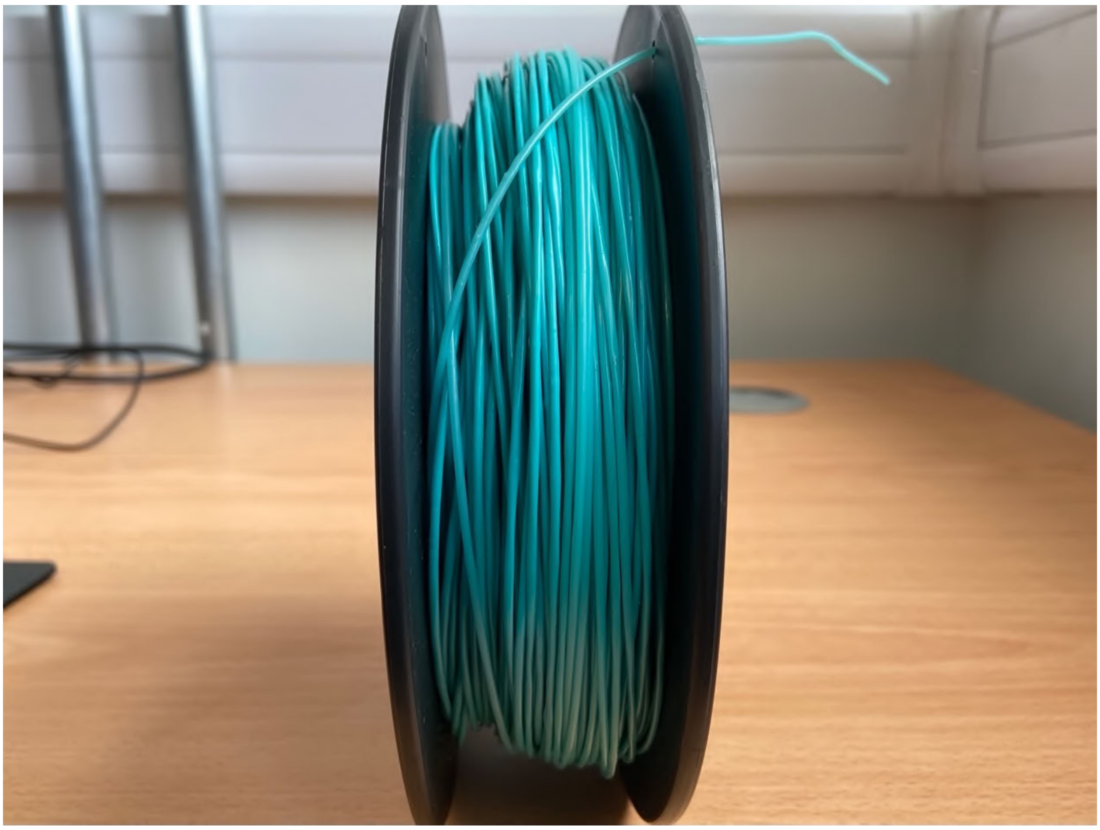


*Figure 76. Facemask filament 2 – 100% PP, Tao, 2021.*

*3D printing*

3D printing the facemask filament was smooth on both 3D printing pen and printer, similar to filament D. The surfaces are almost as fine as a PLA print, although warping occurred (Figures 77 - 79).

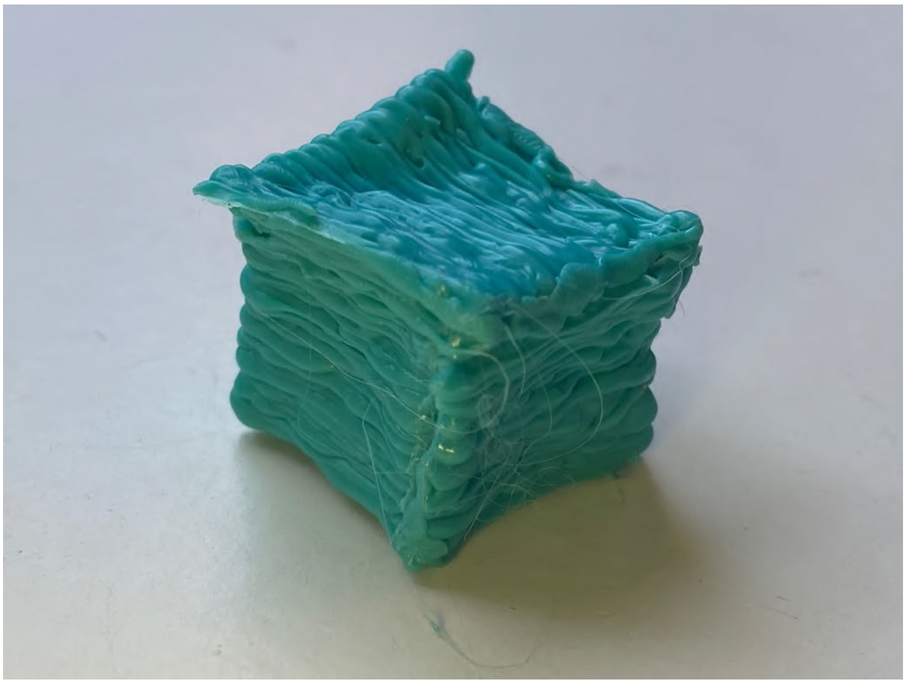


*Figure 77. Result of printing on the pen - facemask filament, Tao, 2021.*

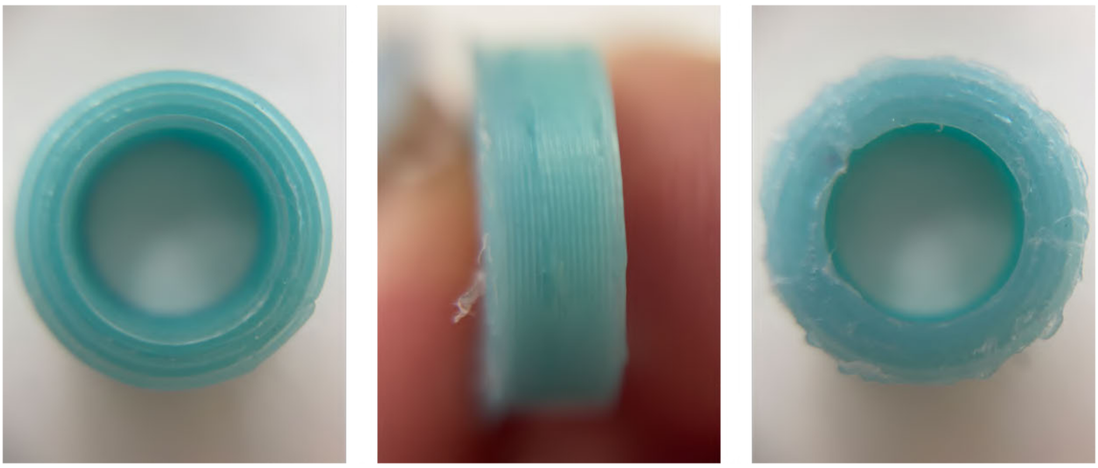


*Figure 78. 3D printed ring using facemask filament, Tao, 2021.*

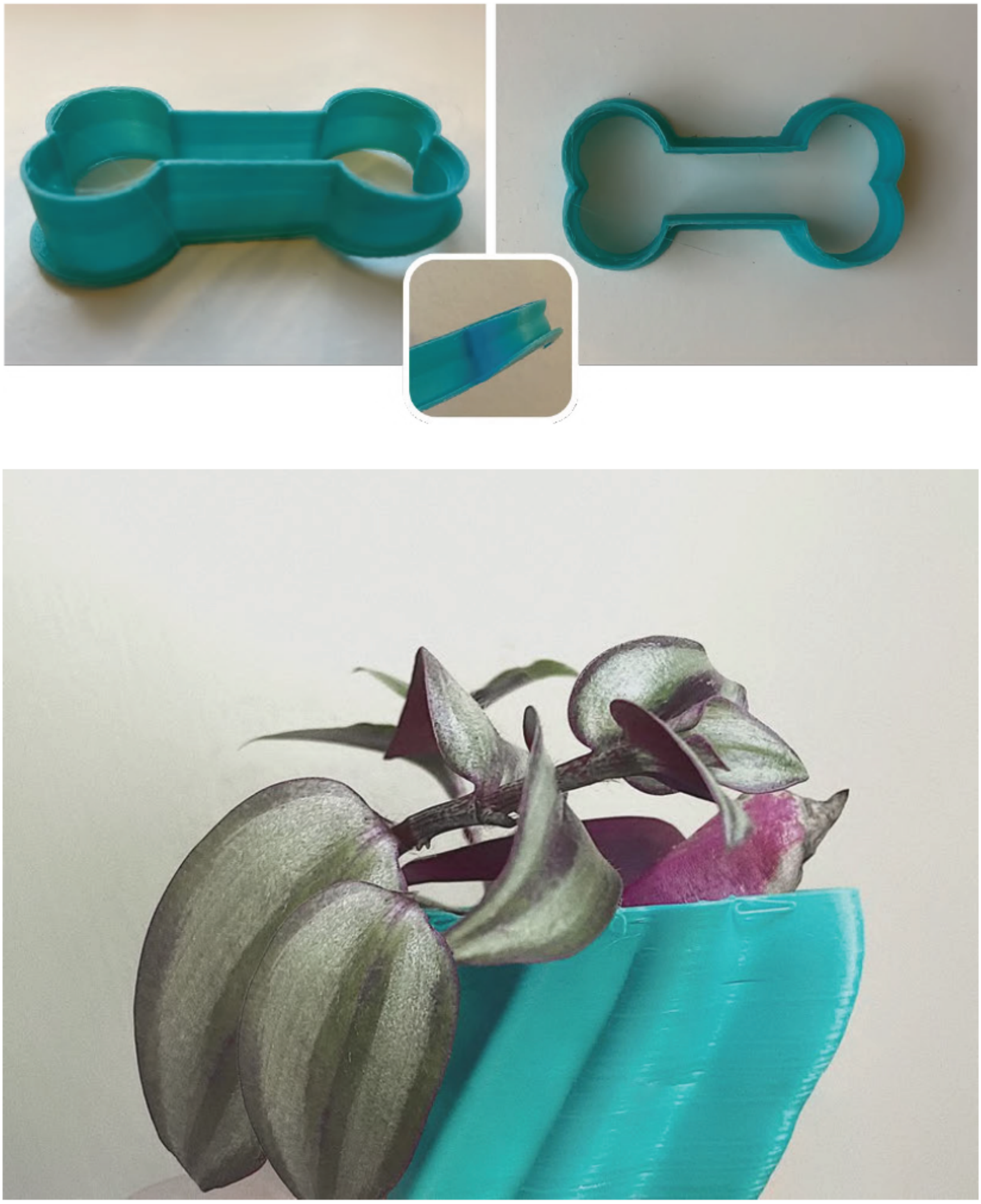


*Figure 79. A cookie cutter and a plant pot printed from facemasks, Tao, 2021.*

This chapter discussed the entire hands-on process of the researcher's experience with ocean plastic, from the first encounter on the beach, to the final products produced. This chapter included thorough experiments on four types of ocean plastics, proposing a variety of applications. The process used engineering and design knowledge, which set this research apart from a sole material science study. The researcher sees the potential and possibilities of ocean plastics after the hands-on process. Recycling ocean plastic is more challenging than regular solid plastic waste, especially with extrusion and 3D printing, although it is part of the plastic waste family and has the basic properties of plastic. In addition, the hands-on process also gave used disposable facemasks a new life, preventing them from entering the ocean. Compression moulding is highly tolerant of contaminants and is a mature method for recycling ocean plastic. Ocean plastic can be recycled into a variety of products using this approach. As for 3D printing, however, while most of the ocean plastic samples in the experiment are printable, the performance was not always stable, and some samples required the addition of PLA to enhance the printing quality. Therefore, more adjustments and experiments are needed in the future.

Ocean plastics can be transformed into something precious, and every object the researcher made is embedded with her time, effort and sense of achievement and satisfaction. The change of attitude towards ocean plastics and the intense emotional connection built throughout the process urged the author to make a change and take action towards the environmental issue. The public should have the chance to see the real situation with their own eyes and deal with the problem with their own hands instead of only being passively educated by the media or school. Behseta (2013: 45) has the same feelings, writing in her doctoral thesis:

> I gained a full understanding of the processes by being involved through a hands-on experience. Furthermore, I not only benefited by having a deeper understanding of the process but can fully relate to, and have total empathy with, the material, machine, hand and industrial technology. To feel, smell and touch the material at each stage of the process makes one become part of the material and process.

The physical contact during the experiment involving all the sensory feelings to establish a connection with the material was a wonderful experience. It turned repetitive mechanical lab work into something enjoyable and sustainable. The resulting objects are not only experimental data but also provoked feelings of anticipation, surprise and accomplishment within the researcher.

***Author's reflection***

*This chapter capsules my many feelings and emotions, including devastation, anger, satisfaction, pride and so forth. Visits to beaches impacted me on realising the severeness of the environmental issue more than reviewing the literature on ocean plastics and looking at online images and videos. The field trip to the Isle of Harris was a real eye-opener and life-changer (the words used here are in a pejorative sense). I experienced an intense emotion change from looking at the beach afar to stepping on the plastics. Ocean plastic was no longer a pollution term or a disturbing image that could be found online because I saw, smelled and touched it in person. This made me realise the power of immersive experience on environmental issues and everyone should have the opportunity to experience something similar and effective for awareness-raising purposes. Seeing a significant amount of plastic lying on the beach feels much closer to the end of the world than any horror movie about natural disasters and aliens conquering the world, as the main and only cause is us. The experience will urge visitors to contribute positive actions toward the issue. This is where I realised that the use of my experiences and emotions could have a positive impact on the research.*

*Experimenting with ocean plastics was a truly rewarding process for me, and thanks to my previous experience of experimenting in subjects of chemistry and physics, it was not challenging to learn to operate the equipment and read polymer line graphs. Through these experiments, I gained a wealth of knowledge about plastic that took me from knowing almost nothing about the material to being able to identify its type after seeing and touching it. Working in the polymer laboratory as a designer and adding creative ideas into the making process was intriguing. Through this process, I observed the difference between a designer and a material scientist in terms of the way we treated waste materials and realised the important role that designers play in solving the ocean plastic problem. This further led me to confirm that waste experiments are of interest for future research.*

*The realisation of recycling ocean plastic in different methods made me take a new look at the plastic material. Even waste plastic can be repurposed into decorative and functional projects, why are plastic products not used properly in the first place? Why are people blaming plastic for damaging the environment? Why is plastic "evil"? I* *sought to present the result of this experiment to the public and encourage them to question themselves, "which is evil, plastic or my behaviour?"*

# Chapter 7 Investigation on the experience of others – case studies and interviews

This chapter will analyse existing projects that focus on recycling plastic, zero-waste products and their social impact. The recycling methods used in these cases have been tested many times by different users, some of which have been put into the market, so the technologies are accessible and mature. Comparing this research with these cases can help the researcher effectively evaluate and summarise ocean plastic recycling methods. Some of these cases have already had a positive impact on specific communities in terms of environmental awareness from both business and non-profit perspectives. Therefore, the author will assess the approaches and results of environmental education and public engagement in different fields with different audiences through analysing “the experience of others”. Precious Plastic is a critical case to discuss in this chapter as it provides open-source knowledge and experience on both waste plastics recycling technologies and plastic awareness education. Five cases in different sectors related to Precious Plastic, including a non-profit charity, independent studios and a zero-waste retailer will be further analysed. Four of these are Scotland-based and their founders will be interviewed about their own experiences with plastic recycling and impact on clients’ environmental awareness and plastic-related behaviour. The Global Research & Innovation in Plastics Sustainability (GRIPS) 2021 conference that the researcher attended in March 2021 offered a comprehensive understanding of plastics from scientific, commercial and social aspects. Therefore, this chapter will end with a discussion of the influence of Smile Plastics on plastic recycling and the impact of WRAP on citizen behaviour. The researcher obtained the information of these cases mostly through their websites, social media and YouTube. When referencing “n.d.” or a reference appears only at the beginning or end of a paragraph, it means that some of the information in the paragraph came from the case’s official website or YouTube, and the author only uses one in-text citation to avoid repetition.

## 7.1 Precious Plastic (Precious Plastic, n.d.)

When it comes to recycling plastic from the designer’s and maker’s perspective, Precious Plastic is the most suitable case to discuss. The case of Precious Plastic is vital to this study because both projects focus on the three aspects – plastics, recycling and people – in addressing the plastic problem. Its mission is to make changes through recycling, making biodegradable materials and adopting zero-waste lifestyles. Furthermore, Precious Plastics, as an open-source project, creates and shares all of the recycling research and development outcomes for people around the world to use for free, because the team believes that knowledge is "an asset for humanity that should not have a price". It also forms a global community to encourage people to share and communicate their own recycling methods and awareness-raising events on the platform to reduce plastic waste.

### 7.1.1 Precious Plastic exists to reduce plastic waste

Precious Plastic has developed four versions in nine years. It started as a university project recycling plastic. Dave Hakkens, the founder, built and displayed the Precious Plastic Version 1 recycling machines at the Design Academy Eindhoven degree show in 2013 (Figure 80). He simplified the recycling process from complicated industrial systems by improving old electronics and using metal waste. Even in the first version, the entire recycling system included a great selection of recycling machines, capable of dealing with most plastic waste. It included a scale, a shredder simplified from an industrial one, a moulding oven converted from a home oven, an injection moulding machine, and an extruder. The project's potential was seen after three people replicated the machines independently (Precious Plastic, 2013).

*Figure 80. Precious Plastic Version 1, One Army, 2013.*

Precious Plastic Version 2 (Figure 81) included the same machines, but they were improved and refined by Hakkens and a team of five. The pieces of equipment were made modular (Figure 82) to be upgraded, repaired, and customised by users. The machines were designed using basic tools and local materials that could be found anywhere worldwide. It means everyone interested in the project or plastic waste could start the recycling journey from scratch and build the equipment themselves. This step was where Precious Plastic began to connect *people* to address plastic pollution. Besides, the range of products produced had increased (Figure 83). Goods made by Precious Plastic, such handles, containers, toys, phone cases and lampshades, offer more possibilities for recycling ocean plastic (Precious Plastic, 2016).

*Figure 81. Precious Plastic Version 2, One Army, 2016.*

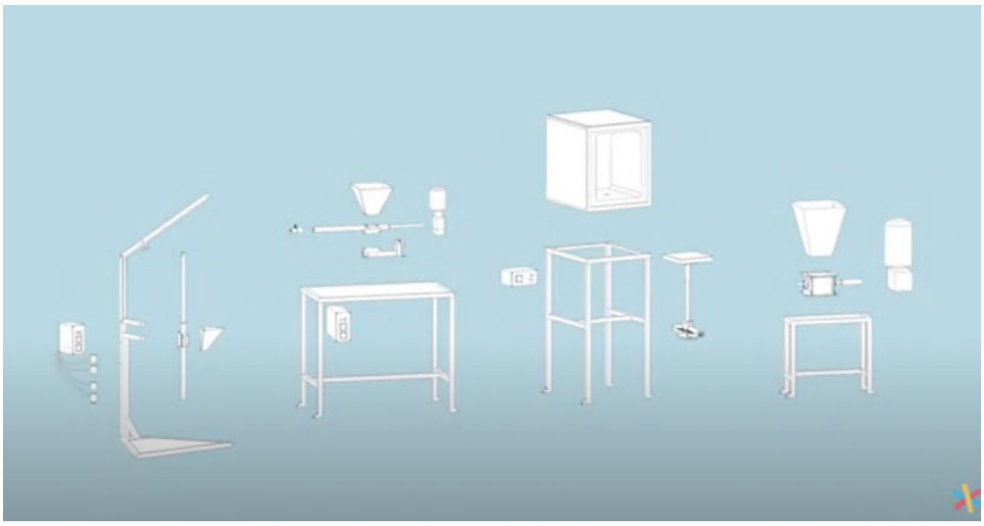


*Figure 82. Precious Plastic Version 2, One Army, 2016.*


*Figure 83. Precious Plastic products, One Army, 2016.*

The team grew more prominent and released Precious Plastic Version 3 – Plastic Recycling Workspace (Figures 84-85). This version aggregates all existing equipment and tools into a shipping container, which can be set up anywhere in the world, such as cities, landfills and beaches, meaning that the recycling process could take place on the spot, helping to tackle some of the severe plastic pollution areas and at the same time increase local's income (Precious Plastic, 2017).

*Figure 84. Precious Plastic Version 3 (1), One Army, 2017.*

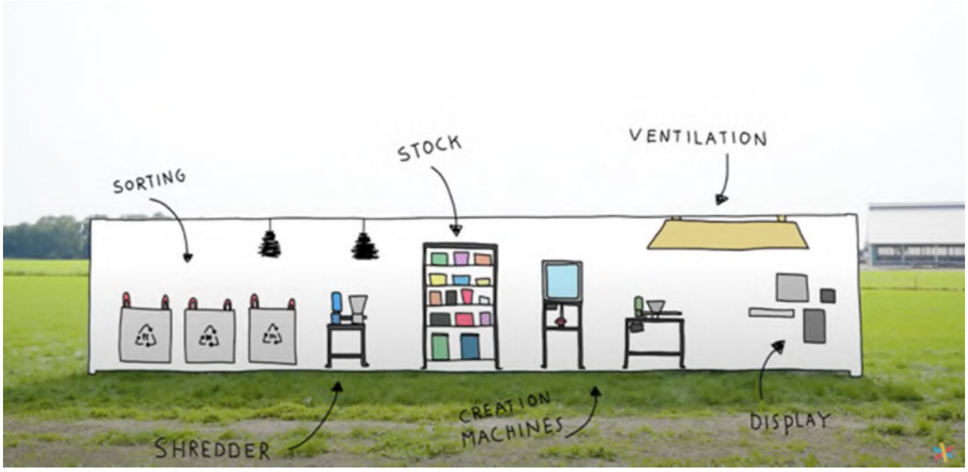



*Figure 85. Precious Plastic Version 3 (2), One Army, 2017.*

In Version 4, 112 people from around the world came together to work and upgrade each recycling machine to meet a higher and wider range of needs. The team also introduced a sheet press machine that could press high-quality sheets to produce a wider variety of products. For example, furniture and constructional parts, along with various functional products, can be made to suit various demands (Figures 86 - 87; Precious Plastic, 2020).

*Figure 86. Precious Plastic Version 4 (1), One Army, 2020.*

*Figure 87. Precious Plastic Version 4 (2), One Army, 2020.*

Due to limited equipment, this study did not use the method of injection moulding, and the study of Precious Plastic filled this gap and proposed the possibility of injection moulding ocean plastic. According to the experimental results of this research, ocean plastics can be recycled using all Precious Plastic machines and can be used to manufacture products made with Precious Plastic techniques, bringing more possibilities for repurposing ocean plastic (Tables 5 - 6).

**Table 5**

Product comparison

| Products categories | Precious Plastic | Ocean plastic |
|---|---|---|
| **Panels, sheets and blocks** | Yes | Yes |
| **Furniture** | Yes | Yes<br>*Increase thickness for furniture like chairs that supports heavy objects* |
| **Jewellery**<br>*Including watch, glasses* | Yes | Yes |
| **Lights** | Yes | Yes |
| **Small products**<br>*Carabiner, socket, candlestick etc.* | Yes | Yes |
| **Exterior products**<br>*Swing, bench etc.* | Yes | Yes<br>*Increase thickness for products like benches that supports heavy objects* |
| **Household products**<br>*Basket, handle, coaster, clock etc.* | Yes | Yes |
| **Entertainment products**<br>*Toy, chess, skateboard etc.* | Yes | Yes |
| **Building blocks and beams** | Yes | Very likely, but it requires experimentation |
| **Stationary** | Yes | Yes |

**Table 6**

Equipment and technique comparison

| Equipment and technique | Precious Plastic | Ocean plastic |
|---|---|---|
| **Injection moulding** | Yes | Yes |
| **Sheetpress** | Yes | Yes |
| **CNC carving** | Yes | Yes |
| **Sheetpress & bending** | Yes | Yes |
| **Saw, drill and screw through** | Yes | Yes |
| **Polishing** | Yes | Yes |
| **Zelenew extrusion (Figure 88)** | Yes | Yes |

Precious Plastic Universe, including roles of collection points, machine shops, workspaces and community points, is created to make plastic recycling more accessible and affordable. Each role can focus on only one part, working with other parts to form a complete ecosystem that makes the Universe both globally and locally connected. The team created Starter-kit with all the technical and business information (i.e., machine blueprints, floor plans, video tutorials and business plans) for each role to start to build the recycling community (Precious Plastic, 2017).

Moreover, an online community is created to discuss and share ideas, insights and developments. Precious Plastic has brought environmentally conscious people from all over the world together online and spread the knowledge about recycling plastic waste to a broader audience over time. People can show their interest in recycling plastic by “raising their hand” on their location on the website map and potentially form a local recycling community with those who also raised hands in that area. The online community also includes Bazar, a marketplace, where people can buy and sell machines, shredded plastic and products. (Precious Plastic, 2017).

The Precious Plastic Universe and community are the ideal platforms, together with the workspace, offering a potential solution for some coastal areas to engage locals in the ocean plastic recycling process because recycling tasks are broken down into small parts that people can choose according to their interests and abilities. With beach clean-up activities available worldwide, it is not difficult for the collecting to sustain. Locals could benefit from turning waste materials that would potentially lay on their beaches for hundreds of thousands of years into something valuable. Even if some coastal areas do not have the capacity to install all the recycling equipment, a shredder only workspace can be set up to shred the plastic collected from the beach and sell it on the Precious Plastic marketplace.

However, sorting will be the first challenge facing an ocean plastic collection point when the recycling codes are missing from the waste. It requires the collection team to learn how to distinguish different types of plastics. There are various ways to identify different kinds of plastic without using the differential scanning calorimetry technique. For instance, a floating test can distinguish plastics by density, and a burn test can distinguish plastics by smell, behaviour, melting point and flame (Coxon, 1993). It was observed from the experiment of this study that after a preliminary understanding of plastics, it is possible to distinguish most types of plastics because different plastics generally look and feel different. There are limitations to these methods due to degradation and the addition of fillers, pigments and plasticisers to some plastic products (Coxon, 1993). It is imperative to remove plastic from the marine environment first, and those highly uncertain types can be separated for subsequent experiments or sent away to industrial recycling plants.

The beauty of implementing ocean plastic recycling in a local community is that different areas have different cultures, histories, handicrafts and customs, which produce unique products and services. Every place will produce a particular colour, shape and style of products with local characteristics embodied. For instance, Zelenew from Ukraine created the Zelenew extrusion technique (Figure 88) that extrudes patterns in three dimensions. Over the years, more and more people have been using this technique worldwide to create unique designs from lampshades to containers such as vases, bowls and trays.

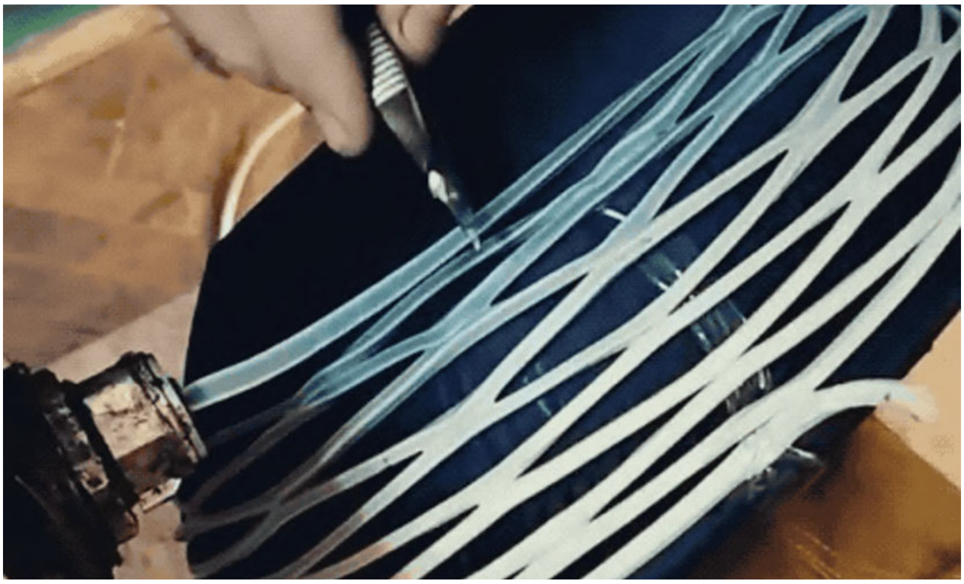


*Figure 88. Zelenew extrusion technique, One Army, 2017.*

As mentioned in the previous chapter, residents in the Isle of Harris repurposed some plastics washed ashore and sell them at the local market. The existence of these products proves that coastal residents consider ocean plastic as a valuable material and resource and are aware of re-using. However, there is a limit to what they can do with ocean plastic, relying solely on cutting or splicing. If there were a Precious Plastic Recycling community and workspace with machines and tools available, almost all types of ocean plastic could be recycled, and the range of products would be much greater. Such a set-up will not only help address the ocean plastic problem but also provide more employment opportunities and financial benefits.

Thousands of people involved in the Precious Plastic Community have been using their “creative genius” to tackle plastic waste, forming a “global Precious Plastic movement” (One Army, 2020). Based on data from more than 1,000 people from over 500 workspaces in 102 countries who participated in the first Precious Plastic Global Impact Survey, over 540,000kg of plastic was recycled by all the Precious Plastic workspaces a year (One Army, 2020). Over 10% of the workspaces were in school and university settings, and 66.3% of workspaces built the machines themselves (One Army, 2020). These figures confirm how effective and necessary it is to spread awareness and take action on recycling plastic through educational methods and activities. Plastic awareness education is not limited to the campus; it can take place anywhere in any form. In fact, it also indicates how “contagious” recycling plastic with aesthetic mind is. Precious Plastic and all the users use their intelligence and creativity to turn waste plastic into “precious plastic”, showing consumers that plastic has potentials far beyond sitting in landfills or on beaches. Through the uniqueness and preciousness, the repurposed products elicit curiosity and conversation, attracting more and more people to join the effort.

### 7.1.2 The environmental and educational influence

It is not just those interested in recycling or aware of plastic problems that need to learn relevant knowledge; everyone does. It does not mean that everyone has to invest in recycling machines or become an expert in recycling, but rather gain a more comprehensive understanding of plastics. People should know why recycling is important, why the use of raw plastic should be reduced and why plastic waste is valuable, thus forming a more responsible plastic-related behaviour. Bernini (2021), who has been working for Precious Plastic since version 2 and is responsible for design and strategy, stated his opinion about plastic education:

> I am always baffled at the general ignorance (lack of knowledge) surrounding plastic as a material, as a problem and its consequences. But this lack of knowledge can easily be addressed by a decentralised and creative army of recyclers. Explaining in simple terms and with a positive attitude what plastic is and how it can be used resourcefully can go a long way to change how our society looks at and treats plastic.

Precious Plastic's educational model is that the team educate and instruct recyclers, and recyclers educate society at large (Bernini, 2021). Precious Plastic workshops around the world have been educating the broader community about plastic, the problems it poses to the environment, and how to recycle plastic creatively and solve the problem collectively. This section covers environmental education projects carried out by the Precious Plastic team and community members around the world.

*Regional pilot projects*

Precious Plastic, in collaboration with the UN, conducted the first pilot project in Kisii, Kenya, where they converted an old chicken shed into a Plastic Recycling Workspace to address the large amount of plastic waste dumped from the city (One Army, 2017). Due to the lack of knowledge and techniques for recycling in the area, waste would often enter the local food chain, flow into the river and sometimes get burned. Three Precious Plastic members built the workspace using local materials and old electronics in ten days with some local help. They built equipment from old washing machines and bicycles so the washing machine cylinder would roll from people pedalling the bike to clean up the plastic waste – different situation forms different solutions. In addition to the physical set-up, the team also delivered the knowledge of how to run the workspace to locals. With unemployment in Kisii as high as 60%, the pilot project would be conducive to reducing plastic waste from the waste stream and enhancing the income for the locals, especially the youth groups. Locals created new methods of making goods to suit community needs. For example, one of the locals combines extruding and weaving together and makes baskets, containers, and chain-link that can be used on the farm. Products made in the workspace were showcased at the Sustainable Business Conference (Figure 89) and Nairobi Design Week, gaining greater exposure and attracting more people in Kenya to get involved. As a result, students at the International School of Kenya started the Plastic Rafiki project to seek design solutions to the plastic waste problem in Kenya (Plastiki Rafiki, n.d.). According to a former student, the purpose was to understand how a project like this could impact real people in the real world (Kiruga, 2021). They built and modified the machines to better suit a Kenyan context. So far, this student-led project has fabricated 21 machines, set up three workshops, processed 2,300kg of plastic waste, created 68 product designs and provided 23 job positions; and these numbers are increasing over time (Plastiki Rafiki, n.d.). The workspaces expanded in East Africa to Uganda and Tanzania, and locals have set up exhibitions and made products such as household and decoration items, face shields and teaching aids (One Army, 2021).

*Figure 89. Sustainable Business Conference, One Army, 2018.*

A year later, the Precious Plastic team went to Puerto Varas in Chile and set up a women-run workspace to tackle local plastic waste problems. The women involved in the project range in age from 25 to 84, and everyone was able to understand the knowledge, ideas and techniques and create valuable products out of plastic waste (One Army, 2018). With more severe plastic pollution and less material prosperity in these developing countries, people seem to contribute more to the recycling business when they see the possibilities and potential to make a living out of it, and they create their own methods based on local handicrafts combined with Precious Plastic techniques to make unique products that are only available at that specific area. The challenge that these pilot projects and Precious Plastic are all facing is how to create critical drives and incentives because ethical or environmental reasons alone will not last long (One Army, 2018). These projects are also strong evidence that, with the proper knowledge, plastic recycling can be adapted to different situations and has the potential to reach everywhere around the world.

*Educational workshops*

Precious Plastic workshops have been held for all ages in various venues, including schools, offices, beaches and museums. The pandemic forced some workspaces to shift the educational workshops online. The workshops, sometimes theoretical and sometimes practical, cover topics including plastic problems, waste hierarchy, plastic types, knowledge about existing local public recycling, plastic safety, plastic waste's impact, and design and machine knowledge. The practical workshops can be as simple as teaching participants to make unique tote bags from ironing colourful disposable plastic bags. Theory-based workshops can be in the form of lectures or seminars to guide residents to learn and support existing local recycling systems.

Precious Plastic workshops take place on almost every continent around the world, sharing the same goal of educating society about plastic problems but with diverse creativity based on unique community situations (Bernini, 2021). For example, Precious Plastic Parafitt, based in Budapest, Hungary, organises workshops with people who have intellectual disabilities. In Asia, in addition to holding workshops in schools and events, Precious Plastic Malaysia has enhanced the geographical coverage of educational workshops to achieve the goal of "where we go that is where we educate" by building a green truck that capsules all the recycling machines (Precious Plastic Malaysia, 2021), equivalent to a miniature mobile version of the Precious Plastic workspace. There are workshops in China, Spain, Bangkok, Germany, Korea and so on, working with schools, companies and the more extensive community to educate people on the potential of plastic waste.

One of the Precious Plastic workspaces in Porto, Portugal, *VIVA Lab*, was created to promote "a culture of education, design and innovation by turning thinking into doing in cities" (VIVA Lab, n.d.). The lab works closely with schools and universities to rethink the future of education by implementing new educational programs. One of the lab's primary focuses is supporting the understanding and fostering of the Maker culture. In addition to popular digital technologies such as 3D printing, laser cutting and CNC, the Precious Plastic recycling workspace is available for participants as young as six years old to start their maker journey. Maker experience is necessary to be introduced to children at a young age when they begin to feel curious about everything in the world to cultivate their creativity and imagination, as well as sustainability. In particular, the combination of hands-on and plastic recycling can foster a sense of plastic responsibility in children from an early age. As this study has proved the feasibility of 3D printing and laser cutting recycled ocean plastic in Chapter 6, it is essential for workshops with digital tools like VIVA Lab to include recycling ocean plastics in the engagement content to educate participants about the negative impact and the potential of ocean plastic.

*Plástico Precioso Uramba (n.d.)*, a precious plastic workshop located on the west coast of Colombia off the Pacific Ocean, has sensed the worrying plastic pollution on the beaches and is using Precious Plastic recycling methods to reduce local ocean plastic waste. With no road communication with the port of Buenaventura, rubbish trucks or sanitary landfills, the island relies on boats to provide food and supplies for daily life. In addition, the tributaries of the Uramba River bring a large amount of plastic waste due to the high and low tidal movements, resulting in a worrying accumulation of plastic pollution in coastal areas. Burning plastic is what Uramba had always done to deal with waste plastics. Plástico Precioso Uramba believes that burning plastic should not be an option, and the habit this community has been forced into must change. It aims to transform plastic waste into valuable objects and is interested in educating locals, children and tourists about the use of plastic waste and establishing a model in the community to guide local areas towards a plastic-free environment. The workspace organises fun and educational local ecotourism experiences in conjunction with plastic recycling practices and uses social media platforms to showcase recycled products and share information about the local ecosystem and plastic impacts on the local marine environment.

*Off Cut Studio (n.d.)*, based in Leeds, England, is a member of the Precious Plastic community. Unlike most members recycling domestic plastic waste, Off Cut Studio focuses mainly on repurposing acrylic waste from design studios. It collaborates with UK based jewellery studios to collect and recycle their acrylic off-cuts. After self-developing a thorough recycling process and making unique and creative products (mainly jewellery; Figure 90), the studio gained many audiences and clients who are willing to learn the knowledge and technique. It began with training individuals and studios, then moved online in 2021 to organise bigger-scaled workshops with participants from around the world. Even though online workshops have limitations, such as lack of physical interaction with the materials and machinery, they are more convenient and financially sustainable because the registrations are usually cheaper, and there is no need to travel. Thus, it is suitable for people from different places to participate without moving around. The work and design that Off Cut Studio produced had a significant influence on the material design for the participatory workshop in this study. The researcher took inspiration from this case to design jewellery components that workshop participants could assemble themselves and received an incredible amount of positive feedback.

*Figure 90. OCS earrings, Off Cut Studio, 2021.*

*Plastic Shed* is a Manchester-based Community Benefit Society. It was built around education and creativity to provide opportunities for everyone in the society to work together on reusing plastic waste. Team members are from different backgrounds, including filmmaking, well-being, environment and creativity, and art, but all have the same goal to address the current plastic problem. It organises personalised workshops for schools, business teams and community groups and runs open-to-all drop-in tutorial sessions for locals to participate in for free and turn their plastic waste into new things. They believe that young people can be very passionate about recycling plastic waste and protecting the environment when they are aware of the issues. Moreover, a workshop for business teams could be beneficial in providing a creative break during intense workloads, motivating team members, whilst also acting on plastic waste problems. It is also advantageous to form communities towards “a more equal and sustainable society” (Plastic Shed, n.d.). The organisation had worked with unemployed women and youth groups. “We recognise that everyone has creative potential with the right support” (Plastic Shed, n.d.). Plastic Shed organised online workshops and tutorials during the lockdown period and found that creativity and purposeful activities at home played a significant role in taking care of people’s mental health during difficult times. The use of non-medical interventions, such as domestic crafting to address the broader social health determinants, enables patients to manage their conditions and closes the gap between the community sectors and health services (South et al., 2008; The King’s Fund, 2017; Burns and Van Der Meer, 2021).

The cases discussed in this section attempted to solve the plastic problem in different social aspects, involving school children, underprivileged groups, designers, makers, local communities and tourists, from different perspectives, including technology experience, social health factors, creative business, environmental education and local pollution. Whether online or offline, the impact of plastic education workshops on the environment is favourable. Offered with both options, the public has the opportunity to be inspired by the transformation of global problems from being useless to precious and to be involved in different actions to address plastic pollution. The successes of these workshops suggest that plastic recycling and education can be integrated into different areas to penetrate all sectors of society, reach a wider audience and achieve a broader meaning. The fact that these events are actively accepted by participants opens up great possibilities for using ocean plastics as an educational tool in different settings around the world.

## 7.2 Precious Plastic related projects and interviews

This section includes five cases related to Precious Plastic to varying degrees. When looking through the Precious Plastic map, the researcher found a few Scotland-based workspaces. The researcher identified three for further contact by evaluating their social media and websites, namely Recycle Rebuild, Still Life workshop and DOBA studio, and conducted semi-structured interviews with the founders. Bambú Living Sustainably is an Edinburgh-based shop that sells zero-waste products and has been positively influencing residents to reduce their use of plastic packaging. Therefore, the researcher interviewed the two founders to understand public perceptions from a business perspective. Norwegian Trash is one of the few in the Precious Plastic Community that turn ocean plastics into products, so the author seeks to gain inspiration and comprehend different possibilities of ocean plastics through analysing this case.

### 7.2.1 Recycle Rebuild and interview (Recycle Rebuild, n.d.)

Recycle Rebuild is a Scotland-based non-profit organisation whose mission is to reconstruct regions after disasters by creating job opportunities, addressing environmental issues, empowering communities, and replacing supply and demand for some building materials and products. The team aims to form a circular economy system where the team identifies high-demand products and employs and trains community members to make products from up to 100% recycled waste materials, which is similar to the Kisii project in Kenya. Then the profits made from selling the products can be reinvested into growing micro-enterprises to meet the broader long-term demands of the region.

In addition to disaster-prone areas, there are many regions where people lack adequate housing mainly due to poverty. According to United Nations (2019), around 1.6 billion people around the world (more than 20% of the world's population) might live in substandard housing, meaning that more buildings are needed so that everyone in the world could have a decent place to live (Habitat for Humanity, 2012; Recycle Rebuild, 2019). To design more affordable, durable and environmentally friendly building materials, Recycle Rebuild collaborated with Precious Plastic to design Lego-style building bricks out of plastic waste (Figure 86). Only a hammer is needed to connect the bricks, making it feasible for anyone without professional construction experience to build. The bricks can be used as load-bearing units alone or in conjunction with standard building materials such as wood and metal. The team believes that the bricks could be used to provide low-cost but high-quality sanitation facilities, low-income housing, fast-built post-disaster shelters and earthquake-resistant public buildings in the right circumstances. Moreover, the bricks can be deconstructed, rebuilt and recycled with little effort.

Like all other products that Precious Plastic has made, users can access the detailed "how-to" instructions for the bricks on the Community page for free. Different studios have now used the brick design, not just from low-income or post-disaster regions. The most successful and impactful example is the collaboration between a France-based art and exhibition studio, Atelier Samji, and Adidas. The collaboration created four exhibitions and showrooms for Adidas Originals' Clean Classics and END PLASTIC WASTE campaigns, recycling hundreds of kilograms of plastic waste (Figure 91). As a multinational corporation, the world's leading sports brand has used recycled materials in some of its product lines for years. This time, Adidas integrated recycled display objects into the showroom to echo the recycling theme of the campaign, giving a more complete feel to the product line. While following sustainable and eco-responsible design trends may be a marketing strategy for Adidas to attract a more extensive customer base, campaigning with entire recycled showrooms and products can positively impact environmental issues on both customers and competitors. After a "sober, elegant design", plastic waste was transformed into both decorative and structural products, from a brick designed for disaster-prone areas to shopping centre showrooms. Even if the collaborations and campaigns only took place in selected stores, they proved the possibilities and potential of replacing conventional displays with recycled plastic material, proposing a more environmentally friendly alternative for the whole retail industry. Moreover, the display of plastic bottles, particles and bricks serves as an educational medium to show customers the recycling process and how plastic waste can be valuable and beautiful, inspiring them to look for recycled products in their lives.


*Figure 91. Recycled plastic installation at Adidas, Samji Studio, 2021.*

Recycle Rebuild's most impactful work is Project Dominica. The team travelled to Dominica to help locals recycle plastic relief supplies that could not be dealt with properly after Hurricane Maria. The mission focused on addressing plastic pollution while educating and training locals about plastic waste and recycling. The team set up a recycling centre in Portsmouth, the second-largest city in Dominica, for surrounding communities to collect, sort, shred plastic waste and then produce new products based on community needs. The project organised five community clean-ups, collected 5,545 kg of plastic waste and contributed 4129 volunteer hours (Recycle Rebuild, 2019).

As a Caribbean island country with beautiful natural views, Dominica is a destination for ecotourism and scuba diving. Developing tourism from recycling is one of the main drives of Recycle Rebuild in Dominica. The team collaborated with Champs Hotel in Portsmouth and a certified dive instructor, Kayla Rognlie, to demonstrate the harmful effects of plastic waste and the process of converting the waste into marble-look floor tiles and jewellery (Anichi Development, 2018). Rognlie has been leading beach clean-ups in Dominica, where she has seen first-hand harmful effects of plastic on marine life and the environment. With Recycle Rebuild involved, she said:

> we can make our clean-ups closed loop, which means that every underwater clean-up, every dive against debris, every beach clean-up we do, we take all of those recyclable plastics, anything that is not contaminated by salt, or oil or anything like that and we are able to recycle them. It has been a huge community-building opportunity.
>
> (Rognlie quoted in Anichi Development, 2018)

The Marketing Manager for Anichi Development, Nisha Mc Intyre, commented on the collaboration with Recycle Rebuild:

> recycling and repurposing Dominica's waste plastics strengthen the island's resilience and create new alternative forms of employment for Dominicans. It is an initiative with tremendous socio-economic potential and one that also benefits Dominica's tourism product.
>
> (Intyre Quoted in Anichi Development, 2018)

The team also organised educational recycling activities at St. John's primary school in Dominica, and the students showed great enthusiasm by collecting approximately 30,000 bottle caps in a month.

Existing literature indicated that visible ocean plastic waste would reduce tourists' satisfaction to some extent (Krelling, Williams and Turra, 2017). Thus, in places like Dominica, with locals' and tourism professionals' joint effort, implementing a plastic recycling hub in tourist attractions will not only boost tourism by removing plastic waste off the beach but also provide the tourists with more fun and educational ecotourism activities.

In order to understand more about how the organisation impacts the public and communities, an interview with the founder, Rory Dickens, was conducted on 20th May 2021. The interview also attempts to grasp Dickens' experience of recycling as an architect (from a designer's perspective).

Dickens (2021) believes that designers hold the key to addressing waste and climate change, and they have the ability to "posh the waste up". He said:

> you can approach a similar task from a different aspect, and I think people understood that designers kind of create more clever ways of thinking about it. I mean art, fashion, all these kinds of things help think about the problem, and whether or not, designers are creating the next machines that solve these problems. Like Tesla, it's the idea, with the right amount of funding, the commercial venture that uses *design* to solve the problem.

When asked his opinion of plastic material, Dickens believes that plastic is a valuable material, and the way people design and use plastics is sometimes wrong. He suggests that designers need to change, and the system and society need more change. When asked about behaviour change, Dickens offered an interesting idea, "one thing I would say is if you want people to change, after the natural disaster is the best time because you basically reset their world. But the solution must align with the hierarchy of their necessary need". He suggests that many sectors should work together to achieve environmental and sustainable goals by using an example in Dominica:

> what was also interesting is you had a lot of aligning with other NGOs. For example, the Red Cross is not an environmental charity, but they had to clean up the waste and the street trash to reduce dengue because of the increase of the mosquitos. Then you could [induce locals to clean up the litter with] a sustainability message about health, "what hidden in the packaging is going to kill your family", which makes it more adoptable.

Dickens also points out the different public perceptions in developing and developed countries. Residents in developed countries see recycling products as an attractive trend, whereas re-using is a livelihood choice in many developing regions. He noticed small changes in people's behaviour after environmental education activities, such as stopping using a straw at a bar, but he considers it difficult to monitor real and big changes. Dickens believes it is a potential market to turn waste plastics into souvenirs targeting westerners because recycled products are more expensive than mass-produced ones. He also added:

> first, residents understand the entire value and then realise it's worth more because of all the statements it's going to make. Then it becomes fashion. We all know that clothes all cost the same price to make, but a Gucci bag is way more expensive than you can get from Primark. That's the same message. You are using that kind of buyer attitude that definitely works.

Strategies to promote recycling in different places should be designed according to the local situation. In developed countries where many people pursue lifestyle and quality, recycled products should be developed in this direction where demonstrates the "statement" and "fashion". In many developing countries where the problem of food and clothing is not solved, recycling should meet people's needs and become a source of livelihood. (See the full transcript in Appendix 3)

### 7.2.2 Still Life Workshop and interview (Still Life, n.d.)

Still Life is a Precious Plastic community member and a design workshop based in Glasgow, Scotland, making furniture and other household products (Figure 92) from recycled plastic and locally sourced hardwood. Still Life works closely with local communities to source household and commercial plastic waste. The studio also collaborates with other designers, artists and makers to expand their product range and impact. So far, the studio has made home products such as tools, candlesticks, vases, dough scrapers, coasters and trays. One of the most attractive aspects of the studio's creation is its ability to create unique and aesthetic patterns while retaining traces of the plastic's history (Figure 93). This conveys to customers awareness and a sense of pride in turning waste into art, and this "aura" will then be displayed in their homes after purchase. When an object looks attractive and has obvious traces of recycling, it opens up an opportunity for a conversation between the owner and the visitor, offering a potential communication to raise awareness. An interview with the two founders was conducted on 6th May 2021.

*Figure 92. Stools, Still Life workshop, 2021.*

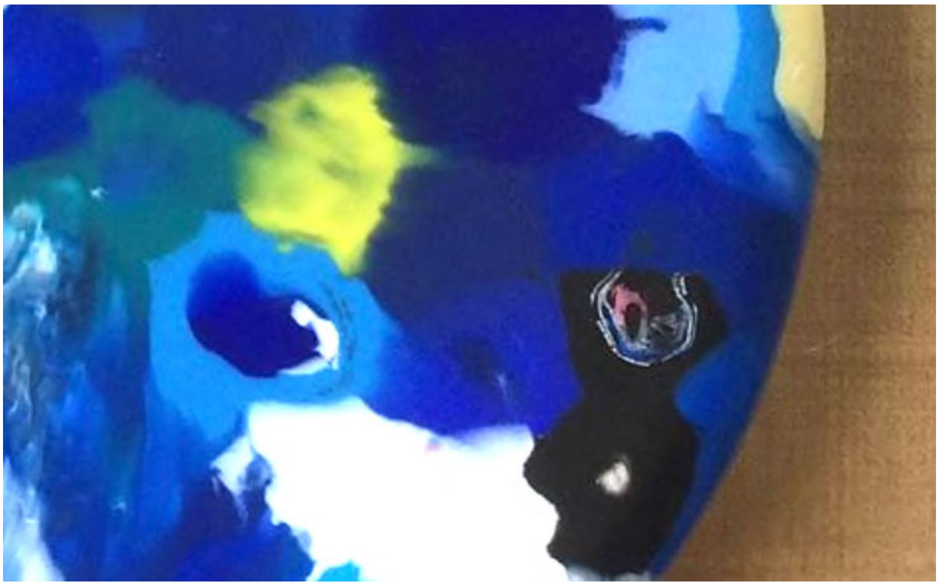


*Figure 93. Pepsi logo on the stool, Still Life workshop, 2021.*

Like the researcher, the two designers also established a personal connection with their recycled work (Still Life, 2021). “The products sell out very quickly every time, and it’s like a reward when you see products sold out. You are like, oh my god, people do actually like it.” They also added:

> I think we got attached to the stools. We definitely have favourites. Because of the way that you melt the plastic into the mould, it’s almost a bit like painting. We kind of treat it like that making each one. That’s the really fun part. […] We’ve got rough ideas of how things will look when they come out of the oven, but there is always the element of chance, kind of like ceramics. You’ve got an idea, but you never know exactly. Part of it is up to the kiln, but it’s the oven in our case. Yeah, but that’s part of the fun. It’s always exciting opening up the mould.

The workshop receives plastic waste from various sources, such as local shops, family and friends. They also have clients who purchased products from them donating their plastic waste, “making it more circular”. When asked their opinions about plastic material, they said, “plastic is a good material. That’s part of the problem. It can be used for so many things, and it’s so cheap. It’s a battle. There just need more laws around, like the labelling of it, and where it goes after. There needs to be more accountability.” The designers seek to create something that can last people’s lifetimes and can be passed down to the future generations, like furniture or ceramics. “We also want people to question what the stools are made of. […] When they got it in their house, people see it, it has a bit impact hopefully, maybe make other people start to think about how they use plastic.” They noticed their behaviour change after seeing the amount of plastic waste in one shop where they collected waste plastic from and hearing the number of plastics in the sea and landfill. They also noticed a shift in consumer perceptions of plastic waste through their design and creation. (See the full transcript in Appendix 3)

### 7.2.3 DOBA Studio and interview (Doba Studio, n.d.)

DOBA is a Precious Plastic community member and a plastic recycling design studio based in Edinburgh, Scotland. It was founded by two Polish designers who initially designed a series of watches out of plastic waste for the undergraduate degree show

(Figure 94). Their passion for reducing plastic waste and changing people's perceptions continued after designing the first product. The studio was built from scratch using Precious Plastic open resources. It has worked with local shops and communities to collect plastic waste, such as milk bottles and bottle caps. After the watch design, the studio has been making coasters and selling them at local cafes where they collect plastic waste from and Bambú Living Sustainably, a local zero-waste market stall. The studio runs an Instagram account and a website to disseminate the work, sell products and educate viewers on plastic recycling and zero-waste lifestyle. Besides, the video they made, *Making Coasters from Recycled Plastic Bottles and Lids*, has over 220,000 views with over 100 comments on YouTube (Doba Studio, 2021), which significantly impacts the public about plastic waste recycling. Not only are the products made from waste, but the wrappings are also made from wasted food sacks. The studio will be organising plastic recycling workshops after the pandemic.

*Figure 94. Recycled watches, Michalak, 2020.*

An interview with the founder was conducted on 25th April 2021. As the studio was opened in the middle of the pandemic and did not have the opportunity to have direct contact with the public, Urbanski (2021), the founder, mostly talked about recycling, his own behaviour change and the interaction with locals who donate waste plastics. As for recycling, he finds PET toxic and had no knowledge and technique of recycling it properly, which is consistent with the author's experiment. He recognises the ocean plastic problem but considers it as a challenging material to work with. He also noticed the problem of contaminants caused by using one shredder to process everything, which was also an unavoidable issue of this study. When asked his opinion of the plastic material, he answered:

> when it comes to making more plastic, that's not a good idea, so that's why I'm using the plastic that was already created, which is not used anymore by anyone. […] So, for me making more plastic out of fossils and fuels, this is evil – this is a very bad idea but working with plastic waste is great. I'm not sure about the fumes that I create during the process, but I think it can be solved and using some filters. I think it's precious. We should definitely not bury it under the ground but use it for other ways.

Urbanski (2021) also confirmed the emotional connection that the author discovered between the maker and the finished product when it comes to recycling. He said:

> I don't know if you see our website, every single tile, you can buy a set of tiles or individual ones that are more unique, I choose them to be sold to be unique, so I named them, every single one is named differently (Figure 95). So, the moment I'm choosing the name for it, it is emotional.

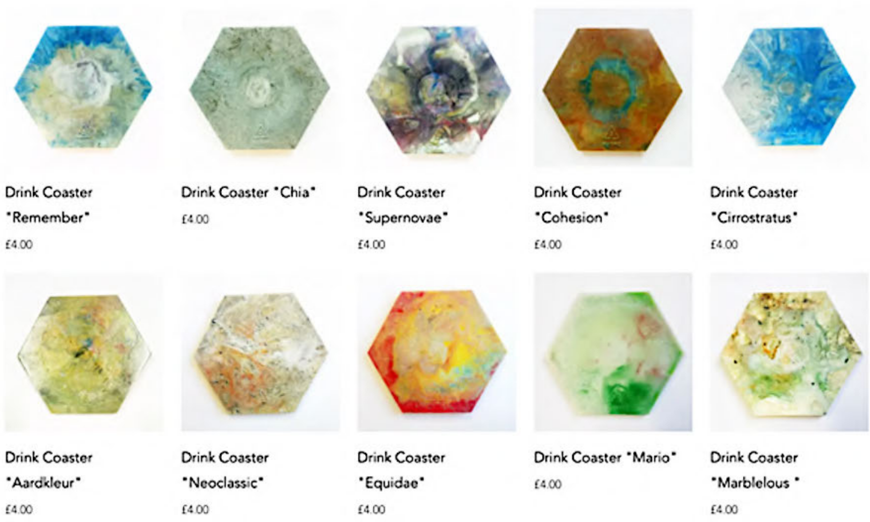



*Figure 95. Named coasters, Doba Studio, 2021.*

He believes that he develops more and more positive plastic-related behaviour while recycling. “If I buy anything made of plastic, it has to last at least two months. So yes, my behaviour totally changed after I realised how much plastic is wasted. I’m like not totally but 98% plastic-free now.” He suggests, to influence others to adopt positive behaviour in terms of plastics, through action is better than through pure words:

> I’m influencing them (family and friends) without saying anything but just showing me as an example, like you can buy better food when you go plastic-free, so that’s the way I’m influencing my family. When it comes to plastic, we need time to understand that plastic is bad.

He also adds that people who bring plastic waste to the studio are motivated to do so and spread positive words to others. He believes that as more people become interested in the topic, it will educate people to behave more responsibly and change their perceptions. (See the full transcript in Appendix 3)

#### 7.2.4 Bambú Living Sustainably and interview (Bambú Living Sustainably, n.d.)

Bambú Living Sustainably is an Edinburgh-based start-up founded by Simona Zhou and Michael Mangus to raise awareness of excessive plastic use and offer an alternative. It is also one of the shops that sell DOBA studio’s coasters, both online and at local markets. Simona has a clinical research background interested in improving healthcare and grows increasing concern about the negative impacts of massive plastic consumption on the environment, wildlife and humans. Understanding from a scientific perspective and being aware of the devastating consequences of plastic pollution, she created Bambú to provide a more ethical and sustainable lifestyle to consumers. The brand runs an Instagram account and a website to advertise the shop, sell zero-waste products and educate viewers on knowledge and tips about zero-waste lifestyle. It also owns stalls at pop-up events and two local markets, Leith Market and Leith Community Croft Market, two major and popular markets in Edinburgh. Their business model has been raising public awareness of reducing plastic consumption, attracting people around Edinburgh (locally) and Europe (online) to shop in a zero-waste style, changing the way they and their family and friends live with plastics. Even though Bambú does not recycle plastic waste or conduct workshops, its owners constantly interact with the public with their no-plastic lifestyle influence and assess their responses. In the absence of workshops and direct contact with the public during the pandemic, understanding activities that still have the opportunity to interact with and influence the public is beneficial to investigate public perceptions.

An interview with the founders was conducted on 20th May 2021. When asked what more effective way is to influence the public, they believe face-to-face conversation is more engaging – "it's a lot more tailored" while online platforms serve as a research medium where people can take time to learn, and it provides an impactful space when a situation like the pandemic occurs. They suggest that the public should be provided with more accessible options to tackle environmental problems. They have also witnessed the pattern that they influence clients of zero-waste and less plastic lifestyle, and their clients influence people they know. They added:

> I mean a lot of people came to us, buying gifts because we have a lot of locally made things. […] So, it's not just a gift; it's also kind of a way to say, "this is actually a zero-waste product; it's plastic-free". […] It's almost like the butterfly effect where our customers are impacting their friends and families by making them aware that these products are available.

They identify that this influence works both ways. Business owners influence consumers to adopt zero-waste lifestyles, which in turn increases the demand for zero-waste products, thereby forcing suppliers to reduce/eliminate wasteful packaging on their products.

They also point out that zero-waste is never completely waste or plastic free, it is an easy term to put people into the lifestyle, and "step by step they are transitioning to a more sustainable lifestyle". In the end, they added, "I think ultimately, it's better to turn off the tap, as people say not using plastic in the first place. Until then we also need to find some solutions of using and re-using that has already been generated."

Even though Bambú is not involved in plastic recycling work, the business approaches the problem from another angle – to stop the use from the origin. This example does not seem to be directly related to the other cases mentioned in this section, but they have formed a new module to collaborate together to tackle the plastic problem – raising awareness through recycling campaigns and products, changing public plastic behaviour, reducing plastic consumption and using zero-waste products. (See the full transcript in Appendix 3)

### 7.2.5 Norwegian Trash (Norwegian Trash, n.d.)

Norwegian Trash is a Precious Plastic community member and a plastic recycling and furniture design studio founded in 2019, based in Norway. Norwegian Trash springs from the environmental collective Nordic Ocean Watch (NOW) since 2014, processing marine litter by facilitating, organising and mobilising beach clean-ups. Norway is experiencing economic growth from fish farming, which has become one of the largest and fastest-growing sources of plastic waste. NOW has collected and sorted over 2.4 tonnes of marine litter and stored it in a barn in Hoddevika in Stadlandet. Giving new life to the plastic in the collection was the inspiration for Norwegian Trash. Norwegian ocean plastic is a free, short-distance resource that can be found along the entire coast. Resurface Table 01 is the first product that Norwegian Trash brought to the market from the Norwegian fishing industry (Figure 96). It has been nominated for the Dezeen awards under the sustainable design category.

*Figure 96. Resurface Table 01, Norwegian Trash, 2021.*

From waste plastic that no one wants, to a potential award-winning product, the Resurface Table 01 demonstrates that ocean plastic can become a resource and have a new life with design as a tool. Black plastics are the most abundant ocean plastic that the researcher saw during field trips and beach visits. Most of them exist in the form of incomplete large panels with unknown histories. However, black plastics were not the researcher's and other makers' favourite, as the colour was so dominating, and it was challenging to create an attractive appearance. Resurface attempts to create demand for black waste plastic and demonstrated that even the most unwanted plastic can be turned into beautiful, durable products. Each table is made from 20kg of ocean plastic, and like almost any product made from recycled plastic waste, there are slight imperfections such as air entrapment from production. However, the studio believes these blemishes tell the story of the journey from ocean plastic to a finished piece of furniture.

Awareness-wise, a third of Norwegian Trash profits go directly to their sister organisation, Nordic Ocean Watch, to fund their ocean awareness-raising work. The online shopping website not only shows product information but also sends out educational newsletters about plastic and waste. In addition, in collaboration with Nordic Ocean Watch, Norwegian Trash organises workshops and pop-up events to engage locals and tourists to raise awareness of Norwegian ocean plastic problems. The studio believes that hand-on experience is more powerful and effective to convey the knowledge and inspire people to take action to protect the sea. In August 2020, Norwegian Trash invited tourists and locals of all ages to participate in the pop-up ocean plastic factory event in Lofoten to sort, grind and melt plastic waste into new things. On Oslo's waterfront promenade, the same collaborators set up a plastic laboratory and workshop in a converted container to experiment with plastic types, production methods and design prototypes. People in Oslo are invited to watch, learn and contribute to the work.

The beauty of these cases is that every individual, business and organisation that join the effort to address the plastic problem interprets it differently, based on their background, experience and vision for the future. The multi-orientation paves the way for reaching and inspiring every aspect and corner of society to take feasible action.

### 7.3 Global Research & Innovation in Plastics Sustainability (GRIPS) 2021

The following case studies were discovered during the Global Research & Innovation in Plastic Sustainability 2021 exhibition and conference. The conference included a mix of academics and practitioners in the plastic industry. Smile Plastics is a well-known design studio specialising in producing recycled plastic panels, while WRAP is a charity organisation focusing on citizen science and behaviour change, and they both presented their business model and social impact at the conference. These two cases provide the researcher with new perspectives on assessing the commercial and public value of recycling plastics and responsible plastic-related behaviour.

### 7.3.1 Smile Plastics (Smile Plastics, n.d.)

Smile Plastics is a materials design and manufacturing studio making hand-crafted panels from waste materials (Figure 97). It was founded by two designers, Adam Fairweather and Rosalie McMillan, who have been working on sustainable design with waste materials. Unlike Precious Plastic focusing on passing on the knowledge, Smile Plastics is a profitable business that changes clients' perceptions around waste via innovation, offering a range of classic panels out of plastic waste, including banknote, electronic waste plastic (mobile phones, keyboards and fridge), wellington boots and water pipes, while also customising service with bespoke design. Besides, Precious Plastic focuses more on application possibilities while Smile Plastics works on creating different aesthetic patterns. The customised service offers either personalising panels to meet the client's design requirements in terms of application, quantities, colours and patterns or examining the client's waste streams and recycling them into panels.

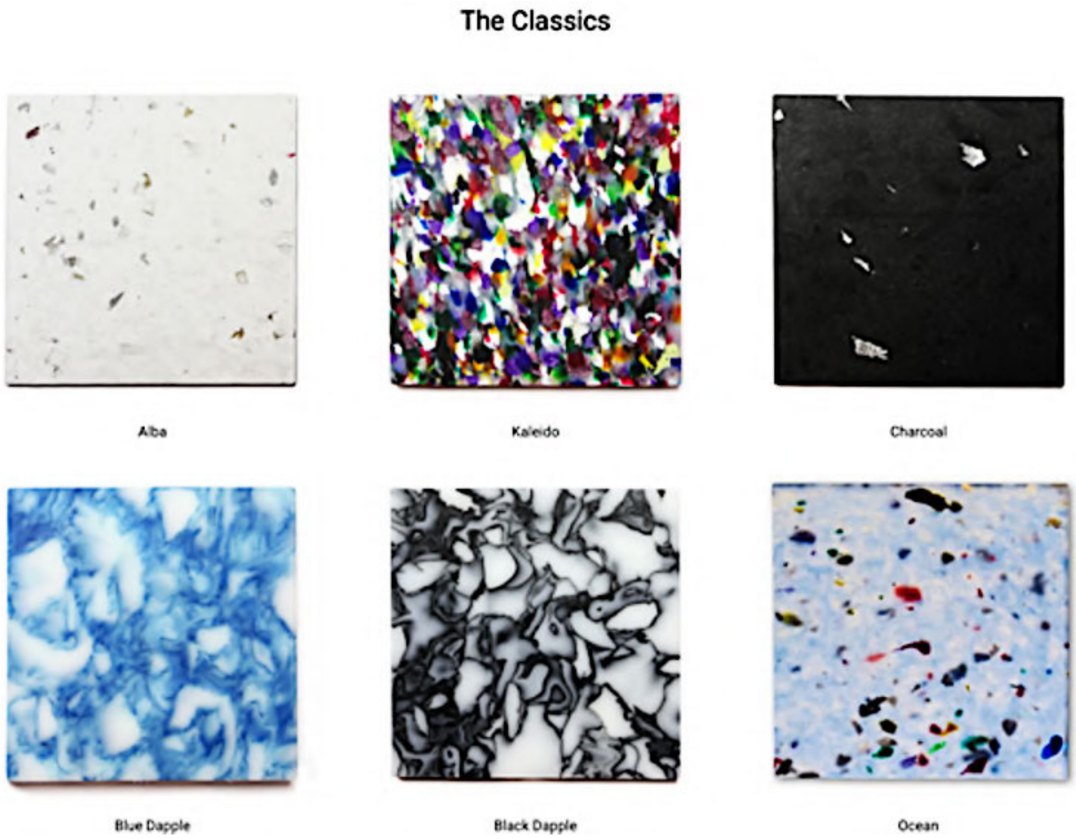



*Figure 97. Pattern ranges, Smile Plastics, n.d.*

Smile Plastics lists the benefits, properties and recommended applications of the recycled plastic materials they offer on their website (Figure 98). Based on the experimental results in this study, recycled ocean plastic materials have most of the benefits and properties that Smile Plastics does and can be used for all the applications Smile Plastic proposed.

| BENEFITS | MATERIAL PROPERTIES | POTENTIAL APPLICATIONS |
| --- | --- | --- |
| **Highly versatile**<br>Wide range of applications from products and furniture to large-scale sculpture and construction | **Hard, dense and rigid**<br>Though we can produce softer, rubber like Custom materials | **Store and Exhibition Design**<br>Plinths, displays, cabinets, signage and partitions |
| **Unique**<br>Good consistency between panels, but each one will have its own distinct pattern | **100% waterproof**<br>Mould and weather resistant | **Bar / Cafe / Restaurant Design**<br>Countertops, tabletops, partitions and bathrooms |
| **Handmade**<br>Each panel is composed by hand | **Solid and consistent**<br>Allowing you to have a solid and consistent decorative edge | **Office Design**<br>Tabletops, shelving, seating and bathrooms |
| **Sustainable**<br>100% recycled and 100% recyclable | **Moderate scratch resistance**<br>It can be refinished | **Product and Furniture Design**<br>From jewellery to homeware, to dining tables, both indoor and outdoor |
| **Easily cared for**<br>The materials are easy to work with, clean and maintain | **Moderate UV resistance**<br>Except our Alba material, which has lower UV resistance. It can be refinished to restore its original aesthetic | **Residential**<br>Panels, countertops, splash backs, cabinet doors, furniture and shelving |
| **No VOC off-gassing**<br>All the Classics range materials are made from chemically inert recycled plastics. There may be trace levels of VOC, as well as aromas from the products' previous life | **Reshaping**<br>Can be heat formed into shapes | **Recreation**<br>Playgrounds, swimming pools and spas |
| | **Finishing**<br>Matt / planed finish and can be polished | **Bathroom Design**<br>Bathroom panels, wet rooms, cabinet doors, counters, bathroom furniture and shelving |

*Figure 98. Benefits, properties and recommended applications, Smile Plastics, n.d.*

The studio aims to "use art and technology to unlock the hidden potential in recycling, and open people's eyes to the unexpected beauty of scrap" to inspire more people about sustainability and recycling. Design studios and other commercial businesses can purchase samples, while commercial materials library and university materials library can request them for free on the Smile Plastics website to learn and get inspired. Offering material libraries to universities is an advantageous approach to educate students and staff about the possibility of waste plastics. During the design student engagement activities, the researcher noticed that most students did not have the thoughts of using recycled ocean plastics because they were never informed of the potential of recycled materials during the design education. When they are presented with the information and knowledge, they show a great intention to practice.

One of the most iconic designs is the Pinterest award-winning bathroom vanity (Figure 99). It was a three-way collaboration – designed by an interior design studio, made by a cabinetry maker based in London with material supplied by Smile Plastics. The vanity has been well received by online/offline audiences. This project also paved the way for collaborations with other design and making studios and businesses, including furniture, kitchen and bathroom countertops, art exhibitions, stationaries, planters, building walls, park benches, etc. The studio has been commissioned to produce panels to make tables, chairs, counters and front signs for cafes, bars and restaurants. Besides, Smile Plastic materials were used at exhibitions, on coffee machines, in offices and hotels and by well-known brands such as Stella McCartney and Urban Outfitters.

*Figure 99. The Pinterest award-winning bathroom vanity, Smile Plastics, n.d.*

It created a series of panels for Selfridges at their London store, which is one of the most influential Smile Plastics commissions (Figure 100). Selfridges is one of the largest luxury department stores in the UK, with customers coming from all over the world and its most creative display team influencing many of its competitors. The displaying strategy may seem like greenwashing, as the only focus of a department store is consumerism. Whether the display theme is related to the environment or recycling, it is all about promoting consumption, contrary to sustainability and protecting the environment. Nevertheless, these products did have environmental advantages because when they had to be produced, recycled plastic and other waste, some of which was generated from the store, was used rather than raw materials, thus reducing the pressure on the environment and encouraging and inspiring competitors to follow this path. To expand the impact on the environment, shops should provide the customers with knowledge cards, leaflets or stickers about the histories of these display materials, thereby inspiring them to rethink their materials choice when they purchase new products such as furniture and what their daily plastic waste can be turned into.

*Figure 100. Selfridges commission, Smile Plastics, n.d.*

Just like what Smile Plastics mission says, the studio did "unlock the hidden potential in recycling and open their eyes to the unexpected beauty of scrap". The materials are solid evidence that waste can sometimes be more attractive than raw materials – it adds unique and advantageous character to the products, creates conversations, and inspires. Smile Plastics materials offer the possibility to replace conventional materials such as marble with recycled plastic waste, with many more options. The increasing number of collaborations between recyclers and other fields demonstrate that "recycled beauty" is being recognised by more and more industries. The eco-chic trend encourages an increasing number of businesses to offer consumers more sustainable choices and encourage them to take action too.

### 7.3.2 WRAP (WRAP, n.d.)

Warp was first founded in 2000 as a not-for-profit company and then became a charity after a decade. The organisation works with governments, businesses and citizens across six continents to promote sustainable resource use and waste material re-use through "product design, waste minimisation, re-use, recycling and reprocessing of waste materials". "Tackling a single part of an issue can just move the problem elsewhere." The charity aims to develop an approach that takes the whole system into account and create solutions that work together. WRAP considers the challenge facing the world is how to lift the world's population out of poverty while reducing the demand for resources to the level that "one planet can sustain" as currently it is estimated that 1.7 planets' worth of resources are used every year. The purpose of this study is in accordance with WRAP's two missions, namely "re-thinking", focusing on transforming consumption through citizen campaigns and promoting collaborative business change, and "re-defining", focusing on "re-use and recycling through market and infrastructure development and improved collections".

Transforming the plastics economy to eliminate plastic pollution and transforming recycling into a system to emphasise material quality and markets are two priorities of WRAP's plans for a sustainable planet. The organisation works with the Ellen MacArthur Foundation, a charity committed to creating a circular economy (Ellen MacArthur Foundation, n.d.) to develop, support and build a network of the Plastics Pacts in Europe and around the world. The Plastics Pact removed the equivalent of 1.5 million non-recyclable black plastic trays from supermarket shelves, reduced problematic and unnecessary plastic packaging sold in the UK by 40%, increased the average recycled content in plastic packaging from 9% in 2018 to 13% in 2019, announced the investment of more than £100 million in new factories delivering 240,000 tonnes of recycled plastic per year between 2018 to 2020 and encouraged two million more people to recycle all they could on every occasion between 2017 to 2020 (WRAP, 2020a).

To educate the public and raise their awareness of plastic, WRAP has launched campaigns to engage the citizens. Clear on Plastics (n.d.), a social media led awareness campaign, aiming to clear the confusion and provide evidence-based information on sustainability and plastics, such as explaining the role of plastics and demonstrating the balance between the alternatives' benefits and drawbacks to enable them to make their informed choices. Clear on Plastics campaign believes that before the public's behaviours change, they should be armed with clear information to make sustainable decisions. Similar to Bambú, Clear on Plastics posts images and videos to educate their followers to reduce the use of plastic and learn about recycling. The contents of their videos are diverse and easy-to-understand, including recycling tips, experts sharing their knowledge about recycling, as well as fun examples of how to reduce plastic use in different situations in everyday life, rather than literal information. This is consistent with Ballantyne, Packer and Sutherland (2011)'s research that citizens should be provided with simple and achievable options to lead action. The main website of Clear on Plastics includes frequently asked questions and answers, from knowledge about plastic to what people can do to reduce plastic pollution in their everyday life. Besides, it also informs the viewers that plastic as a material is not all "evil" by answering questions like "why can't we just ban all plastic packaging?", "why can't we replace plastic with other materials?". Such information should be available at all plastic education activities to guide participants to have a fair and objective view of plastic material. These Q&As not only educate the citizens on the specific knowledge and help them develop a sustainable lifestyle but also consider plastics as a valuable material that should be re-used and recycled.

Recycle Now is another campaign that WRAP launched in 2004 (n.d.). It is a national recycling campaign aiming to inspire more people to recycle more of the right things more often. It collaborates with local authorities, government, waste management companies, brands and shops to develop behaviour change interventions to galvanise citizens to recycle more effectively. Its webpage offers useful tools for the users to gain a thorough understanding of recycling. For example, users can enter their postcodes to find out what they can recycle at home and locally and search for an item to check if it is recyclable. Recycle Week is Recycle Now's the most important annual event where key stakeholders such as retailers, brands and media come together to celebrate and promote recycling. Recycle Now provides campaign assets, including social media packs, toolkits and knowledge and activity packs for partners to engage consumers.

Apart from campaigns and educational social media posts, WRAP also works with young people in the community to provide them with the knowledge, skills and courage to understand their impact on the environment and inspire them to improve recycling. Scouts are one of the target groups that WRAP has been working with to make a change. The power of working with children is that they share with their family and repeat what they learn, spreading recycling knowledge and raising more people's awareness. One of the children involved in WRAP's activities commented that he loved recycling and reminding his family of recycling, and the other one said the activities made him aware that he should make more effort to recycle than he already did (WRAP, 2021). This is compatible with Duvall and Zint (2007) and Damerell, Howe and Milner-Gulland (2013)'s research suggesting that young people are able to shape others' perceptions and behaviours. Young people's positive environmental influence is also verified during the public engagement in this study (see Chapters 8 and 9).

WRAP assesses citizens behavioural changes by surveying UK households every year since 2004 to gather evidence on recycling knowledge, attitudes and behaviours. In March 2019, over five thousand people took part in the online interviews and showed strong evidence of an excellent behaviour change in the past year (WRAP, 2019). Recycling is increasing and more consistent (WRAP, 2020b), and it is believed that there is a positive association with behaviour change when UK households recognise Recycle Now (WRAP, 2019). Almost 80% of people who have seen/heard of Recycle Now, Recycle Week and/or have received recycling knowledge via social media reported an increase in recycling (WRAP, 2019). Recycle Now's logo, along with recycling information, is on almost every packaging in the UK (Figure 101). WRAP's director Peter Maddox thinks it is worth it to "bang the drum" for recycling because these small actions and changes by a large number of people influencing more people do make a difference (WRAP, 2019). The survey also suggests that education about the right recycling knowledge is necessary and urgent to achieve behaviour changes from broader citizens since UK households dispose of 1.5 items on average that could be recycled in the general bin, and over 80% of them put one or more items mistakenly in the recycling bin that are not accepted locally (WRAP, 2020a). According to the survey, the biggest barrier to recycling is the uncertainty about what can or cannot be recycled (WRAP, 2020a), which was discussed at the GRIPS2021 conference that recycling should be made more accessible and instructional for the public (WRAP, 2020b).


*Figure 101. Recycle Now's logo on packages the researcher received, Tao, 2021.*

Laura Copsey, the Behaviour Change Project Manager at WRAP, gave a presentation at GRIPS 2021 about action that WRAP took to develop citizens' behaviour changes and the impact, including the campaigns and collaborations mentioned in this section. Based on their experience engaging with the citizens, the general public is confused about the right solution to solve the plastic problems; therefore, fact-based communication is essential.

After the presentation, the author asked Copsey the question,

"*How does WRAP assess changes in citizens' behaviour after all the action you have taken to engage the public? What are the effective ways to lead to behaviour change based on your experience?*"

Copsey (2021) said that there was not a systematic way to assess behaviour change as it was perceived behaviours, but citizens did show intentions and willingness to be more sustainable in different ways, which should be amplified. Citizens' responses to the campaigns and behaviours interventions are being monitored and analysed. There are also "anecdotal" ways to assess the influence, such as monitoring comments on social media. She also said:

> […] We are learning from our campaigns; also, we do behaviour change interventions, so that is where we actually carry on something on the ground to see how citizens respond to it and generally get a really good snapshot of something being scaled up, something we need be doing more and how we could communicate more. […] By anecdotally, I mean comments underneath things we are putting on our social media saying "I have not actually realised that" or "now you said that I get it and I am gonna act this way slightly differently" […] I think something that is very key for citizens is that we are all talking very clear in a consistent way. We are not mudding the water, making it too confusing. Part of what we are trying to do is educating, saying change does not happen overnight. […] It is about sedimenting your audience and trying to understand who is doing the right things and how we can improve them, and who is not doing the right things and how we can get them there as well. (Copsey, 2021; see the full transcript in Appendix 3)

There are a great number of studios and businesses turning plastic waste into a variety of products and other departments working on reducing plastic use and promoting sustainable lifestyles around the world, and the number has been growing dramatically. The increasing attention shows that the issues of plastic waste are being recognised, and its potential is seen. Besides, these cases inspired the researcher to pay more attention to the connection (Cain, 2011) between each individual and the ocean plastic situation. What are their previous experiences? How will these experiences influence their perceptions? What action will these perceptions lead to? How can these factors work together to make an impact at a macro level?

This chapter used Precious Plastic as the primary case to discuss plastic recycling methods that are not covered in the experiment of this study to form a more comprehensive ocean plastic recycling system. It also evaluated cases in various areas that repurposed ordinary plastic waste to propose the possible applications of recycled ocean plastics and examined public engagement activities conducted by others to investigate public perceptions on recycling and recycled products. These cases inspired the researcher in designing public engagement events.

Case studies and follow-up interviews played an indispensable role in this study, which not only provided the author with more possibilities of recycling methods and applications, but also offers the author valuable insights on addressing the ocean plastic problem from "origin to solution" perspectives. Zero-waste companies encourage consumers to "turn off the tap" and stop using plastic in the first place. Charities intervene in consumer plastic-related behaviour to reduce plastic use and increase recycling. Design studios change consumers' perception of plastic waste with *craftsmanship, uniqueness* and *creation*. This combined research method "stepped in" to mitigate the Covid-19 impact on direct contact with the public, as the researcher could indirectly assess public engagement through the experiences of others. The insights obtained from the interviews enriched the entire societal enquiry in this study, which could not be achieved by solely interacting with the general public. It also provides updated research methods for future public engagement investigations.

***Author's reflection***

*The value of case studies in this study went beyond providing inspiration and experiences within a real-world context. It started as an alternative plan to combat the challenges of the pandemic but brought unexpectedly valuable insights to the study. The cases evaluated work as a "gap filler", working together with the experiment and public engagement to complete the research. It was fascinating to research these inspiring works and read about other people's experiences and stories. Under the circumstances that time and equipment were limited, and practical operation was impossible, I gained a better understanding of plastic processing technology through reviewing these cases.*

*It was also exciting to see people contributing to solving the plastic issue around the world, through recycling or educating others. These actions proved the effectiveness of different environmental education methods as more and more people are influenced to change their behaviours through these activities.*

*Interviews with those business and charity leaders not only confirmed my discovery through my own practice but also made me see what I did not realise or notice before. The combination of case studies and interviews enabled me to see the bigger world through their eyes and experiences, which would not have been achieved by conducting workshops alone.*

# Chapter 8. Participatory Research

As discussed in Chapter 3, environmental education plays a positive role in behaviour change. In this study, education activities took place in traditional teaching environment and outside of the teaching settings. The purpose of this chapter is to understand public perceptions of ocean plastic based on their previous knowledge and experience and use educational activities to intervene their awareness and behaviours. This chapter will discuss activities and workshops conducted by the author prior to the outbreak of Covid-19, as well as alternatives implemented during the pandemic. The events took place online and offline, with participants of all ages from different occupations.

## 8.1 Environmental education lectures

Looking back to the Precious Plastic case study, it is easy to notice that almost every member in the community, including the founder himself, has a design background or is related to design or crafting to some extent. Dickens (2021), the founder of Recycle Rebuild, told the author in the interview that he believed designers held the key in addressing waste and environmental issues as they created more clever ways for people to think (Appendix 3). Plastic collecting and recycling involves many vital jobs, such as the Ocean Cleanup project, where engineers design machines and seafarers manoeuvre the vessel to collect plastic waste from the ocean. The collected ocean plastic then gets sorted and redesigned into sunglasses (The Ocean Cleanup, n.d.), and this is where designers using their creativity to convey the environmental message to the public.

The number of designers who utilise waste materials or taken sustainability into consideration has soared significantly. The researcher proposes that not only the knowledge but also the practice of sustainability should be made available to beginners in design while they are getting trained to enter the commercial industry. These lectures were not an ordinary one-way teaching process as the author also aimed to get inspired by design students' creative thoughts during the discussion at the end of the participation.

This chapter included five lectures that were delivered from 2019 to 2021, four of which took place in Edinburgh Napier University for undergraduate design students

(Product, Graphic and Interior & Spatial Design) and one for staff and students of design programs in College for Creative Studies, a university in the US. Four lectures were delivered to the students in four different years at Edinburgh Napier University. They were carried out in the same modules during their study, so in the following sections, the terms "first-", "second-" or "third-year students" simply refers to the time when the lecture took place.

*Lecture 1*

The first lecture was delivered to third-year design students during the module, Design Studies 2: Design Research, in November 2019. It was estimated that over 70 students attended the class. However, the author was invited as a guest lecturer, so there was no exact number of the attendance. The lecture contents included the current state and impact of ocean plastic, as well as the author's research and experimentation. Students were shown a website[18], which mimics how plastic travels in the ocean over time. They were then invited to see, touch and smell the samples that the author made, including the recycled sheets, coasters and laser-cut keychains and have a discussion with the author. In addition to being shocked by the current state of ocean plastic, students were most curious about the details of the recycling process. Questions such as *"Where did you recycle the plastic?"* and *"What machines did you use?"* were asked the most.

An online survey was set up on Menti.com to gather students' opinions. Students were asked if they had any thoughts about using ocean plastic in their design and if the lecture had any impact on their perceptions about ocean plastic. They could also leave comments and feedback about the lecture and their experience with ocean plastic during the lecture. A total of 15 students left their thoughts (Appendix 4). Five responses expressed shock at the amount of plastic in the marine environment and how plastic travelled around the world, and considered the lecture impactful. Over a third of students claimed that they never considered using recycled (ocean) plastic in their design before the lecture, but they would in the future. Three of them believed that recycled ocean plastic souvenirs and tokens could be a strong statement to raise awareness and conserve the ocean. For example, a student replied, *"[...] I believe that*

[18] http://plasticadrift.org built by Dr Erik van Sebille, David Fuchs and Jack Murray.

*this is a great project you are working on, and I hope more individuals as well as me, will be involved to save the ocean".*

*Lecture 2*

The second lecture was delivered to second-year design students during the module, Debating Design 2, in November 2019. Since there was not a sign-in system in place to count the attendance, a rough estimate of the attendance for the lecture was about 50 students. The structure was similar to the first one, where the author presented the content first, and then students were invited to interact with the materials, ask questions and give feedback. Students remained interested in the making process and were surprised by the fact that all the experiments were done in the university. Students also found it fascinating to smell the "ocean" in the samples that the author made.

The same questions were asked on Menti.com for the students to answer. A total of ten replies were collected (Appendix 4). Two agreed that recycling ocean plastic into souvenirs would be a great idea. Two suggested that consumers should be fully informed about the recycled products they purchase, such as the amount used and where they are collected. Surprisingly, students were not as shocked as the last class about the ocean plastic situation. Most students agreed that there needed to be a significant change, but they were also concerned that the solution might create more rubbish or start a new unnecessary waste cycle. Besides, students in Graphic Design found it harder to incorporate ocean plastic in their designs compared to the other two design disciplines.

A student from Product Design Programme approached the author for collaboration as he was designing university merchandise. Although he originally planned to use wood in conjunction with acrylic sheets in his design, he changed his choice after the lecture, switching to wood and recycled ocean plastic (Figure 102). He believes that the collaboration makes his design more logical because the university is located in the coastal city of Edinburgh and the change in material selection makes his design more meaningful, thereby promoting the university along with ocean plastic and sustainability. Two years after, two students from the same course used ocean plastic in their fourth-year design projects and one started to research eco-plastics.


*Figure 102. University merchandise, Dunsire, 2020.*

*Lecture 3*

This lecture was delivered to second-year design students during the module, Debating Design 2, in September 2020. Due to the outbreak of Covid-19, the lecture took place online, using the platform Webex. The attendance was around 30, and most students had their cameras turned off, making it challenging to predict attendances for this lecture. The structure of online lectures was different from the first two. Students did not have the opportunity to interact with the material physically, but the author tried to make up for this unavoidable deficiency by showing more images during the presentation.

Unfortunately, due to the lack of physical interaction and conversation, only three replies were collected on Menti.com (Appendix 4). One student commented that the lecture made him/her realise the problem caused by ocean plastic. Another one answered*: "[…] Had made me realise that ocean plastic can be turned into something beautiful; it is not always a bad thing."* The last student expressed his/her interest in ocean plastic research because he/she had previously researched the use of plastics in general.

*Lecture 4*

This lecture was delivered to first-year design students during the module Debating Design 1 in March 2021. Similar to last time, there were about 30 people in attendance, and all the cameras were turned off. The previous lecture can be considered as an experimental online lecture on dealing with the impact of Covid-19 on lecturing. Since the last one did not get much response, the author added more online interactions to engage students in this lecture. Another challenge facing the author was that they started university in the middle of the pandemic, so they had been studying online from the beginning, which could lead to a loss of concentration (Bao, 2020; Sun, Tang and Zuo, 2020).

The author asked what they knew about ocean plastic, including the impact on Menti.com. It aimed to compare the changes in students' knowledge before and after the lecture. Twelve answers were collected (Appendix 4). Students' responses mainly included its large quantity, harm to wildlife, microplastics in the ocean and ease of spreading. Two students expressed their lack of knowledge of ocean plastic. One student posted a simple but interesting answer, *"Fish eat plastic, and we eat them, so we also eat plastic."* Students were then given a presentation about ocean plastic and the author's research and experiments. At the end of the lecture, the author invited the students to take part in a poll on whether participating in creative ocean plastic recycling activities would build a strong emotional connection between them and the environment. 14 students chose "yes", and none chose "no effect on emotion" (Appendix 4). They then answered the following question: "What do you feel about ocean plastic after the lecture?" Eight answers were collected (Appendix 4). One responded that he/she was more informed about the amount of ocean plastic. Most of the students still believed that plastic was "evil", but the lecture made them more aware of the methods and possibilities of recycling ocean plastic. One response expressed sadness after seeing the images of animals with plastic around them.

*Lecture 5*

This lecture was held online for mixed design undergraduate, postgraduate students and lecturers at College for Creative Studies in the US in March 2021. Twelve people attended the lecture. Participants were asked on Menti.com about what they knew about ocean plastic and its impact before the presentation. Everyone responded to this question (Appendix 4). Compared to the last four lectures, answers collected were more diverse, and the participants seemed to be more aware of the situation. For example, one person replied: *"[...] I remember hearing once that about 4% of Hawaiian beach sand is microplastics now"*, and another said: *"I know at least a few million tonnes of plastic end up in our oceans every year and disrupt our marine ecosystem."* There was also an answer talking about the difficulty of collecting ocean plastic. Half of the answers mentioned *"animals", "wildlife"* or certain types of animals such as turtles. A quarter of the participants replied about different types of harm caused by microplastics. Four responses talked about the negative impact on the ecosystem or global warming. One participant posted *"environmental hazard"*, and another was worried about the drinking water. Only one participant expressed concerns about awareness and consumer behaviour.

Due to the relatively higher and mixed knowledge level of participants this time, the content of this lecture was more detailed and abundant, including the author's research about ocean plastic, the whole experimental recycling process, as well as the clear multi-angle images and videos taken in the process. After the presentation, participants were asked to answer the following questions: "What do you feel about ocean plastic after this lecture? Has your perception of plastic changed after seeing the transformation?" Seven answers were collected for these two questions (Appendix 4). However, one person complained that the information was overloaded, which caused a distraction, providing feedback for future lecture design. Four participants commented that the lecture made them aware of the potential of repurposing ocean plastic. One replied: *"I think it has a lot of potential to be used in products and start conversations – I especially love those samples that mimic the ocean water!"* Two out of these five still expressed negative and shocking feelings about ocean plastic, but the lecture gave them hope to make a change. One of them commented: *"After seeing the range of possibilities, maybe this scary problem can be turned into a beautiful solution."* One participant remained concerned about the problem due to the difficulties of recycling, including factors of various types and contaminations.

## 8.2 The student design project – A World without New Plastic

In order to investigate more educational methods to raise awareness in the teaching environment, the author created a six-week-long design project called *A World without New Plastic* for the second-year students under the module Design Studies 1 in February and March 2021. Due to the pandemic, the entire module was delivered online, posing significant challenges for tutors and students as the module was a combination of design theory and practice. At the beginning of the module, students were asked to answer the question, "What are the big issues in contemporary design?" with keywords. The most mentioned words included *sustainability, environmental, materials, changing perspectives* and so forth (Figure 103). Two weeks before the design project began, the author delivered a lecture on sustainability and materials to the class in response to their high interest in the topic. The lecture began with an analysis of the bicycle production process, from material mining to transportation to sales. In conjunction with the bicycle story, the author also used different sustainable design examples to encourage students to think and question themselves, "what is behind a sustainable product?", "how to choose materials in my design responsibly?" and "how to achieve sustainability?".


*Figure 103. What are the big issues in contemporary design?, Buwert, 2021.*

Students involved in this project are the same group in Lecture 3. Thus, they already had basic knowledge about ocean plastic. Before the project started, students were asked to choose from three different tutor-led design projects, including A World without New Plastic. Sixty-three students registered for the module, so there were 21 spaces in each design project. A poll was done before students could officially choose a project, and this project received an overwhelming vote. The final grouping was on a first-come-first-serve basis, and this project was the first to fill all the spaces.

Interestingly, Lecture 3 collected the least response, while this project received the most interest from the same students. The comparison led the author to investigate the reason for the attitude change. The author asked the 21 students why they chose this project on Menti.com. Eighteen answers were collected, and seven of them expressed their interest in learning more about sustainability (Appendix 4). Two students said their choice was under the influence of the author's previous lectures. Three of them thought the project sounded interesting. Six students expressed their interest in plastic and recycling. Four responses believed that it would be applicable in their future design.

In this project, students were asked to explore possibilities for a future world without new plastic. There were three options to choose from.

1. A design pitch: Create a design (product/interior), make prototypes and then make a poster. Everything has to be made of plastic waste.
2. An educational method: Create a new recycling plastic method. Inspire and assist the public in adopting the method by providing an easy-to-understand instruction booklet, so that people can recycle their everyday plastic waste at home. Use imagination.
3. An educational infomercial: Create an infomercial storyboard to raise public awareness about plastic pollution, including impact and possible actions etc. Everything included in the storyboard should be made of plastic waste. Connect all the storyboards into one infomercial film.

To make the project more inclusive and accessible, the choice of materials was open to all types of plastic waste, not just ocean plastic. Since it was a group project, in order to make the teams more diverse, each team consisted of two Product, two Interior & Spatial and one Graphic Design students, and the extra student was randomly assigned to one of the groups. Students were asked to produce a three-minute film and a portfolio, explaining the project, background research and insights gained throughout the project.

Each group created a private Facebook group and posted their progress of research and creation on the page. Students were asked to investigate and document the types of plastic in everyday products. The author monitored the development of students' understanding of plastic waste and the topics they worked on by viewing the Facebook pages' update and conducting weekly tutorials. The four groups identified the themes of Indoor Greenhouse, Seabird Habitat, River Clean-up and Plastic Mural, respectively. Despite the difficulties caused by lockdown to implement the design project, three groups went on local field trips to observe river and ocean plastic, understand the situation and design for the sites. Without any access to the university design workshop, each group managed to produce prototypes and posters made from plastic waste after spending six weeks with their everyday plastic products (Appendix 4). Processing methods included cutting, weaving, melting and assembling.

Students wrote about their experiences and thoughts about the project in the final submission. All of the groups agreed that the project helped them better understand the knowledge of plastic and the problems caused by plastic waste in the world. It was backed up by a poll on the Facebook group page, with all groups voted "Yes" to the question "Have you gained more knowledge about plastic after this project?" Starting from plastic waste, each group identified different problems surrounding plastic and used a variety of methods to solve the problems they found. Moreover, two groups had noticed their changes in plastic-related behaviours throughout the project. All groups believed that they would take more responsible action with plastic products/disposal/waste in the future.

## 8.3 A participatory workshop at the Edinburgh Climate Festival 2021

The workshop was conducted at the Edinburgh Climate Festival on 14th August 2021. It was a first-time, free and community-led event, aiming to celebrate and inspire climate action. It was an open-door event with over 50 stalls and activities. The festival lasted seven hours and had an estimated 3000 people participated. The researcher named the workshop "SAVE THE OCEAN, Ocean Plastic Crafting Workshop" (Figure 104), and designed a series of activities for participants to choose from, suitable for all genders and ages. Due to the equipment, time and space limit, the workshop had to be semi-personalised. The author prefabricated recycled ocean plastic sheets of different thicknesses at the Polymer Laboratory. Patterns from

Scottish statement features such as Edinburgh Castle, Highland cow to natural objects such as butterflies, leaves and stars to organic shapes were designed to be laser cut on the premade sheets, offering participants a wide range of options.


*Figure 104. SAVE THE OCEAN, the Ocean Plastic Crafting Workshop, Tao, 2021.*

The activities included categories of jewellery making, keychain assembling, 3D printing experience and "Just Be Creative". Since there was no power supply, 3D printing was done by 3D printing pens instead of a 3D printer. Recycled ocean plastic filaments were provided as 3D printing materials, but PLA filament was also available for the participants to compare the performance. In addition to physical materials, the author created a two-minute video about ocean plastic and its impact to show the participants at the beginning of the workshop. After displaying the video, the author introduced the materials and their histories. Participants used the tools provided and chose from the premade objects to make keychains, pendants, necklaces, earrings or 3D printed widgets. Uncut sheets were also available for those who wanted to be creative and personalise the whole ornament. At the end of the workshop, participants were asked to complete a 16-question online questionnaire with an estimated completion time of five minutes.

The workshop was one of the most popular activities of the festival, with participants constantly taking part in. Due to time constraints and the social distancing restriction, the workshop could only accommodate 90 participants throughout the day, although people kept showing up and expressing a willingness to participate. Most of the participants were children who came with their parents, and they took part in the activity together. Most the children started their participation by saying: "I want to save the ocean". There were more females than males and more younger people than the elderly. Most men who attended the workshop were to accompany their children. Older people mostly just came to share their experiences or ask questions rather than crafting. For example, an older man (65+) told the author that he witnessed a tremendous amount of plastic being washed ashore in his hometown, and that he used to volunteer for beach clean-ups on the west coast of Scotland. Thus, when he found out that the recycled plastic in the workshop came from the west coast of Scotland, he became more excited and asked extra questions about the author's research. An elderly lady (60+) was interested in knowing what 3D printing was and how it worked, as she had never come across it before. The most obvious phenomenon the author observed during the workshop was that when almost everyone heard that the materials offered was 100% ocean plastic retrieved from Scottish beaches, they became more interested and excited to participate. Figures 105 - 108 present some examples of objects made by the participants. Appendix 5 listed all of the results.

*Figure 105. Participants' outcome 1, Tao, 2021.*

*Figure 106. Participants' outcome 2, Tao, 2021.*

*Figure 107. Participants' outcome 3, Tao, 2021.*

*Figure 108. Participants' outcome 4, Tao, 2021.*

Forty-one responses were collected from the post-participation survey (Appendix 6). The figure is close to the number of adults who participated in the workshop, since most of the time parents and children attended the event together, but only parents could fill out the questionnaire. Most people (95%) were aware of ocean plastic before the participation, with 66% of them knowing it very well. It could be explained by the fact that most people were attracted to the workshop by the name on the banner, and some of them expressly indicated that they wanted to "save the ocean". Furthermore, 35 people had encountered ocean plastic in their previous experiences. Less than half of the people had purchased souvenirs that were made of recycled materials. One of the participants answered: "*I do not think I have. I have not come across many recycled souvenirs, and sadly, eco-friendly gifts are usually more expensive although I like to support them.*" Although most people never purchased recycled souvenirs, 71% wanted to buy souvenirs made of recycled materials if they had the choice. Only a third had previous experiences with personalised souvenirs or participating in tourist experience activities to make souvenirs, but almost all believed they would have a more personal connection with a customised souvenir. Besides, almost everyone chose to participate in a tourist experience activity or an educational workshop like this one in the future.

Through a series of public engagement activities, the author investigated different methods to raise awareness of ocean plastic in different settings. This chapter has demonstrated all processes and details of the events. Although the activities did not take place as planned because of the pandemic, the author managed to find alternative ways to continue to engage the public. The author adopted multiple approaches and tools to engage the participants, including educational lectures, research-led teaching, participatory workshops, observation and interactive presentation software, visual aids, online questionnaire and social media platforms. Most people are aware of ocean plastics and have varying degrees of knowledge about them. Traditional educational settings have the advantage of monitoring participants' awareness and actions, while ocean plastic educational activities outside the teaching environment can reach a wider audience. Participants in educational settings (design students) were more concerned about the making *process*, while the general public focused more on the *experience* and *result*. Different concerns lead to different actions, and each person with diverse expertise in various fields can contribute to this action from a unique perspective.

Designs students and engineers can address the ocean plastic problem by amending the design and manufacturing processes. The public can correct their plastic usage behaviours in daily lives by convincing themselves that positive results can be achieved. The results will be further discussed and assessed in Chapter 9 and 10.

***Author's reflection***

*It was challenging to organise and conduct as many public engagement activities as possible during the pandemic and intimidating to work with the public for the first time, but it turned out to be a rewarding process when the audience showed great interest and was actively engaging. Feeling satisfied with the experiment process is different from engaging the public. The former comes from creation and invention, and the latter comes from public recognition and influence.*

*In this study, I was intrigued by the public perception of ocean plastic. Most people have negative opinions and believe that plastics are "evil" without realising how useful the material is if used properly and it is human beings who make the material "evil". It was exciting to see people intend to change their behaviours and take action after participation. Therefore, it inspires me to not only consider raising public awareness of reducing plastic consumption, but also strengthen people's choice and reuse of plastic products, encouraging people to realise that plastics can be precious.*

# Chapter 9. Findings and Discussion

This chapter presents and discusses the results of the research. Findings are organised into the following themes: “current state of ocean plastic”, “the possibilities of ocean plastic”, “ocean plastic as an educational tool”, and “emotion, visualisation and environmental behaviour”.

## 9.1 Current state of ocean plastic

Findings of field trips and sample collection are primarily consistent with the statistics in the literature review. A large proportion of ocean plastics collected on the beach could not be determined of origin or type due to the condition of the items (Marine Conservation Society, 2011). The author found more plastic waste on remote beaches than on urban ones (Okuku et al., 2021), but the finding does not determine whether people who live in rural environments litter more than those in urban areas (Schultz et al., 2013). The density of plastic waste on a beach is related to factors such as its terrain, ocean current, human flow and beach clean-up activities. The “ocean” smell on the collected samples supports the theory that marine animals mistake ocean plastic for food because of the smell (Savoca et al., 2017).

With millions of tonnes of plastic waste entering into the ocean every day (Jambeck et al., 2015), not only is the problem of plastic waste in the ocean urgently needed to be addressed, but the Covid-19 pandemic has put even more pressure on the problem. People’s PPE-related behaviours during and after the Covid-19 pandemic are similar to regular plastic waste. For example, more PPE waste has been found on remote beaches than urban beaches (Schultz et al., 2013; Okuku et al., 2021), which highlights the importance of environmental education and socio-psychological influence (Heidbreder et al., 2019). The author constantly noticed discarded masks outdoors. Their lightweight and abundance, combined with incorrect disposal, make it easier to find their way into the ocean. The occurrence of Covid-19 has brought more plastic pollution to the marine environment, and it is urgent to solve the ocean plastic issue, requiring concerted efforts of all sectors of society. The outbreak of the pandemic has also confirmed that using plastic is a shortcut to solving human problems and one of the most effective ways to do so. It has also led to a hierarchical shift in values, with health concerns overriding environmental concerns when it comes to using single-use plastic materials (Grodzińska-Jurczak et al., 2020), meaning that this pattern repeats itself every time a pandemic like Covid-19 occurs and resulting in more plastic being produced.

## 9.2 The possibilities of ocean plastic

The researcher mapped some of the experimental processes to investigate where ocean plastic went in this study, instead of entering the ocean (Figure 109). The flow diagram also provides a reference for future studies of ocean plastics. The methods of recovering ocean plastics can be divided into two categories, subtractive and additive approaches.

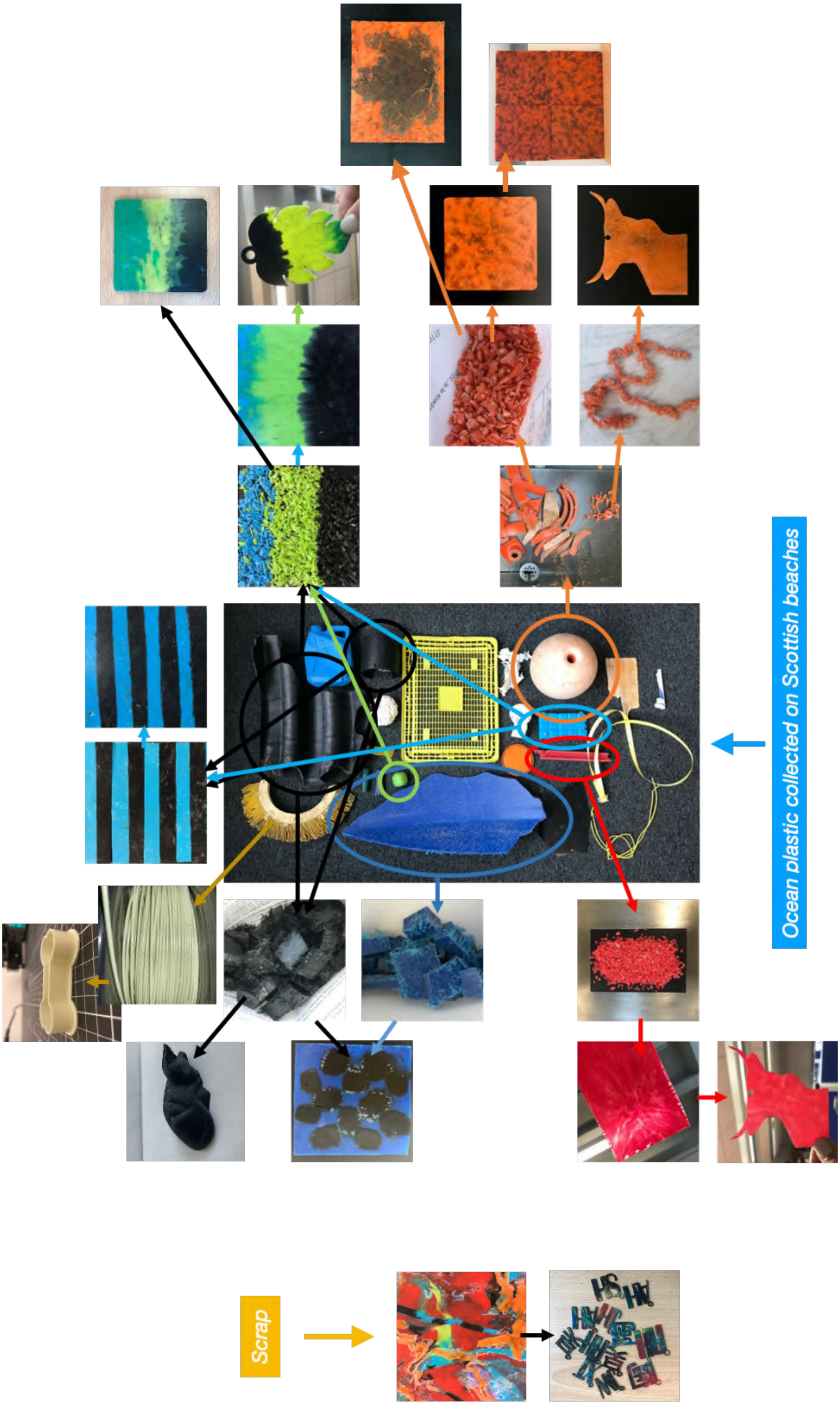



*Figure 109. Where did ocean plastics go in this study? Tao, 2021.*

*Recycling ocean plastic with subtractive approaches*

Table 7 summarised how each type of ocean plastic performed in compression processes. All types of ocean plastic in this research can be compression moulded. Compared to other methods employed in this research, compression moulding is the easiest to operate and can obtain desired results. In addition to the benefits discussed in Chapter 4, such as good surface in the final product and minimal mould maintenance (Swift and Booker, 2013), more were discovered during the experiment. Tolerance to contaminants is one of the most fundamental and essential elements of recycling in this research, as one of the reasons recycling ocean plastic is more complex than recycling regular plastic waste is that the pollutants are more numerous and persistent, and compression moulding has the highest tolerance of all methods used. It does not require strict plastic size reduction, as long as it is smaller than the mould. In the case of recycling ocean plastic by compression moulding, the success rate was almost 100%, and no experiment failed due to the existence of pollutants. The recycling time depends on the size of the final product, but it is relatively fast compared to other methods. The whole process can take as short as five minutes if compressing the size of a coaster. Precious Plastic and Smile Plastics have used the compression moulding method to produce sheets and panels from plastic waste. To make the process easier and accessible, some designers even use their ovens to replace the machine, or a panini press. Another advantage of compression moulding is that it allows for a higher level of creativity. Not only can the operator plan the colour scheme before the compression process begins, but the mould can also be taken out at any time for further creation. These benefits suggest that compression moulding can be ideal for reprocessing ocean plastic to many products.

**Table 7**

Compression moulding performance

| Ocean Plastic Type | Compression Mouldable | Performance |
|---|---|---|
| PE | Yes | PE and PP ocean plastics perform similarly. The difference between compressed PP and PE items cannot be identified by naked eye. The compression of these two ocean plastics is simple and stable with no failure. When the two materials are mixed and compressed, they blend together well, just like one material. Shrinkage occurs, and the thicker the mould, the more obvious the shrinkage. However, shrinkage is usually within 1mm off the edge, and with the mould used in this experiment (maximum length 15cm, maximum thickness 4mm), shrinkage is no more than 1.5mm. According to the Precious Plastic Community, PE shrinks more than PP, but it is not noticed in this experiment due to the small mould sizes. Warping and air entrapment sometimes happens but it can be alleviated by longer preheating and cooling time. Scrap material can be re-processed again to get the same result. Different surface finishes such as shiny, matte and textured can be achieved during compression by adding texture sheets into the mould. According to the Precious Plastic Community, the compressed surface can be sanded and polished with different grains to achieve a fine matte surface. Apart from the ocean odour coming out of the material, the whole process is almost odourless, which is ideal for experience-based events. |
| PP | Yes | |
| PS | Yes | The compression of PS ocean plastic is also simple and stable with no failure. It performs similar to PE and PS above. However, air entrapment is higher, warping is less noticeable, and compressed items are harder and more brittle. Thin ones break easily while thick ones are stronger. According to the Precious Plastic Community, sanding and polishing a compressed PS object with the addition of polishing paste can achieve a shiny surface. |
| PET | Yes, but further tests needed | It is not challenging to compress ocean plastic PET, and the operation is similar to that of the above ocean plastics, but the result was not satisfactory. The colour of compressed objects changes from transparent to cloudy, and the surface is cracked and easily broken. When they are recycled again, the results are even less desired. A further comparative experiment between virgin, everyday waste and ocean plastic PET is needed after the pandemic to determine the reason of the result in this experiment. |

Table 8 predicts how each type of ocean plastic would perform in injection moulding processes based on the case study of Precious Plastic. The injection moulding method was not used in this research due to the lack of machinery in the laboratory, but it is a commonly used recycling method that can provide more possibilities for recycling ocean plastic. It is similar to compression moulding and is Precious Plastic’s most used and mature recycling method. Even though only a small percentage of the Precious

Plastics community uses ocean plastic and most uses domestic or commercial waste, the performance of ocean waste can be predicted based on the results of domestic waste due to the minimal material requirements of injection moulding. Instead of heating the plastic in the mould, injection moulding heats it before entering the mould, thus saving cooling time. Besides, since moulds do not need to be compressed, they can be designed in a variety of shapes. As a result, a wider variety of products can be produced. In terms of pattern creativity, however, injection moulding is inferior to compression moulding. Only the choice of colour is selectable; the area, layout and shape of colour are completely random and uncontrollable. Moreover, the final product is more likely to contain other plastic impurities left in the heating chamber.

**Table 8**

Injection moulding performance prediction, based on how-tos on the Precious Plastic Community

<table>
<tr><th>Ocean Plastic Type</th><th>Injection Mouldable</th><th>Performance Prediction</th></tr>
<tr><td>PE</td><td>Yes</td><td rowspan="2">Injection moulding these two ocean plastics are similar to compression moulding. Operator intervention on colour is less than compression moulding, so the resulting colour is more surprising. Different textures can be achieved by adjusting extruding speed and mould temperature.</td></tr>
<tr><td>PP</td><td>Yes</td></tr>
<tr><td>PS</td><td>Yes</td><td>Injection moulding PS ocean plastic is similar to compression moulding. It can achieve a shiny surface by applying silicone oil to the mould and preheating it.</td></tr>
<tr><td>PET</td><td>Yes, but further tests needed</td><td>No member on the community has experimented injection moulding PET. Based on the extrusion performance of the PET ocean plastic in this experiment, injection moulding of PET ocean plastic is feasible, and the results may be stronger than compression moulding.</td></tr>
</table>

Shrinkage and warping often happen, varying from plastic to plastic, whether injection moulding or compression moulding, resulting in size inaccuracy. The complexity of the product shape is limited for the possibility and convenience of demoulding. Unmolten particles are sometimes visible on the surface. Air entrapment is almost inevitable in every finished product, as confirmed by this experiment and Precious Plastic. Under the correct weight and temperature conditions, PE, PP, and PS types of ocean plastic samples showed no problems in the experiment. These three are also the types of plastic waste that Precious Plastics and Smile Plastics use in their production. PET ocean plastic, on the other hand, is mouldable with unsatisfying results. Transparent objects become cloudy but unique when compressed, resembling a marble pattern. However, the recycled PET becomes crispy and snaps easily. As a result, no ocean plastic PET bottle had been successfully recycled into a complete product. This might be because PET bottles degraded excessively in the marine environment.

Injection moulding typically produces final products that do not require further processing, except for beams, whereas compression moulded plastic sheets can be machined to accommodate more needs. The sheets can be sawn, laser-cut, CNC-milled, and polished. One of the fundamental principles of this research is to be as sustainable as possible and explore more ocean plastic possibilities. Thus, the combination of compression moulding and laser technology can minimise mould costs and material waste when waste is unavoidable because the offcut can be recycled again. CNC-milling generates more ground waste that is difficult to be recovered but can create more details and dimensions of a product, such as a key hanger (Figure 110). Table 9 and 10 summarised how each type of ocean plastic performed in laser cutting and CNC milling processes.

*Figure 110. CNC-milled key hanger, Precious Plastic, 2021.*

**Table 9**

Laser cutting performance

<table>
<tr><th>Ocean Plastic Type</th><th>Laser-cuttable</th><th>Performance</th></tr>
<tr><td>PE</td><td>Yes</td><td rowspan="2">PE and PP ocean plastics perform similarly. The thinner the sheets, the clearer the cut. The laser melts the plastic when cutting, so when the sheet is thick, the molten plastic re-glue the cut edges back together. The laser accumulates molten plastic along the cutting route at the bottom of the cut object, but it is easy to scrape off because it’s powdered and leaves no trace. Contaminants such as dirt, sand and other types of plastic affect the cutting result, leaving an unsmooth or burnt edge. Engraving is not clear, especially since most compressed sheets are mixed coloured. The laser process is fast, which is ideal for experience-based events.</td></tr>
<tr><td>PP</td><td>Yes</td></tr>
<tr><td>PS</td><td>Yes</td><td>The performance of laser-cutting PS ocean plastic is similar to the above two. Less molten plastic accumulates on the edges, and engraving is clearer.</td></tr>
<tr><td>PET</td><td>N/A</td><td>It was not experimented as no PET ocean plastic sheets were successfully made in this research.</td></tr>
</table>

**Table 10**

CNC-milling performance – based on this study and the Precious Plastic Community

| Ocean Plastic Type | CNC-millable | Performance |
|---|---|---|
| PE | Yes | Members of Precious Plastic Community have tested CNC-milling on recycled HDPE sheets. It is feasible and provides the materials with more possibilities. However, the CNC-milled the surface may not be smooth enough, and sometimes the air entrapment are obvious. The surface can be polished, depending on where it is. A member of the Precious Plastic Community uses CNC-milling to create bends and joins on the recycled sheets, so the milled surface is hidden. |
| PP | Yes | Recycled PP has not been tested by the Precious Plastic Community or in this research. As recycled PP ocean plastic always performs similar to PE, it could be predicted that it would perform similarly during CNC-milling process too. |
| PS | Yes | It is feasible to CNC-mill recycled PS ocean plastic sheets. However, it leaves an unsmooth surface and reveals the air entrapment. It can also be used to create bends and joins so the non-smooth milled surface can be overlooked. |
| PET | N/A | No test has been done. |

After a series of processing steps, many of the samples still contained the smell of the ocean. This experiment confirmed that even if the plastic samples were recycled at high temperatures, the odour would not disappear quickly, even though it dissipated eventually after being exposed to the atmosphere for a while. This can also be associated with emotion and memory because, in addition to the emotion itself, the mood induction procedures may also trigger emotion-related cognition (Ehrlichman and Halpern, 1988). The smell is one of the body's most important senses, and in many ways, memories evoked by smells are more emotional than those evoked by verbal cues (Cain, 1984; Cann and Ross, 1989; Herz and Cupchik, 1995; Brianza et al., 2021). The author first made the connection between smell and memory based on personal experiences in her childhood. She recorded in the reflective journal:

> *"I loved Barbie when I was little, and I love creating different looks for them, which were my happiest moments. Their hair had a particular chemical smell, and even now, whenever I think of or 'smell' it in my head, I think back to when I combed their hair 20 years ago. The odour is still strong in my brain."*

The researcher finds that the ocean odour on the recycled objects intrigue herself during the experiment, and it is the same with participants during the workshops.

A participant commented in the post-participation survey in capital letters:

*"SMELLS LIKE THE OCEAN."*

Therefore, emphasising the feature of the ocean odour on the ocean plastic can potentially strengthen consumers' memories of the experience and recall the experience when they smell the ocean water, thus enhancing their awareness and behaviours.

In terms of the above processing methods, many plastic products made of raw plastic can also be made from ocean plastic, and ocean plastic is almost indistinguishable from everyday plastic waste after being processed. Thus, ocean plastic can be recycled into various products with high potential. Nevertheless, there are three types of products that need to be avoided:

1. Products with high accuracy requirements, such as machine parts;
2. Products of a single colour (except black);
3. Products requiring high strength.

Ocean plastic pre-treatment takes longer and requires greater effort than household plastic waste, and ocean plastic often cannot be decontaminated completely. Contaminants often appear as black dots and uneven colours on the surface of recycled items or give off a smell of the ocean. These factors generally do not affect the performance of recycled products. Material collection and pre-treatment is cumbersome, time-consuming, labour-consuming and costly. Even if ocean plastic could be potentially made into many products, it would be more expensive than what is already on the market, so mass production is currently impractical. Therefore, locally produced, ethical products are the way to recycle plastic from the ocean, not only as a product but also serves as a messenger. Combined with this research's experiments and case studies, the unevenness and uncertainty of surface patterns of recycled plastic products make them more attractive to consumers. This also requires the designer' skill to interpret the "imperfection" differently and marketing strategy to turn this feature into an "authentic" selling point. Defects caused by contaminants thus can be considered part of the "design" to make recycled products more unique. Ocean plastic can be recycled in two directions, both educational:

1. Products ready for sale;

2. Materials for environmental education activities.

When consumers are willing to pay more for products made from ocean plastic, meaning they treasure the exceptional value assigned to the product (Jeffrey, 2015), they should get more than just the ordinary function. The amazing and unique patterns achieved from recycling ocean plastic, and the stories behind the finished products, are impossible to achieve with virgin plastic. Product history such as where the materials are collected and how they are processed, information and knowledge about ocean plastic and what consumers can do to address the problem should be provided along with the sale. It could be a souvenir that people purchase while on holiday or a home product purchased from a local or online shop. The combination of souvenirs and recycled ocean plastic could be one of the ways coastal areas move towards sustainable tourism and a circular economy (Forestell, 1993; Orams, 1995; Weaver, 2005; Ballantyne and Packer, 2011). Ocean plastic is an underutilised material resource that is freely available to locals who live in coastal areas (Vones et al., 2018). The use of ocean plastic in souvenirs has the potential to benefit the local area, the environment and visitors, as it could use locally sourced material, provide jobs opportunities, boost the local economy, solve local pollution problems, reduce carbon emissions from long-distance transport and offer visitors souvenirs with environmental values and local craftsmanship (Xie, Wu and Hsieh, 2012; Anastasiadou and Vettese, 2018; de Andrade Matos and de Azevedo Barbosa, 2018; Elomba and Yun, 2018; Sthapit and Björk, 2019). Dickens (2021), when interviewed by the author, also agreed that the uniqueness of handicraft was pursued by consumers, and he said,

*"[…] they want something really unique, you know, and that's how art and crafts kind of get the ability to be sold, that uniqueness is what important in the tourist setting that stands out, you get an edge because of that."*

More and more consumers are seeking authentic souvenirs that reflect the region's values or souvenirs made from local materials (Elmba and Yun, 2018; Sthapit and Björk, 2019), giving ocean plastic increasing opportunities to be repurposed and re-recognised by the public. Tourism satisfaction and enjoyment (Jarvis, Stoeckl and Liu, 2016) influence tourists' perception and attitude towards marine debris (Krelling, Williams and Turra, 2017). The potential of combining recycled ocean plastics and craftsmanship has been recognised on the researcher's social media. Every time the experimental work is posted on Instagram, it receives positive responses, with people wanting to buy the finished products (Figure 111; more in Appendix 7).

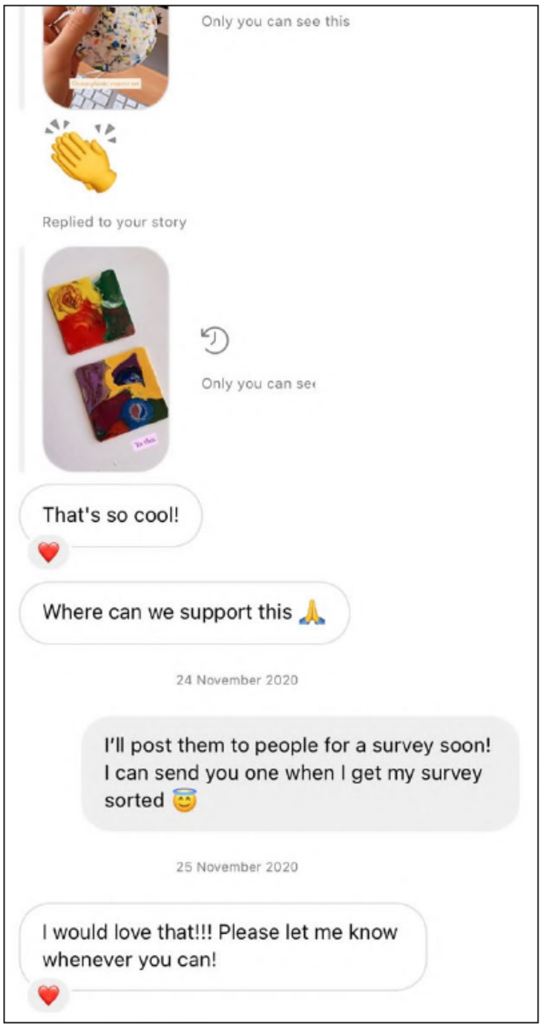



*Figure 111. Reaction on social media, Tao, 2020.*

The participants involved in the public engagement activities commented:

*"I loved this idea of making the ocean plastic into tourist gifts, I feel like sticking with basic gifts like keychains or magnets would work really well as long as it's been marketed loads as recycled ocean plastic. I definitely would buy!"*

*"[…] I also really like the uniqueness of a tourist having a souvenir [made of ocean plastic]."*

These advantages are not limited to the tourism sector but also apply to all crafts, maker and design businesses.

*"[…] Have you thought about jewellery? It seems to be a very popular thing to do to raise money for conservation of the ocean, but I've never seen jewellery made from ocean plastic. […]"*

Even if the product is not a souvenir in the traditional sense, it still carries the function of a souvenir, a reminder of an experience (Gordon, 1986) and endowed with mighty, sublime and wonderful meanings (Goss, cited in Peters, 2011: 236).

*"Might be good to consider making an item which is usable rather than decorative. […] If they use it, they are more likely to keep it."*

*"I think it has a lot of potentials to be used in products and start conversations."*

Ocean plastic as a material for environmental education activities not only has the benefits discussed above as products but also integrate the factors of co-creation, participatory experience and environmental education. The advantages of compression moulding, injection moulding, laser cutting and CNC milling in terms of short-time consumption and ease of customisation are beneficial for experience-based activities. Compression moulding allows participants to be more creative in design, while injection costs less time. Some of the disadvantages, such as air entrapments, can be overlooked when it comes to recycling ocean plastic and the emphasis is placed on the recycling experience and uniqueness, and can be perceived as the unique beauty of handcraft as well as the memories of the experiences. The activities can take place anywhere that involves the exchange of value and knowledge, such as schools, workshops, museums, heritage environments, festivals and tourist attractions. In addition, due to the high level of personal involvement and the effort and time it takes to objectify the memento, the consumer may form stronger associations with the experience (Anastasiadou and Vettese, 2019). This was confirmed by the designers and makers during the interview and could be amplified to a wider public that when people who work with waste plastics spend time and effort to see the potential, they begin to build emotional connection and value the material, thus changing their perceptions.

One industry that has been affected by ocean plastic is tourism, with fewer visitors when more plastic is found in the marine environment (Krelling, Williams and Turra, 2017). However, on the flip side, tourism is also the sector responsible for ocean plastic pollution, and action must be taken to meet sustainability demands (Budeanu, 2000; Lee and Moscardo, 2005; Miller and Ward, 2005; Powell and Ham, 2008). Therefore, taking the example of tourism, tourists collect ocean plastic on the beach and take them to the shop to make an "only one in the world" souvenir while contributing to ocean plastic reduction. Participants commented:

*"I think it would be appeal to people who visit seaside towns to have their souvenirs made from ocean plastics as it protects the ocean of the place they visited."*

*"I like it better than normal souvenirs."*

*"It looks better than the normal ones!"*

*"Really fun and looks better than I expected."*

*"Knowing it's made from recycled ocean plastic makes me like it more!"*

The required machines can be simplified or replaced with easily found alternatives, and the degree of personalisation can be adjusted according to the situation of the target setting. For instance, if an activity takes place at a workshop with all the equipment available, the participants can be engaged through the entire recycling and creation process, while if it takes place at a festival without power or specific equipment, they can be provided with pre-made ocean plastic sheets and crafting tools (like the workshop in Chapter 8). The activity should be designed with the aim of raising participants' awareness of ocean plastic, and the mementoes they create serve as reminders to practice the plastic behaviours learned in the experiences in their daily lives. A brief experience of making the personalised memento out of ocean plastic can potentially enhance the participant's lifelong awareness after taking it home and encourage them to start conversations about the issue with others. More on ocean plastics and environmental education activities will be discussed in detail in section 9.3.

*Recycling ocean plastic with additive approaches*

If the characteristics of ocean plastic are seen as its strengths, a solution may be found – waste as a new resource (Reilly, 2014; Lucier and Gareau, 2015; Hunt and Charter, 2016; Raubenheimer and McIlgorm, 2018). Plastic remains in the marine environment for centuries due to its high persistence (Derraik, 2002; Gall and Thompson, 2015; Niaounakis, 2017). This property, together with vast quantities and the rich colours and wide varieties, makes an excellent material. As an emerging technology, 3D printing is attracting increasing attention and interest, and the use of 3D printing technology has gradually expanded from the professional fields related to design and manufacture to more areas. Table 11 and 12 summarised how each type of ocean plastic performed in extrusion and 3D printing processes. All kinds of ocean plastic samples collected can be extruded and 3D printed, with different behaviours. PE, PP and PS perform similarly in the extrusion process, and they can all be smoothly extruded into complete and uniform filaments. When extruding the same type of plastics, even if the material contains different colours, the extrusion process fully blends the colour and produces the filament with an even and uniform colour in most cases. In the 3D printing process, 3D printing pens are more tolerant about contaminants than the printer, and all the filaments made during the experiment can be fed through the pen. 50% PS ocean plastic works surprisingly well on the pen as the print was the finest compared to the rest. Apart from 100% PS and PET ocean plastics, all other filaments have the potential to replace PLA and ABS to be used on 3D printing pens. As for 3D printer, Ocean plastic PP performs best and can even print complete objects out of 100% ocean plastic. PE performed similarly to PP, but no intact object was printed with 100% ocean plastic PE in the experiment. PS prints well, but the filaments and printed objects are brittle. Extruding ocean plastic PET is difficult because the extrudates are too soft to pull out the filaments, and even if the filaments are extruded, they are not smooth but crisp. The waste from the extrusion process of the other three ocean plastics can be recycled and re-extruded in much the same way, but PET cannot be re-extruded into filaments anymore. Printing PET ocean plastic filament is very unstable because only the small ring was printed entirely, and other times, the printer's nozzle always got jammed by the filament. Regarding the odour discussed previously in the literature review and last section, the ocean odour can be smelled on the first extruded filaments, but the printed objects are odourless.

**Table 11**

Extrusion performance

<table>
<tr><th>Ocean Plastic Type</th><th>Extrudable</th><th>Performance</th></tr>
<tr><td>PE</td><td>Yes</td><td rowspan="2">PE and PP ocean plastics perform similarly. It can produce a consistent filament no matter what percentage of PLA is added. 100% ocean plastic creates the smoothest surface, and the more PLA added, the rougher the surface for PE but not PP. In addition, the cross section of extruded filaments mixed with ocean plastics and PLA is fibrous. Contaminants are obvious on the filaments. It takes time to pull out the continuous filament of the desired diameter, but the resulting waste can be re-extruded, or compression moulded.</td></tr>
<tr><td>PP</td><td>Yes</td></tr>
<tr><td>PS</td><td>Yes</td><td>The performance of extruding PS ocean plastic is similar to the above two. PS ocean plastic filaments are more brittle and smell more like the ocean.</td></tr>
<tr><td>PET</td><td>Yes, but further test needed</td><td>Extruded PET ocean plastic is extremely soft, so it takes a long time to pull out a consistent smooth filament. However, compared to the cloudy result from compression moulding, extruded PET ocean plastic is clearer. The filament is brittle and contains obvious contaminants. The resulting waste is challenging to be extruded and pulled out to be a continuous filament, and the process generates more waste. In this experiment, PLA was not added in the extrusion of PET because the melting temperature difference between PET and PLA is large. The scrap was extruded again, but the material behaved even more poorly due to the possibility of degradation.</td></tr>
</table>

**Table 12**

3D printing performance

| **Ocean Plastic Type** | **3D printable** | **Performance on a 3D printer** |
|---|---|---|
| PE | Yes | **1. 100% PE ocean plastic filament:** It is able to print, but the performance is not stable, and prints are not complete. There are more printings that failed than succeeded, and in most cases the filament does not come out of the nozzle and jam the printer. This is caused by the contaminants in the filaments. Adhesive products such as hair spray and stick glue are required in order to keep the prints on the printing bed during the printing process.<br><br>**2. 50% and 40% PE ocean plastic filament:** Both of the filaments are printable and perform similarly. The two filaments and their prints cannot be distinguished by naked eyes. Prints are complete every time, and the side surfaces are smooth and acceptable. There is lack of viscosity between layers. Adhesive products such as hair spray and stick glue are required in order to keep the prints on the printing bed during the printing process. The bottoms warp slightly sometimes.<br><br>**Further experiment:** 65-80% PE ocean plastic filament should be extruded and tested on 3D printer. |
| PP | Yes | **3. 100% PP ocean plastic filament:** This filament has the best result compared to other filaments made of 100% ocean plastic. Prints are complete, and the side surfaces are smooth and acceptable, but not as fine as the 50% and 40% PE prints. The viscosity between layers is not as good as PLA. The filaments print successfully every time. Adhesive products such as hair spray and stick glue are required in order to keep the prints on the printing bed during the printing process. Obvious warping occurs on one side of the print bottom.<br><br>**4. 50% and 40% PP ocean plastic filament:** Both of the filaments are printable and perform similarly. The two filaments and their prints cannot be distinguished by naked eyes. They are also similar to 50% and 40% PE prints. Prints are complete every time, and the side surfaces are smooth and acceptable. Adhesive products such as hair spray and stick glue are required in order to keep the prints on the printing bed during the printing process. Warping rarely occurs.<br><br>**Further experiment:** 70-85% PP ocean plastic filament should be extruded and tested on 3D printer. |
| PS | Yes | **5. 100% PS ocean plastic filament:** It is able to print, but the performance is not stable. Printing can sometimes be completed but the prints are often defective. The filament sometime jams the nozzle, causing the print to fail. There is lack of viscosity between layers. Adhesive products such as hair spray and stick glue are required in order to keep the prints on the printing bed during the printing process. Warping is not as obvious as 100% PP prints. Prints contains slight ocean odour.<br><br>**6. 50% PS ocean plastic filament:** It is able to print, and the performance is much better than 100% PS ocean plastic filament. Prints are complete every time, and the side surfaces are smooth and acceptable. There is lack of viscosity between layers. Warping rarely occurs. Adhesive products such as hair spray and stick glue are required in order to keep the prints on the printing bed during the printing process. Warping rarely occurs. |
| PET | Yes, but further test needed | **7. 100% PET ocean plastic filament** is printable. The ring is printed completely, and the quality is better than 100% PE and PS ocean plastic. However, the printing process is not stable, because the filament jammed the printer while printing the cookie cutter and the kitten, which kept occurring after multiple adjustments. Printing 100% PET ocean plastics is promising due to the completeness of the ring but requires multiple extrusion and print tests. |
| **Performance Comparison** | | **4 > 2 > 3 >6 > 5 > 7 ≈ 1** |

Extruding and 3D printing ocean plastic is more challenging than the other methods, as the contaminants can affect the performance, depending on the size and type of the contaminants, which confirmed Hunt and Charter (2016)'s findings. When the contaminant is smaller than the set diameter or its melting point is lower than the set temperature, the effect on performance is minimal for both extrusion and 3D printing. When the contaminant is larger than the nozzle and does not melt, such as sand and gravel, it may lead to extrusion failure, plug the nozzle and even damage the equipment. Moreover, sometimes during extrusion, the contaminant is smaller than the nozzle but larger than the set filament diameter and does not melt at the set temperature, so in this case, extrusion is successful but may cause uneven filaments and the failure of 3D printing. The extrusion temperature is set for the primary plastic used, and when other plastic impurities mixed in, the temperatures that are required to melt the mixture are different (Goodship, 2007). As a result, there are situations where the primary plastic melts while the impurities remain solid (Goodship, 2007), or the mixture melts, but the impurities over decompose, which can also seriously affect the subsequent printing. It could be fixed by slightly adjusting the temperature, but this may also cause material degradation, affecting the printing performance.

The success of 3D printing ocean plastic using a regular 3D printer is indeed a breakthrough. Unlike other recycling methods, where success was predicted prior to the experiment, the possibility of 3D printing ocean plastic was utterly uncertain. In fact, it was predicted that the printing experiment was more likely to fail because recycling ocean plastic for 3D printing has not been widely explored, even as this technology becomes increasingly accessible (Hunt and Charter, 2016). Existing examples of successful 3D printing plastic waste have involved either domestic plastic waste or ocean plastic using a specially manufactured 3D printer (i.e. Parley) rather than a regular 3D printer already available on the market. The author has tested more types of ocean plastic and different ratios of ocean plastic with PLA using the Original Prusa i3 MK3S+, a commonly used 3D printer on the market. Although the addition of PLA is not ideal, it improves the performance of 3D printing ocean plastics and provides more possibilities for recycling ocean plastics. In addition, objects printed using mixed materials can be recycled again to be printed.

While this 3D printing ocean plastic experiment can be considered a success, the properties are not yet stable enough to allow ocean plastic to be used for mass 3D printing or to print precision products. It should therefore be adopted in experience-related settings for demonstration and education purposes, like proposal 2 in the subtractive approach section. Even though the use of 3D printing technology has been increasing over the past decades, it is still a novel and attractive method to the public. 3D printing ocean plastic at experience-related events can attract participants. In the ocean plastic recycling workshop held by the author, many young participants had heard of 3D printing but never seen or used it in person, so they all wanted to try 3D printing. When it is an experience-focused activity, using recycled waste is more sustainable than using materials made from raw materials, and participants can get the sense of accomplishment of contributing to the conservation of the environment. There are many more places where 3D printing ocean plastic can be used in addition to the places where compressed/injected ocean plastic were suggested in the previous section, such as sites involving STEM/STEAM[19] education (Harris and de Bruin, 2018; Khine, 2019; Perignat and Katz-Buonincontro, 2019), including 3D printing experience events, makerspaces, science camps and other science- and technology-related places, where participants can learn different sets of skills to use in real life situations. Both 3D printers and printing pens have advantages in experience activities. A 3D printer can give participants a more intuitive feeling of 3D printing technology and provide more exquisite objects, while a 3D printing pen allows participants of all ages to operate with their own hands. In experiential activities, 3D printing ocean plastic focuses more on the process than the resulting objects compared to the compression/injection because its result is not as aesthetic and attractive as the latter's, but the process is more fun and technological. Besides, the thermoplastic materials used in this research, such as PP, PE and PS, can be recycled repeatedly. Thus, even failed prints can be recycled to achieve their educational and experience value and the goal of "waste no longer being waste, nor producing more waste".

[19] STEM: Science, Technology, Engineering, and Mathematics (Harris and de Bruin, 2018). STEAM: Science, Technology, Engineering, Arts, and Mathematics (Khine, 2019).

## 9.3 Using ocean plastic as an educational tool to address the ocean plastic problem

Many countries and regions in the world are not recycling enough or do not have the capacity to recycle enough plastic waste, putting growing pressure on the marine environment. While plastic waste management is a vital aspect of the solution to the ocean plastic problem, addressing the source of plastic waste is a top priority. Exploring where and how to intervene within the plastic's life cycle before it reaches the ocean is considered the best solution to the problem (Steensgaard et al., 2017). The solution lies with the people, the users of plastics. Interventions throughout the life cycle of plastics involve people re-using and recycling plastic products. Adopting a systematic approach to recycling allows local people to experiment with materials and processes and discover new ways to repair, re-use and transform ocean plastics, encouraging skill-sharing and community education (Vones et al., 2018). In addition, the solution should also occur before the plastic's life cycle, where people choose to reduce or even not purchase unnecessary plastic products. These behaviours and actions can be achieved and enhanced through environmental knowledge and education. Scientists, scholars and authorities have identified environmental education worldwide as an essential approach to address environmental and sustainability issues and build a connection between them and people's lives and work (Hungerford and Volk, 1990; Forestell, 1993; Scott and Gough, 2004; Powell and Ham, 2008). Environmental education should combine theory and practice to have the desired effect. Theory can help individuals understand their relationship with the natural world (Stapp, 1969; Palmer, 2002), while practice can enhance that understanding and lead to environmentally responsible actions.

The education sector should always integrate EE into the teaching plan. It highlights the importance of environmental responsibility and effectively targets young people for positive change (McPherson, 2015; Hartley et al., 2018b). Previous studies suggest that young people in many countries are already aware of environmental issues (Cohen and Horm-Wingerd, 1993; Kahn Jr and Lourenço, 2002; Hartley, Thompson and Pahl, 2015; So et al., 2016; Hammami et al., 2017) and are more willing to take additional actions (Elgaaïed-Gambier, 2016; Hartley et al., 2018b), and EE activities can improve their awareness, attitudes and behaviours. This is also verified in this research's case studies and public engagement activities. In addition, young individuals are not only willing to change their behaviours but also encourage and foster their families and friends to make the change (Duvall and Zint, 2007; Damerell, Howe and Milner-Gulland, 2013).

Many participants involved in the public engagement activities were already aware of the problem.

*"I've looked into the Texas-sizes plastic islands in the Pacific Ocean and it scares the life out of me."*

*"Marine animals suffer."*

*"Ocean plastic kills fish, which leads to no food for phytoplankton. Phytoplankton absorbs the largest amount of CO2 in the world. Hence, global warming."*

*"Ocean plastic are hard to collect, degrade into smaller finite pieces, washes up to shores, is gathered by currents to form plastic islands, and more. Because plastics can break down into microplastics, they can harm wildlife ecosystems."*

They showed great interest in learning about and recycling ocean plastic and expressed their intention to use ocean plastics in future designs as the author's work inspired them.

*"I have never thought of using ocean plastic in my designs before, but from looking at your outcomes, they look gorgeous. This is like an art form. I will be thinking about this material going forward with my own design process."*

*"Since the lecture and the new knowledge learned, I didn't realise how reusable ocean plastic can be."*

*"[…] The exploration of colour has inspired me to consider the use of plastic and upcycling it into my work."*

Some students are inspired to design more sustainably and consider more solutions.

*"There needs to be a major change in how we use plastic and what effect it has on marine life. We need to use alternatives to plastic in our designs."*

*"Moving forward with plastic we need to ensure that we look to reuse existing plastic to ensure that it does not go into ocean. Or a bio solution where bacteria can break down."*

*"The way the world is heading, plastic needs to be understood and changed out for other materials. Was interested to learn more about sustainability."*

Some participants also carried out critical thinking and expressed concerns.

*"I would say plastics have definitely transformed our society and I have hope that we can find more meaningful ways to digress the use of virgin plastic."*

*"I love the idea of using ocean plastic as a resource, but it's the fear of creating more waste than before and starting the whole waste cycle again."*

*"I still feel negative about ocean plastics. Seems like a hard material to work with when there are many types of plastic as well as sediment that can contaminate plastic for a second-generation use."*

As discussed in Chapter 8, after the lectures, or even two years later, some students began to work with ocean plastic and other waste materials in their designs, while others tried to approach the plastic problem from other perspectives, such as eco-plastics. These actions demonstrate the long-term effectiveness of incorporating ocean plastics curricula into educational settings. However, even though students are willing to take action against ocean plastic, the author has noticed a lack of thorough understanding. One of the students wanted to use recycled ocean plastic to reduce the cost of the product. It is a misconception that products made from recycled materials should be cheaper, but in reality, many of them cost more due to the complex pre-treatment waste materials require, especially ocean plastic. Not all useful knowledge and information is likely to be covered in one lesson; therefore, participants should be supported and encouraged to continue the cycle in their daily life after the participation (Ballantyne and Packer, 2011). It is easier to assess behaviour in a school setting because students spend a relatively long time in the setting, and educators have time to observe, remind, and communicate behaviour changes. Therefore, educators must have a continuous teaching plan rather than a one-off lesson. In addition, the assessment method of environmental education courses should be different from traditional courses. Students should be attracted by the courses and not be rejected by the dreary content and exams.

Free-choice learning is considered a practical approach to solving environmental problems (Falk and Dierking, 2002; Ballantyne and Packer, 2011). Through looking into the cases in Chapter 7 and discussing with some of the business founders, the researcher began to amplify the connection between each individual and the whole issue. In each of the cases discussed in Chapter 7, the founders apply plastic recycling to the area that they are good at and succeed in gaining public recognition because they were "free" to choose at the beginning. For example, Recycle Rebuild focuses on using recycled plastics for post-disaster reconstruction because of its architectural background, and Still Life focuses on using them to change people's perception of plastic furniture because of the design and art background. "Free-choice" allows them to use their right expertise and interest to explore the proper solution.

Each person interprets the problem and material differently based on their knowledge and experience. When assisting the author at the laboratory, the technician who has been working on plastics and polymers with an engineer's eye said that while she and other engineers had been working on recycling domestic plastic waste, they never considered design and aesthetic options, and working with the researcher opened her eyes to more possibilities of plastic waste that recycled plastic could be beautiful and attractive. While engineers tend to experiment with physical and chemical recycling methods to produce materials, designers build on the recycled materials to create viable applications which attract attention from more audience. Therefore, the wider audience is reached, the more expertise will be involved, and the more possibilities and opportunities will emerge.

Free-choice environmental education experiences are considered to "have the potential to make an important contribution to community capacity building in relation to environmental issues" (Ballantyne and Packer, 2011: 202). When free-choice is applied in a particular activity, such as an ocean plastic crafting workshop, to encourage participants to take the right action, the process of co-creation can give participants a sense of "free-choice". Lončarić, Dlačić and Kos Kavran (2018) suggest that co-creation with consumer participations affect their perceptions of value and life quality as they act as value co-creator (Chathoth et al., 2013). The participatory workshop of this study further confirmed that participants recognise the effectiveness and value of having “free-choice” to co-create ocean plastic mementoes.

When asked their opinions on co-creating objects using recycled materials in educational workshops like this, participants replied:

*“A good way to engage people - give them something to do whilst learning about a topic makes it more memorable.”*

*“Educational workshops are a playful way of educating the public.”*

*“Great choice as you show that even the smallest rubbish can be given new life. Interactive and not age limited. The host makes a big difference also.”*

*“I think it’s good to learn what things can be used to make something new.”*

*“It’s educational and meaningful. Especially with children.”*

Communicating and sharing are the special characteristics that make experience-based industries such as tourism suitable for environmental education. It is also part of the “value” that is generated from the process of free-choice co-creation. Value can come from the interaction between the consumer and other people, such as family and friends (Tynan and McKechnie, 2009). In addition, the communication between the operator and the consumer can add value to the operator’s perception (Lončarić, Dlačić and Kos Kavran, 2018). One lady, who participated with her 10-year-old daughter, told the author that she believed that, in addition to all the environmental benefits and significance of recycling ocean plastic, its lightweight and unique pattern made it more attractive than many earrings on the market. It played the decorative role and would not make ears painful like ordinary earrings after wearing all day. She also added that her daughter loved crafting and using ocean plastics was an excellent choice because children like her could enjoy the making process and learn about something useful at the same time. After their participation, they brought along her friend and the friend’s daughter, because she commented, “these kinds of educational activities should be promoted to everyone”.

Many people share their extraordinary experiences on social media (Grissemann and Stokburger-Sauer, 2012) and discuss them with other people afterwards (Ballantyne, Packer and Sutherland, 2011). Especially if participants make souvenirs during the experience and take them away, the souvenir could contribute to a better conversation. The person who is told the experience story could see, smell and touch a physical object and relate more to the matter instead of recreating the experience in his or her mind only through the sharer's verbally described memory. 40 out of 41 participants in the workshop commented that they would use the item they made at the workshop to start a conversation about ocean plastic with their family and friends.

*"This is an engaging, fun and responsible way of starting conversations about the topic."*

*"My children were very curious so we will speak about it more yes."*

*"We were already aware of ocean plastic, but I think it's a great catalyst to discussion, conversation and sharing knowledge. Thank you!"*

Souvenirs are often associated with tourism, as reminders of a holiday or as gifts to friends and families after the holiday, but any physical object related to an experience can be classified as a souvenir. According to Merriam-Webster dictionary (n.d.), the definition of souvenir is *something kept as a reminder.* It can be any physical items (Lasusa, 2007) from a holiday, a festival, an occasion, an event, or an experience. In Chapter 3, tourist experiences and souvenirs were discussed as a representative to understand the relationship between general participatory experiences with their resulting souvenirs and environmental behaviour change. When a souvenir is linked with tourism, it is not necessarily the product generated during the travel experience. People can have no contact with souvenirs for the entire trip and buy a fridge magnet at a souvenir shop or even at the airport on the way home, but when they see the magnet on the fridge at home, they may think back to that vacation. Therefore, this piece of souvenir acts as a tangible object that evokes an intangible memory (Gordon, 1986; Khalid and Helander, 2006; Collins-Kreiner and Zins, 2011; Haldrup, 2017; Li and Ryan, 2018).

Dickens (2021) also recognised the benefits of using plastic waste in tourism and the connection between the physical object and intangible memory. He said in the interview:

> Having something customised through your trip [is a good idea]. I think a number of times as a kid I convinced my family to put a penny in the machine that crushed it into a shape that reminds me of Edinburgh castle, the little copper thing. I mean it's pointless, you are actually crushing your money in making something that is not valuable, but we all did it because of that *memory*. And now that machine is everywhere, so same concept but with plastic, a part of the journey they pick up five bottle caps and put those five bottle caps into a machine then get back Edinburgh castle. You know that's kind of cool. Think, imagine you have to clean up the city, to exchange those little thing, local material. People feel good about cleaning up our city, so it's a good idea.

Nevertheless, a souvenir of an environmental experience is not so simple. First, it is not only a reminder of the experience in the past but also of the present and the future and is, therefore, "bilateral". Second, in order for participants to have an authentic and thorough experience to make behavioural changes, participants need to establish an emotional connection with the souvenir during the experience. Besides, it is important for them to establish this connection to accept recycled (ocean) plastic products in the future. Making souvenirs out of waste is an effective way to build such connection, giving participants the experience of co-creating meaningful value (Prahalad and Ramaswamy, 2004b; Neuhofer, Buhalis and Ladkin, 2013), preventing or reversing environmental damage (Ballantyne and Packer, 2011) and providing them with a "trophy" to remind them to do so all the time.

When asked their opinions on making souvenirs out of recycled ocean plastic, almost everyone in the workshop held a positive thought, and some people considered it an excellent initiative to raise awareness. People replied:

*"It is good because it raises awareness that we need for to recycle and make sure that less plastic is thrown into the ocean."*

*"It is a brilliant idea to both raise awareness and to reuse the material."*

*"I think it is really cool. They look good, can be educational, and make a statement."*

*"Great way of alerting people about the issue of ocean plastic."*

A couple of people liked the idea but had their concerns at the same time:

*"I worry it will be returned to the ocean, but I am happy it has been given (a) new life."*

Another advantage of tourism is that when people have the chance to see the environment destroyed by humans and are convinced that their behaviours can make a difference, they are more inclined to take action (Ballantyne and Packer, 2011). This can be associated with dark tourism where tourists seek out places about death and tragedy (Foley and Lennon, 1996), and beaches full of ocean plastics and endangered marine wildlife fit the bill. According to the research of Biran, Poria and Oren (2011: 830), the motivation of dark tourism can be divided into four factors, and the purpose of ocean plastic-related tourism can be classified into two of them, namely: "see it to believe it" and "learning and understanding". When they cannot see for themselves what they have been destroying in person, they should be reminded by providing alternative forms, such as images, videos and something that can reflect the situation (i.e., the website that mimics how plastic travels in the ocean).

When asked if they thought their attitude and behaviour towards plastic products and waste had changed or would change after attending the workshop, most people believed so. The only people who answered *"No"* were already well aware of the ocean plastic issue or strong opinions. Participants replied:

*"We can make a difference and play a role in reusing or reducing our waste products."*

*"I think I am more optimistic that ocean plastic can be reused."*

*"Looking at the jewellery made me think we should do more picking on the beach!"*

*"Yes I will be more careful when I buy products."*

*"Yes, I feel like I have more agency and choice in what I do with plastic waste."*

*"We were already aware of ocean plastic, but I think it is a great catalyst to discussion, conversation and sharing knowledge."*

*"Confirmed my beliefs."*

*"I was already interested in making jewellery from upcycled materials. I would love to learn more about how to use ocean plastic myself. I will look out for other products made from ocean plastic and keep on trying to reduce my plastic use."*

*"I already shared these opinions before but the necklace I made will be a reminder of my beliefs and that good changes can be made in the world."*

*"Will try to seek out more recycled plastics."*

Therefore, if participants are provided with a clear and more effective sustainable service (Forestell, 1993) while enjoying their experiences, they will be more likely to adopt environmentally responsible behaviours in their daily lives and influence more people to do so after.

The challenge for environmental education is to assess its effectiveness after participation, and it is unrealistic for a participant to complete an entire behavioural change cycle during the in-situ experience only (Ballantyne and Packer, 2011). For experience-based sectors such as tourism, monitoring changes in participants' behaviour is tricky because these experiences are often one-off, with no physical contact with participants after they leave the site. Take-home information should be provided to remind participants to adopt environmentally friendly behaviours in their daily life (Ballantyne and Packer, 2011). The "takeaway" can be tangible and/or intangible, which can be a token made during the educational experience, some follow-up events, regular newsletters and social media posts that work as a reminder of behavioural actions.

Environmental education needs the joint efforts of both knowledge providers and recipients. Previous literature and public engagement activities in this study confirm that EE does not guarantee a 100% conversion rate from no environmental action to environmentally responsible action. The reason may be that the participants themselves are not concerned with environmental issues or that taking environmentally responsible actions is complicated and requires significant effort and time. Sometimes EE does not have the desired effect also because participants are informed of environmental problems and willing to change their behaviour but do not know where to start or how to do it. Therefore, attractive and engaging events and easy-to-adopt solutions should be made available to the public and should be reminded from time to time after participation in EE.

## 9.4 Emotion, visualisation and environmental awareness and behaviour

Emotion plays a crucial role in cognition (Epstein, 1994) and influences perceptions and actions (Khalid and Helander, 2006). Research suggests that lasting and vivid memories can be formed if they are associated with strong emotions at the time of their occurrence (Anderson and Shimizu, 2007). "Feeling good" is an emotion that has a considerable impact on consumers, making them feel passionate (Khalid and Helander, 2006) and more likely to do something. In the environmental context, it could be interpreted that when people feel good about their positive environmental actions, they are more motivated to continue doing them.

Emotion is what motivates the author to make a difference in the environment. The author observed her own experience in this process. It is valuable to investigated one's own cognition because direct knowledge of subjective experiences results from first-person contact with them (Chalmers, 2004).

The author identified her four emotional change stages during the research process.

*Stage 1 – Concerned*

The author was emotionally stimulated by the vast amount of plastic waste in the marine environment and its adverse effects when reviewing the literature. It is estimated that eight million tonnes of plastics enter the ocean every year (Jambeck et al., 2015), which is a considerable number that sounds like a serious problem but is hard to picture. World Economic Forum (2016) then provide a more concrete description, saying that eight million tonnes are equivalent to dumping a truckload of garbage into the ocean every minute. Even though it was not happening precisely this way, the author felt the urgency and seriousness of the problem when she played the images of the amount of plastic waste leaking into the ocean every minute in her mind. In addition, the images found on the Internet, such as ingestion, entrapment and entanglement, had boosted the author's emotional changes. The combination of shocking statistics and more visual information led to the author's first emotional reaction.

*Stage 2 – Devastated but motivated*

The second emotional change occurred when watching *Drowning in Plastic* and conducting a field trip. The author cried through the 90-minute documentary and could not calm down for a while. The narrative video allowed the author to see the gravity of the plastic problem in the ocean from the cast's perspective, which was more potent than static data and images. The most destroying feeling came from the field trips to the Isle of Harris. Even though the author had studied ocean plastic, it was hard to believe what she saw was real when she stood on the beach covered with plastic waste. The author was shocked and upset by what human beings have done but keenly aware that change needs to happen. Because the author who experienced such emotional change was eager to take action, she noticed the connection and realised that this emotional change might be applied in public engagement to guide behaviour change.

*Stage 3 – Reconciled*

This was the stage where the author conducted the experiments and established an emotional connection with the ocean plastic (the material rather than the situation). If the author thought that ocean plastic was evil in the past, the author made peace with it in this stage. This stage of emotional change was also confirmed with other designers and makers during the interviews. After two years of experimenting with different techniques, the author began to realise that with the right technology, public awareness and action, the ocean plastic problem, even if extreme, was not insurmountable. There is so much potential for the material to come back into people's lives in new and more aesthetically pleasing ways. The sense of accomplishment and satisfaction from seeing a series of experimental results inspired the author to continue discovering ocean plastic's potential.

*Stage 4 – Hopeful*

When working with the public, whether by introducing the recycling results or through verbal communication, the author felt that the public's awareness of ocean plastic was increasing, and they wanted to be involved in changing the problem. Students showed a greater willingness to design sustainably and consider using waste materials after the lectures, and some of them made a move. The public of all ages was impressed that ocean plastic could be turned into something unique, and they believed there was a market for recycling it into more products.

The author goes through these four emotional stages, *concerned, devastated but motivated, reconciled, and hopeful*, not only as a researcher who studies ocean plastic but also as a general public member. The author believes that the more visual the information, the more it elicits emotional changes because it is more likely to stimulate empathy. This is also consistent with Ballantyne and Packer (2011)'s and Muralidharan and Sheehan (2017)'s theory of culpability, that when people see what they have destroyed, they tend to act. The interview with Urbanski (2021) and Still Life (2021) also confirms that visual impact on information can lead to behavioural change. In addition, all designers that the researcher interviewed in Chapter 7 have also witnessed their emotional connection with the recycled products they make. Therefore, the author mimicked this personal experience in public engagement events with emotional, sensory, physical and creative experiences (Schmitt, 1999), providing shocking statistics, images and videos to gain empathy and then offering participants the opportunity to get their hands-on recycling ocean plastic to gain satisfaction and sense of accomplishment and contribution. This process also sought to create authentic experience to evoke strong emotion and engage participants to achieve long-lasting memory (Anderson and Shimizu, 2007), which could remind them to adopt responsible environmental behaviours in daily lives.

The finding not only confirms the author's reflection on her personal experience but also verifies the findings of other research on the relationship between emotion and environmental behaviour. Some participants, especially children, expressed empathy and emotional connections (Ballantyne, Packer and Sutherland, 2011) with marine animals because they believed their participation in the workshops prevented these plastics from harming the marine animals.

*"It feels great to know that I'm helping the animals."*

After seeing the simulated version of how plastic moves through the ocean, participants reacted strongly.

*"Very impactful to show where the plastic goes if you throw it away."*

*"It makes me consider the nationwide effect leaving litter on a beach in Scotland may end up so far away."*

*"Seeing how far the plastic travels on the map over a period of time was very eye opening."*

The researcher's own experience and conversations with other designers and makers enabled the researcher to identify the connections between the *maker* and the *waste material* that arise during the hands-on process. All interviewees confirmed that they were emotionally attached to the resulting products in different ways after the recycling processes were completed, such as giving each product a different name, wanting to keep it for their own use, or feeling gratified by consumer satisfaction, and they became to value the waste materials they worked with and adopted more environmentally sustainable behaviours. Therefore, when designing the participatory workshop, the researcher wondered if each maker confirmed that an emotional connection was established, could this pattern be scaled up to predict that participants could also build similar connection after working on ocean plastics recycling? How could this connection be strengthened?

In designing the materials used in the workshop, the author considered the "placement" factor after participation – how and where the participants "placed" the objects they made (Peters, 2011). As a result, the premade items mostly take the form of accessories or pendants (Figure 112), which participants can wear after interacting with recycled ocean plastic during the experience, thus prolonging the "connection". Wearing them at a visible "place" also increases participants' chances of starting a conversation with others about ocean plastics after participating.

*Figure 112. Participants wearing the objects at different places, Tao, 2021.*

Some of the "connections" were also extended between participants and others (i.e., the operator, friends and family), as well as between "others" and ocean plastic. For instance, one of the participating girls, under the age of ten, told the researcher,

*"Do you know what is the beauty of what we did today? We saved a lot of fish by making these so they will not eat them!"*

The researchers praised her action and encouraged her to take more action in the future, so her emotions of "feel good" and "passionate" were possibly evoked. In addition, some participants made jewellery for their family members as a gift. A boy, under the age of eight, made a pair of earrings for his mother as a surprise (Figure 113) and told her that they were made of ocean plastic. His mother asked him what he knew about ocean plastic, and he said,

*"I learnt from the workshop. Ocean plastic hurt animals in the sea so we should recycle it and stop putting more plastic in the sea!"*

*Figure 113. A participant making a pair of earrings for his mother & she wearing them, Tao, 2021.*

Participants also verified the idea of *vast possibilities*, believing that ocean plastic, now considered waste, can be used as a new material to create something else that makes recycling more feasible (Vones et al., 2018).

*"I realise that plastic waste can be turned into something beautiful than just waste."*

*"Yes, I was there with a group of kids who I think learned a lot about it. I might look at what other things I could make with recycled materials. I like being creative."*

Participants' reactions to the experience were similar to those of the researcher but milder (Figure 114). This may be due to the limited participation time, with participants not having enough time to digest the information received. Ballantyne and Packer (2011) agree that participants need time to process the experiences cognitively and emotionally in order to develop new ideas and experiment with the activities in their everyday lives.

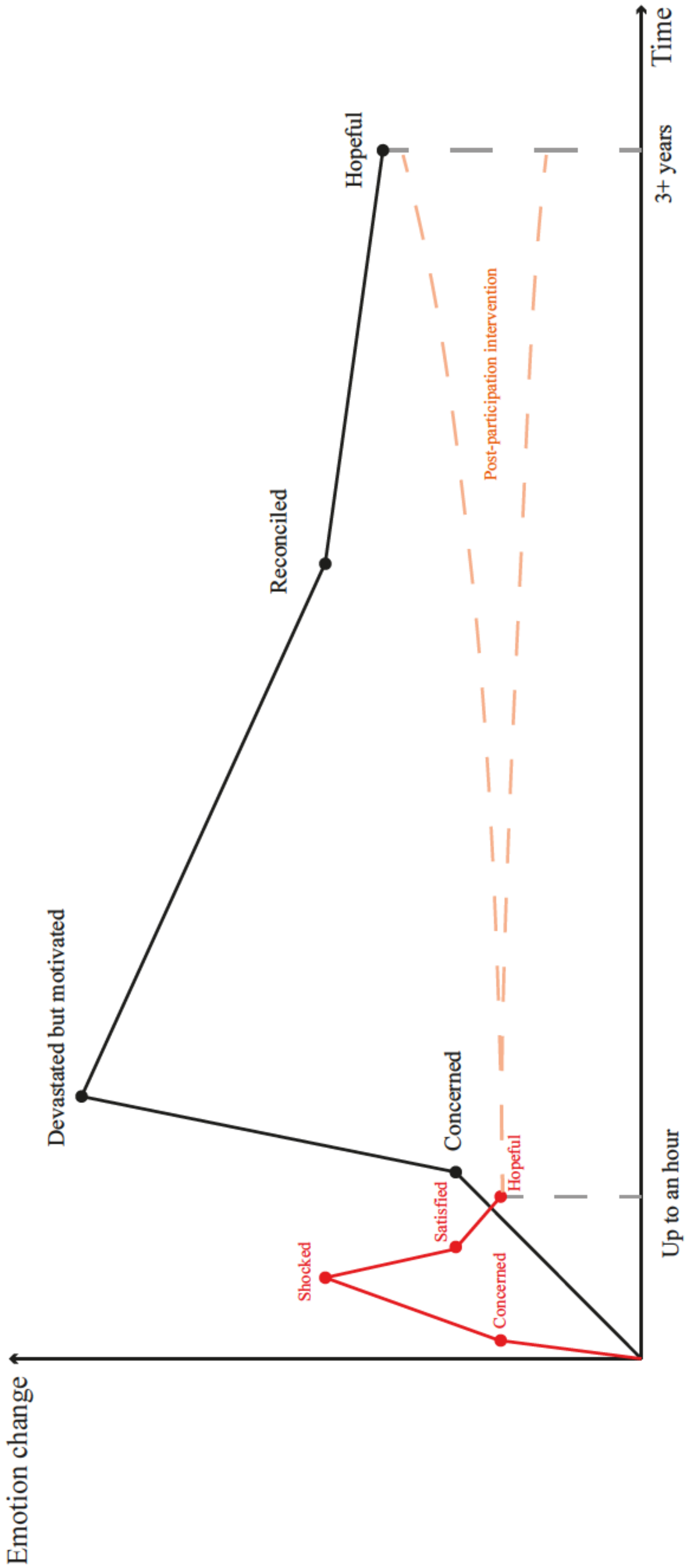



*Figure 114. Emotional change, Tao, 2021.*

These comments indicate a great deal of interest in recycling ocean plastics in environmental education and a recognition of the importance of addressing marine pollution. This is especially obvious when participants are emotionally affected by factors related to ocean plastics, such as when they realise that there is much more plastic in the ocean than they know, the negative impact on wildlife and when they realise that their actions can make a difference. These may not guarantee a behaviour change from every participant, but there are possibilities, and every small step adds up to a significant change. Factors such as the expansion of the Precious Plastic Community, more and more people being engaged in plastic recycling and interested in recycled plastic products, and the increasing number of workshops related to recycling and environmental education illustrate that awareness is rising and more actions are taking place.

# Chapter 10. Conclusion

Plastics are one of the most problematic aspects of marine issues because of their abundance and longevity, as well as the fact that large ones break down into microplastics (Law and Thompson, 2014), which are ingested by marine animals (Van Franeker et al., 2011; Lusher, Mchugh and Thompson, 2013). Retrieving plastic from the marine environment is challenging and adds pressure on the local ecosystem and economy (Hastings and Potts, 2013; Zhou et al., 2016). Since technical solutions may not be sufficient to contain the problem, a perspective emphasising the impact of human behaviour is needed (Heidbreder et al., 2019). There is a significant amount of research on the status and impact of plastic in the ocean, but little research on its recycling from a designer and maker's perspective and public acceptance of recycled ocean plastic material.

The purpose of this doctoral research was to explore the possibilities of using ocean plastic, the waste material, as a resource, through scientific and design experiments and to evaluate the methods used in this process to propose and assess environmental education activities that involve the public to raise awareness of ocean plastic and change behaviours. The research consisted of two parts – the author's making process and public engagements, and the author associated these two by introducing the hands-on experience to the public. Rather than experimenting with how to recycle ocean plastic in large quantities with a purely scientific approach, this research integrated design principles with existing plastic processing methods to make recycling ocean plastic more accessible to the public. It aimed to encourage more people to realise that their actions can bring value and possibilities to ocean plastic, rather than being useless waste damaging the environment. Overall, the research was not designed to invent a definitive solution to the ocean plastic problem or change everyone's plastic-related behaviour. It was undertaken to experiment with tools and equipment available to the researcher in conjunction with existing recycling methods in a design and engineering context, breathe new life into ocean plastic and inspire the public to take more action by showing the possibilities.

This chapter will discuss the value and contribution of this research. It will also review the research limitations and recommend opportunities for future research.

## 10.1 Contributions to the knowledge

The research contributes to practice and theory in many ways. Firstly, it is the first transdisciplinary research on ocean plastics involving science, design and public engagement. Existing research on ocean plastic is mainly conducted from scientific approaches, investigating the ecological (Jamieson et al., 2019) or geographical (Lee, Cho and Jeong, 2006; Hidalgo-Ruz and Thiel, 2013) state (Cózar et al., 2014; Jambeck et al., 2015) and impact (Gall and Thompson, 2015) of the problem and relevant waste management (Gregson et al., 2016; Dauvergne, 2018; Schneider et al., 2018) and policies (Pettipas, Bernier and Walker, 2016; Raubenheimer and Mcllgorm, 2018). However, the complexity of sustainable development problems requires the adoption of joint research efforts across different disciplines (Biasutti, 2015), which emphasises the "transgression of boundaries between academia and society and is intended to be participatory research" (Godemann, 2008: 627). While much of the existing studies have looked at ocean plastic as a negative situation, which is true, very few have looked at it as a potential material. Hunt and Charter (2016) argue that plastic waste poses a severe threat to the marine ecosystem and also cause the waste of a significant amount of valuable plastic materials. The ocean plastic issue is complex, requiring both improvement of the situation and retrieving and recovering the material, so the researcher proposed a new concept of separating the material from the situation, that is, feeling the urgency of the situation, but seeing the potential of the material. Differentiating from materials scientists, who focus mainly on the properties of the material, the researcher has added a design thinking to the process of recycling marine plastics and offers the public a more acceptable solution. For example, what layout and proportion of colours can make the recycled product more attractive? Can this pattern mimic a particular scenario where the consumer can form a special bond? With design and the public involved, ocean plastic is not just a material, it has stories behind it. The researcher has formed a new way of looking at ocean plastic from a designer perspective to achieve a functional and aesthetic purpose and propose more possibilities and opportunities for ocean plastic by engaging the public that brings in social attitudes.

Secondly, the research identified comprehensive recycling methods (Table 13) and applications of ocean plastics. The ubiquitous availability of ocean plastic offers a potential and attractive opportunity for business (Hunt and Charter, 2016; Vones et al.,

2018) and research. Through experimenting and evaluating the works of other makers, the research has analysed different recycling methods on different types of ocean plastic, contributing systematic technical knowledge and reference research on recycling. One of the keys to progress on marine issues is developing novel and innovative market-based approaches (Hastings and Potts, 2013). Therefore, in addition to experimenting with conventional plastic recycling methods, this research has achieved using digital technologies to process ocean plastic using non-specially manufactured machines. The realisation of 3D printing ocean plastic using regular 3D printers available on the market is unprecedented, as the challenges of this application have been identified by research (Hunt and Charter, 2016), but the actual performance was unknown until this research.

**Table 13**

Overview of ocean plastic processing techniques

| Process | Complexity of parts | Plastic types | Tolerance to contaminants |
|---|---|---|---|
| Compression moulding | Simple | Single/mixed | High |
| Extrusion | Medium | Single/mixed | Low |
| Injection moulding | Medium | Single/mixed | High |
| Laser cutting | Complex | Single | Low |
| CNC-milling | Complex | Single | Low |
| 3D printing | Complex | Single/mixed | Very low |

Thirdly, the research contributes to a growing body of literature seeking to understand the public perception of ocean plastics. Understanding perceptions on ocean plastic is considered one of the most crucial steps towards a cleaner marine environment (Hartley, Thompson and Pahl, 2015) by engaging society in the development and implementation of widely accepted solutions (Hartley et al., 2018a). Existing literature focuses on the public perception of ocean plastic as waste in the marine environment (Beeharry et al., 2017; Krelling, Williams and Turra, 2017; Hartley et al., 2018a; Heidbreder et al., 2019). Previous research had identified the public's negative views on ocean plastic (Ofiara and Brown, 1999; Ten Brink et al., 2009; Leggett et al., 2014). In addition to that, this study investigated their opinions on ocean plastics after being repurposed with a new life. In order to promote a "waste as resource" cultural change to address ocean issues, the public as direct consumers must be demonstrated the possibilities of the change, and their perceptions on the change must be understood. The research identified perception change in participants before and after the public engagement activities. Many considered ocean plastics evil and harmful when the researcher first asked their thoughts, but after they were presented and experienced what was possible, they felt hopeful and what they did was meaningful. Beeharry et al. (2017) argue that the individual's perception drives behaviour motivation. Normative pleasure is associated with social values, such as concerns for the environment, which "make us feel better about ourselves when we act in line with the expectation of others as well as our beliefs" (Khalid and Helander, 2006: 199). Thus, the shift in perception from feeling negative to positive may potentially lead to action taken.

Fourthly, the researcher has developed a theory of using visual aids, senses and hands-on experiences to provoke emotional change in order to form environmental awareness and behaviour (Figure 115). Visual aids refer to anything possible to recreate the scene when the participants do not have the opportunity to see the damaged environment for themselves to provoke empathy. Senses refer to any of the five senses associated with the experience that evoke memories after participation. Special sensory memories are acquired from the hands-on experience. Hands-on experiences also provide participants with an opportunity to demonstrate that they can contribute positive change to the environment. In order to achieve awareness and behaviour change, the experience must involve the individual on emotional, physical, mental or intellectual level (Pine and Gilmore, 1998; Zeppel and Muloin, 2008; Ballantyne, Packer and Sutherland, 2011). The study has identified that the effect is more pronounced when all three factors are applied together, with participants showing stronger emotional changes, a deeper understanding of ocean plastic issues, and a greater tendency to take action.

Jordan (2003) argues that products and services should engage consumers at three levels. The first level is the primary function, the second level is the emotions associated with the product or service, which are part of the user experience, and the third level is the aspirational qualities associated with the product or service such as personas or social factors – in other words, what owning the product or using the service means to the user (Jordan, 2003). In this study, the three levels proposed by Jordan (2003) are reached when visual aids, sensory and hands-on experience work together. At the second and third levels, in particular, participants using the service means they are contributing to addressing the ocean plastic problem and making a positive social impact, generating the *feeling good* emotion that can have a significant impact on them and make them feel passionate (Khalid and Helander, 2006), leading to potential environmental action. Koenig-Lewis et al. (2014) have identified that when consumers have a high level of concern for the environment, they are more likely to purchase eco-products, a phenomenon that occurs through *positive emotions,* which in turn influences cognitive benefits.

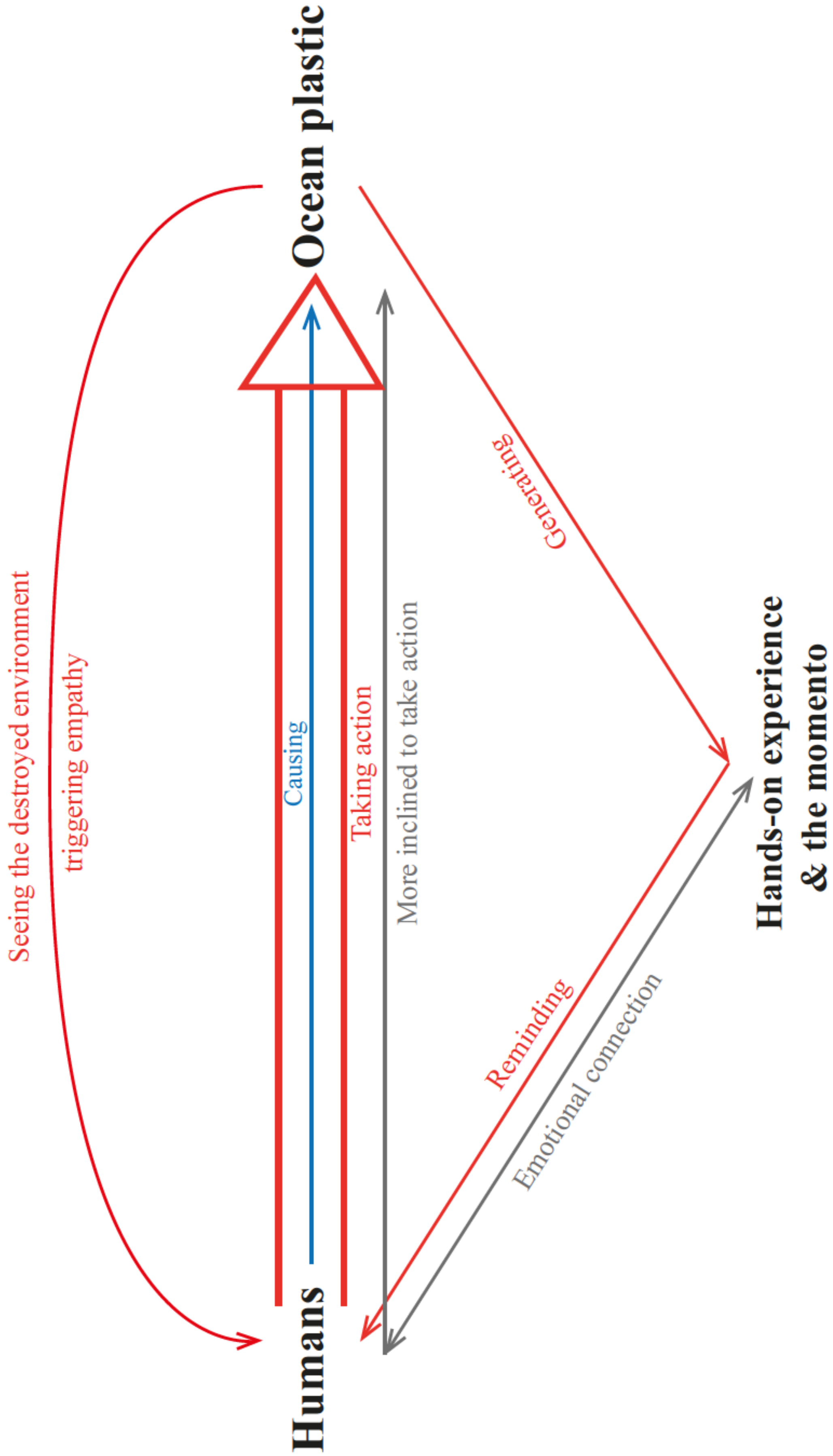



*Figure 115. The relationship between each component in this study, Tao, 2022.*

Fifthly, the study identified value generated from ocean plastic recycling and crafting experiences through communication and interaction. It includes the communication between participants and organisers, the interaction between participants and the experience and material, and the communication between participants and others during and after participation. Chathoth et al. (2013), de Andrade Matos and de Azevedo Barbosa (2018) and Lončarić, Dlačić and Kos Kavran (2018) believe that consumers become a valuable source for the experience organisers through communicating and add value to the experience program. This study finds that the value generation is reciprocal as the experience may also add value to improve the participants' life quality (Tynan and McKechnie, 2009) while they are offering research data. Engaging in an intimate making process and immersing in the experiences of shaping materials are also "inherent values of traditional craft" (Zoran, et al., 2014). The engagement results in unique crafts that carry personal meanings (Rosner and Taylor, 2011). Tynan and McKechnie (2009) argue that value can be created through participants' interaction with others during the experience. Littrell (1990: 238) also suggests that, in addition to the feeling of uniqueness can be enhanced from the special memory of an experience, the same is true of the "pleasure in establishing friendship with others" during the experience. Kals, Schumacher and Montada (1999: 182) stated that: "the sharing of experiences with significant others may function as an amplifier of the impact of stays in nature". In addition, crafting has been recommended to have positive effects on mental wellbeing (South et al., 2008; The King's Fund, 2017; Burns and Van Der Meer, 2021; Plastic Shed, n.d). Therefore, utilising ocean plastic in crafting activities may offer more positive options for intervention in mental illness as it provides a sense of accomplishment that makes the participants feel good.

Finally, the research achieved zero waste and closed-loop recycling[20] of ocean plastics. Tooze et al., (2018: 5) argues that "as a material moves throughout the product life cycle, eventually becoming part of a larger product, it continues to collect embodied impact." As the materials involved in this research were locally sourced, locally processed and locally applied, the impact of each process in the life cycle is minimised. Besides, the applications of ocean plastics proposed in this study, both in products and

[20] Closed-loop recycling is the process in which a product is used and recycled into a new product so that it never enters landfill (Ravenhall, 2019).

experiential services, reduce the ecological footprint of ordinary products because it no longer requires long-distance transportation to the point of sale and the chance of unsold merchandise and unnecessary storage of stock (Anastasiadou and Vettese, 2019) due to limited production and personalisation. Moreover, no waste was generated in this research because when the material is turned into waste, it joins the new recycling process, which circulates until the material loses its properties. Materials such as PET ocean plastic that did not yield desirable results become the subject of future research and experimentation.

## 10.2 Recommendations for future research

Since the limitation of this study has been discussed in Chapter 5, this section will make recommendations for future research to reduce the limitations.

As stated many times previously, this research was affected by the Covid-19 pandemic in many ways. It restricted public engagement activities significantly, so the researcher should plan more diverse ocean plastic education workshops with more participants from different backgrounds. Firstly, the researcher should reorganise the workshops involving different stakeholders mentioned in section 5.5 and should seek collaboration with places including museums, tourist attractions and Edinburgh Festival Fringe. It is also important to research how to engage male audience as the festival workshop attracted more female participants. Based on the findings of this research, existing literature (Elgaaïed-Gambier, 2016; Hartley et al., 2018b) and case studies, the research should also plan workshops specifically targeting school children who showed a great interest in recycling and forcing their families to join the effort. As for design students, after the pandemic, the researcher will have the opportunity to conduct hands-on workshops in the university to investigate what possibilities design students can create on a practical level. In addition, students from other courses should be invited to the workshops to bring more insights from their expertise.

Secondly, behaviour change is the ultimate goal of this research. However, due to the time limit and pandemic restrictions, post-participation emotional connections between participants and the mementoes, as well as changes in their behaviours were not monitored systematically. A post-participation follow-up system should be created to enable the researcher to assess these two aspects. This function can assist the researcher in evaluating the effectiveness of the environmental education activities, how emotion influence behaviours and obtaining feedback to improve further activity design.

Thirdly, this research experimented with four types of plastics in the marine environment. The marine environment contains all kinds of plastic waste, such as PVC (polyvinyl chloride), acrylic and nylon, which have not been experimented with. Many fishing nets and ropes are made of nylon, and they account for a significant amount of plastic in the marine environment, as confirmed by existing literature and field trips. In order to comprehend the possibilities of ocean plastics, it is essential to research all possible types. The researcher, therefore, should conduct more field trips to different beaches and collect samples of these materials not tested in this research.

Finally, in order to understand ocean plastics thoroughly, a comparative study should be conducted to understand the difference between raw plastics, domestic waste plastics and ocean plastics. The comparison should include property tests, such as strength tests, weathering tests, flexural strength tests, and performance tests, such as compression moulding and extrusion, and user tests. Also, as mentioned previously, recycling PET ocean plastic was challenging in this research. The amount of waste beverage bottles made of PET is abundant, so the author should systematically research how to recycle PET ocean plastic effectively in future studies.

**Glossary of terms**

**ABS** Acrylonitrile butadiene styrene resin

**Circular Economy** refers to the economic system that aims to reduce waste and resource consumption, close energy and materials loops and promote sustainable development[21].

**Closed loop recycling** the process in which a product is used and recycled into a new product[22].

**EE** Environmental Education

**EU** European Union

**Filament** Filamentous material used for 3D printing, usually plastic

**GDP** Gross domestic product

**HDPE** High-density polyethylene

**kg** kilogram

**LDPE** Low-density polyethylene

**Maker culture** a worldwide movement of individuals using a mix of digital fabrication and traditional crafts to innovate for themselves[23]

**MT** Metric tonne

**PE** Polyethylene

**PET** Polyethylene terephthalate

**PP** Polypropylene

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[21] Prieto-Sandoval, Jaca and Ormazabal, 2018
[22] Ravenhall, 2019
[23] Kuznetsov and Paulos, 2010

**PPE** personal protective equipment

**Principles of sustainable design** Respect for the wisdom of natural systems, people, place, the cycle of life, energy and natural resources and process[24]

**PS** Polystyrene

**STEAM Education** is an approach to guiding student inquiry, dialogue, and critical thinking through the uses of Science, Technology, Engineering, the Arts and Mathematics[25].

**Zero-waste** No waste generated through increasing reusing and recycling and reducing packaging

[24] McLennan, 2004
[25] https://artsintegration.com/what-is-steam-education-in-k-12-schools/

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**Appendix 1.** Samples and compression moulding and laser cutting results

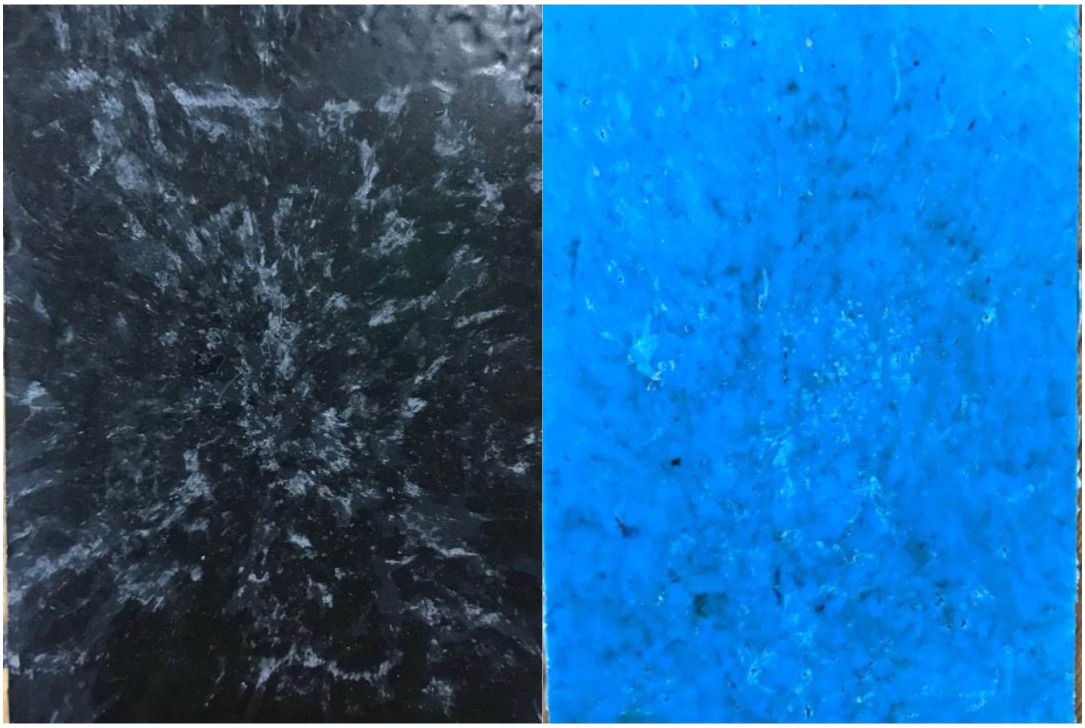
*Samples*

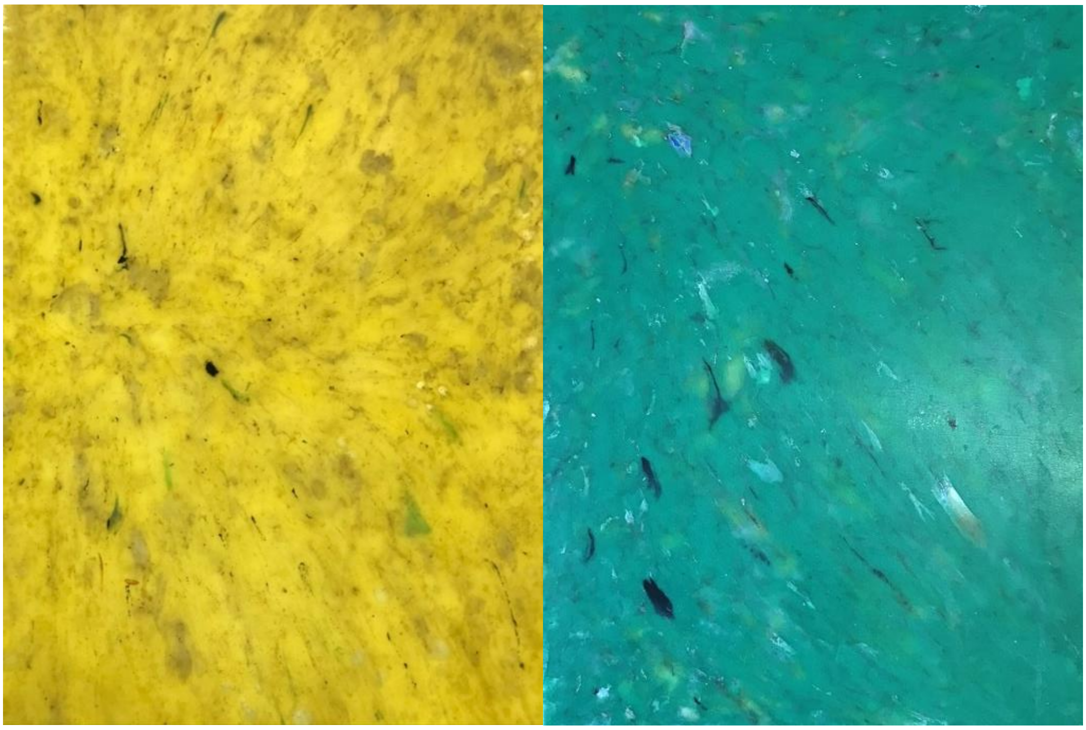




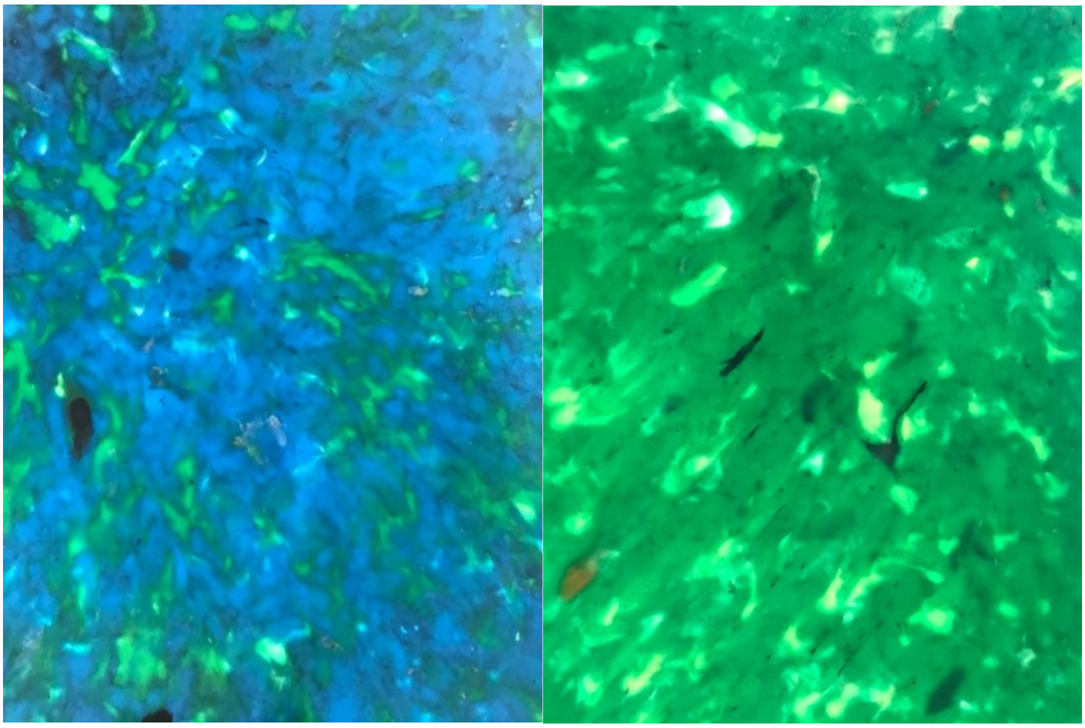


*Single colour sheets*

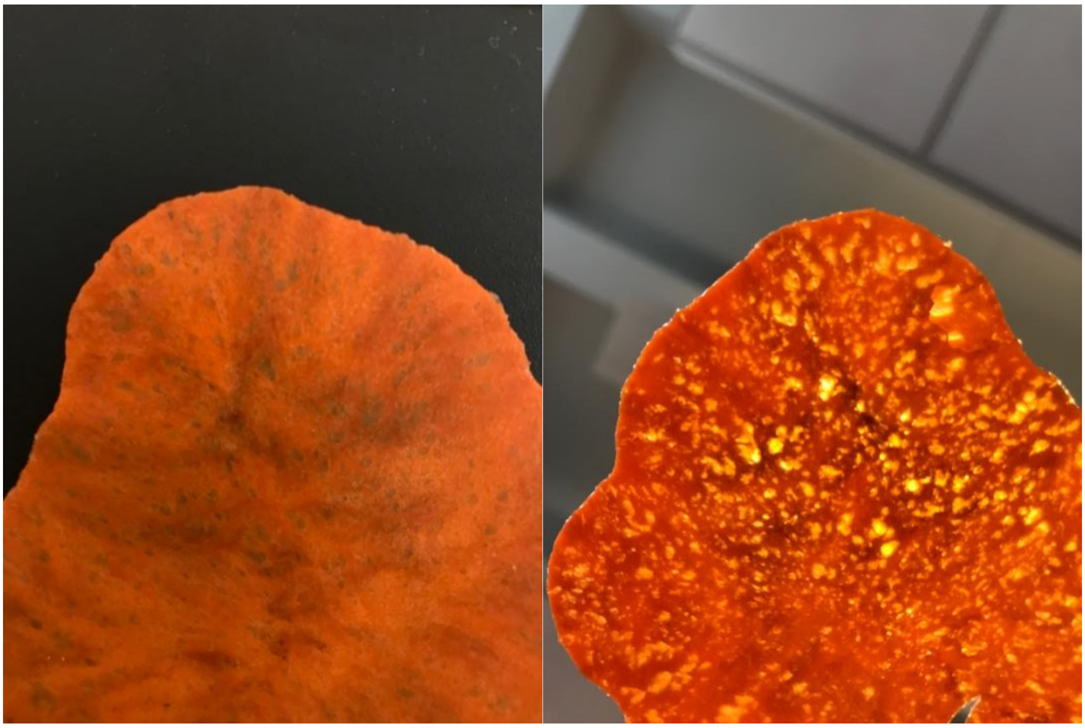


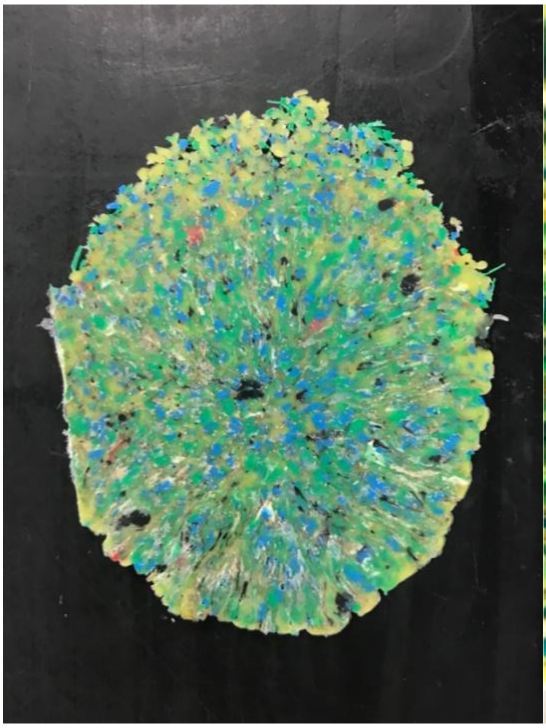
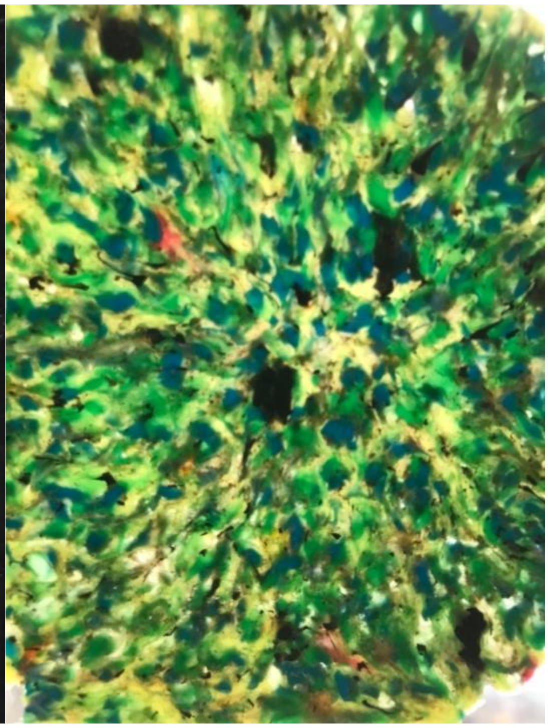


*Under the light*



*Comparison*



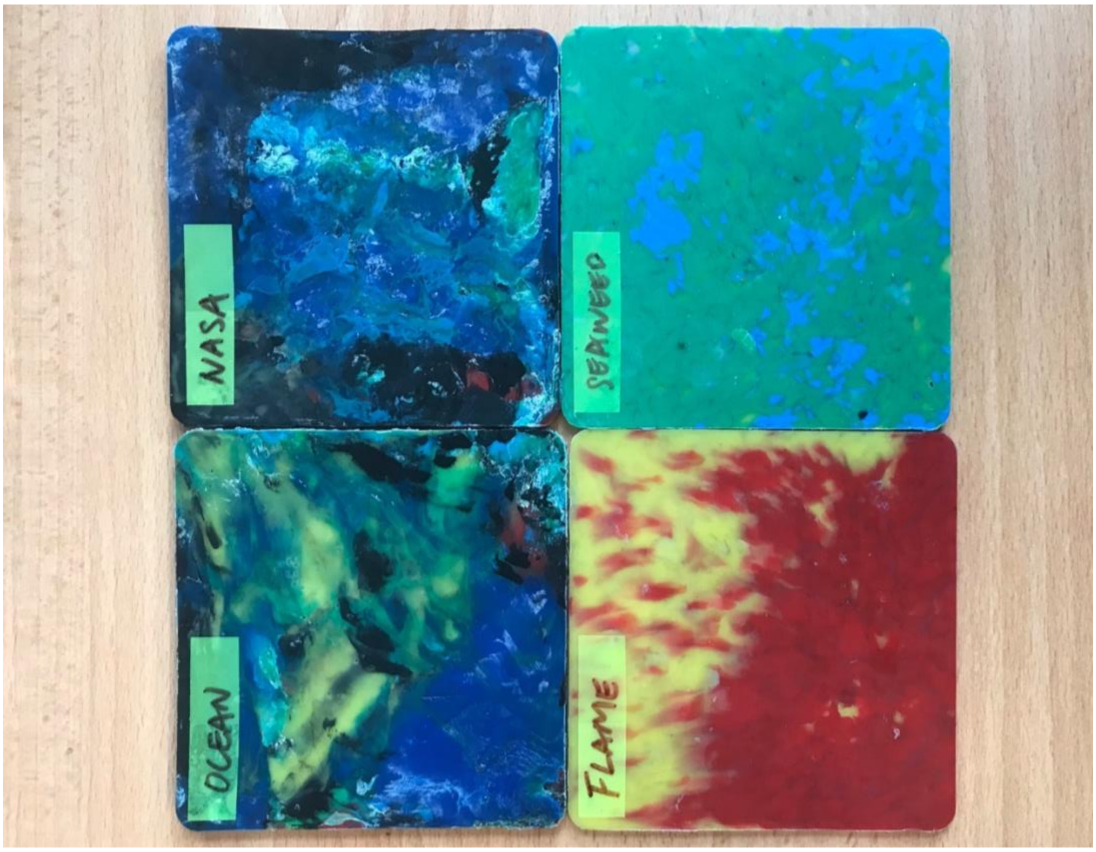




*Application: wall tiles*

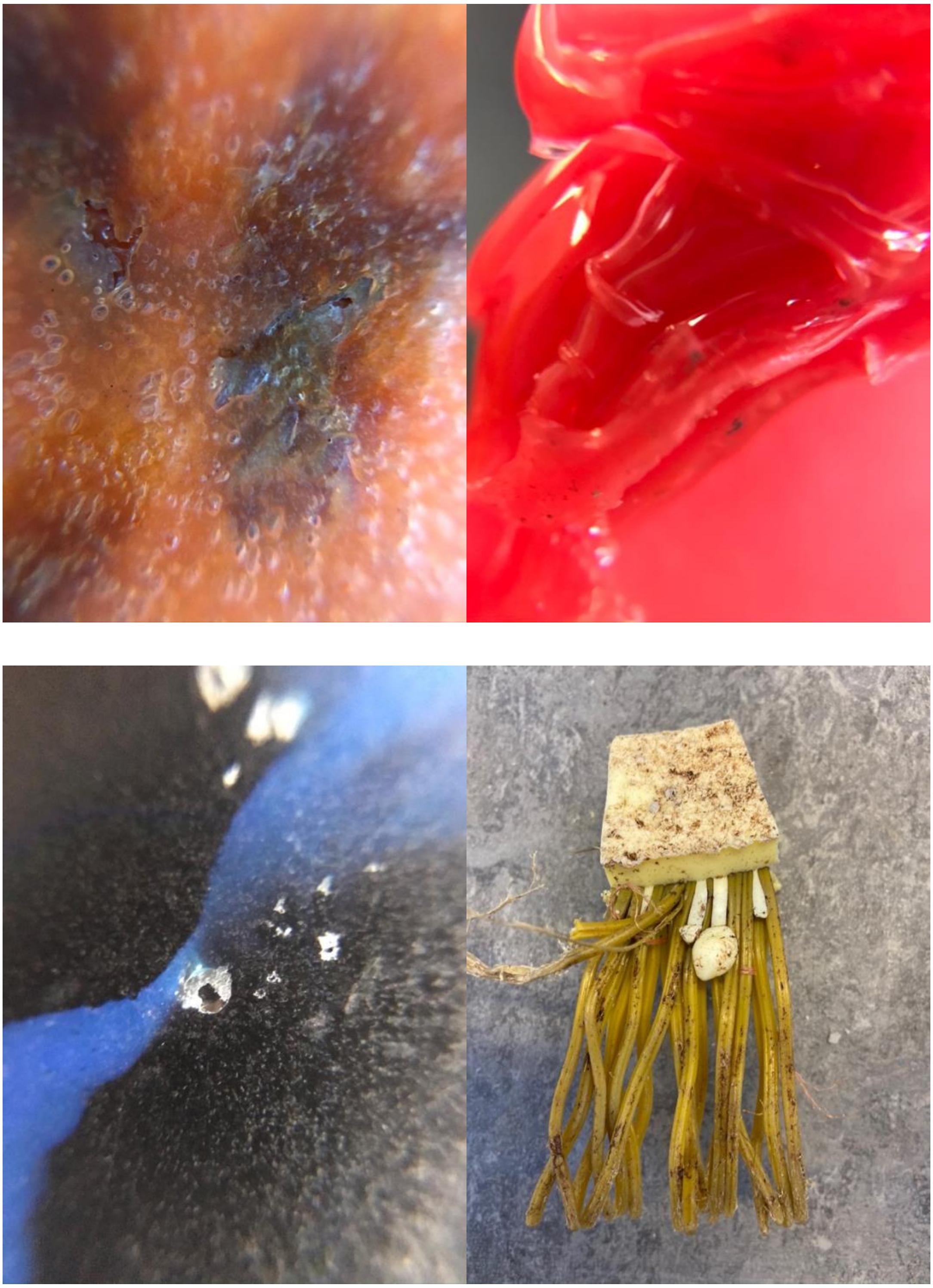
*Jewellery*

*Coasters*

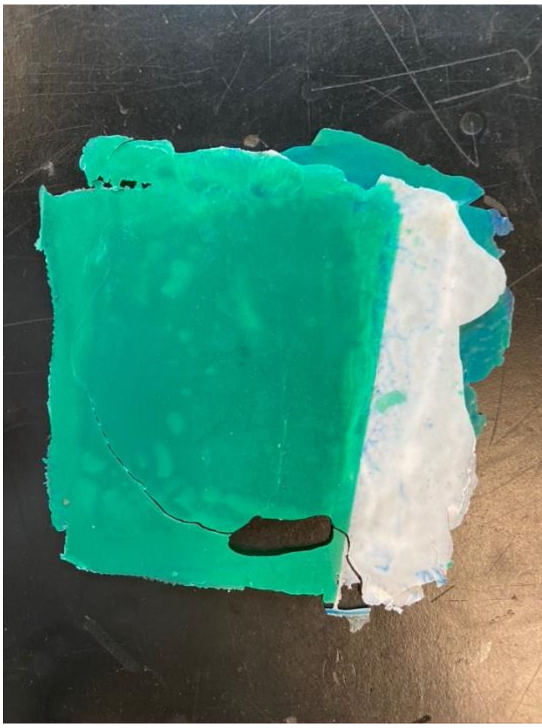
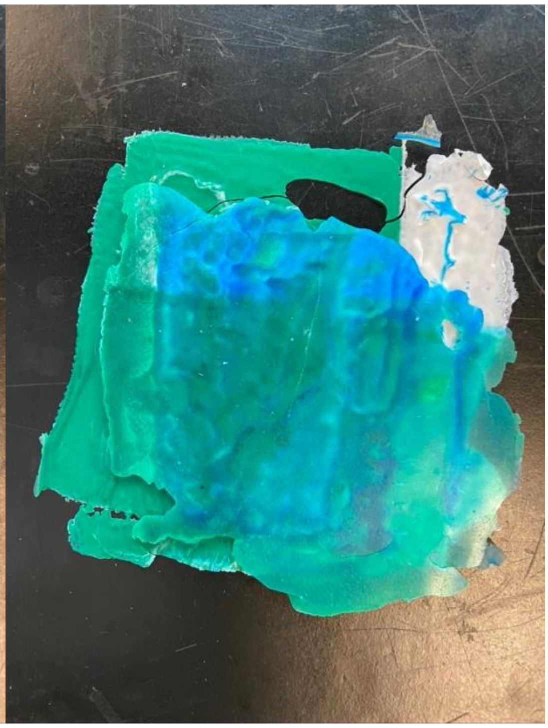
*Using colours to mimic nature*




*Close up details*

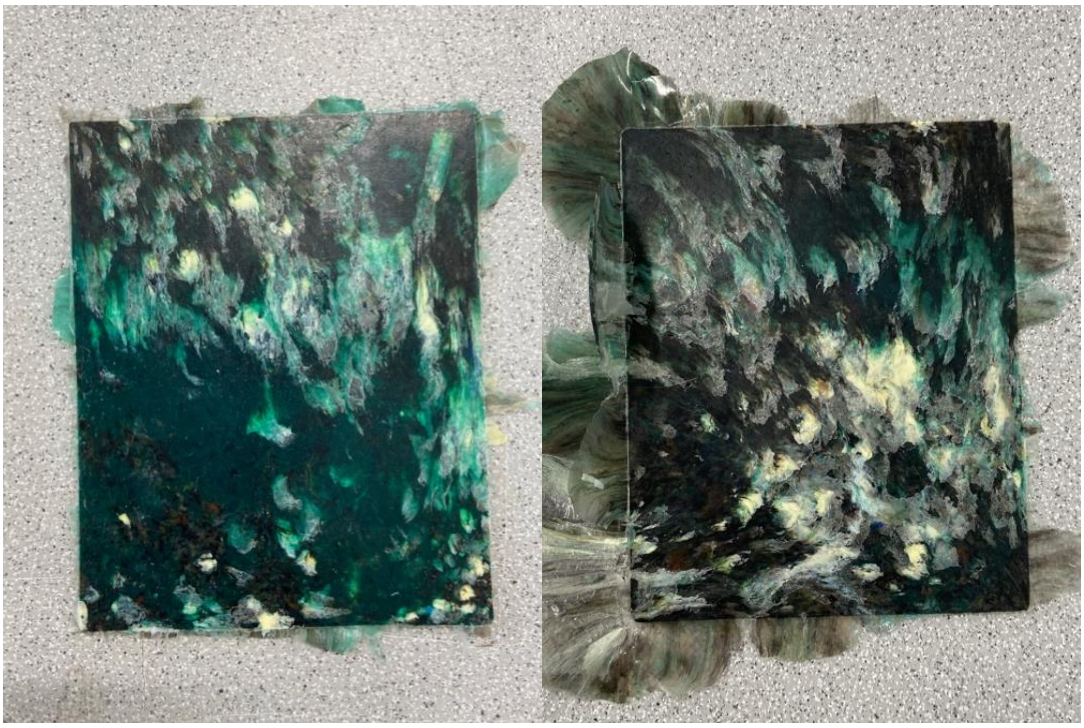


*Other results*

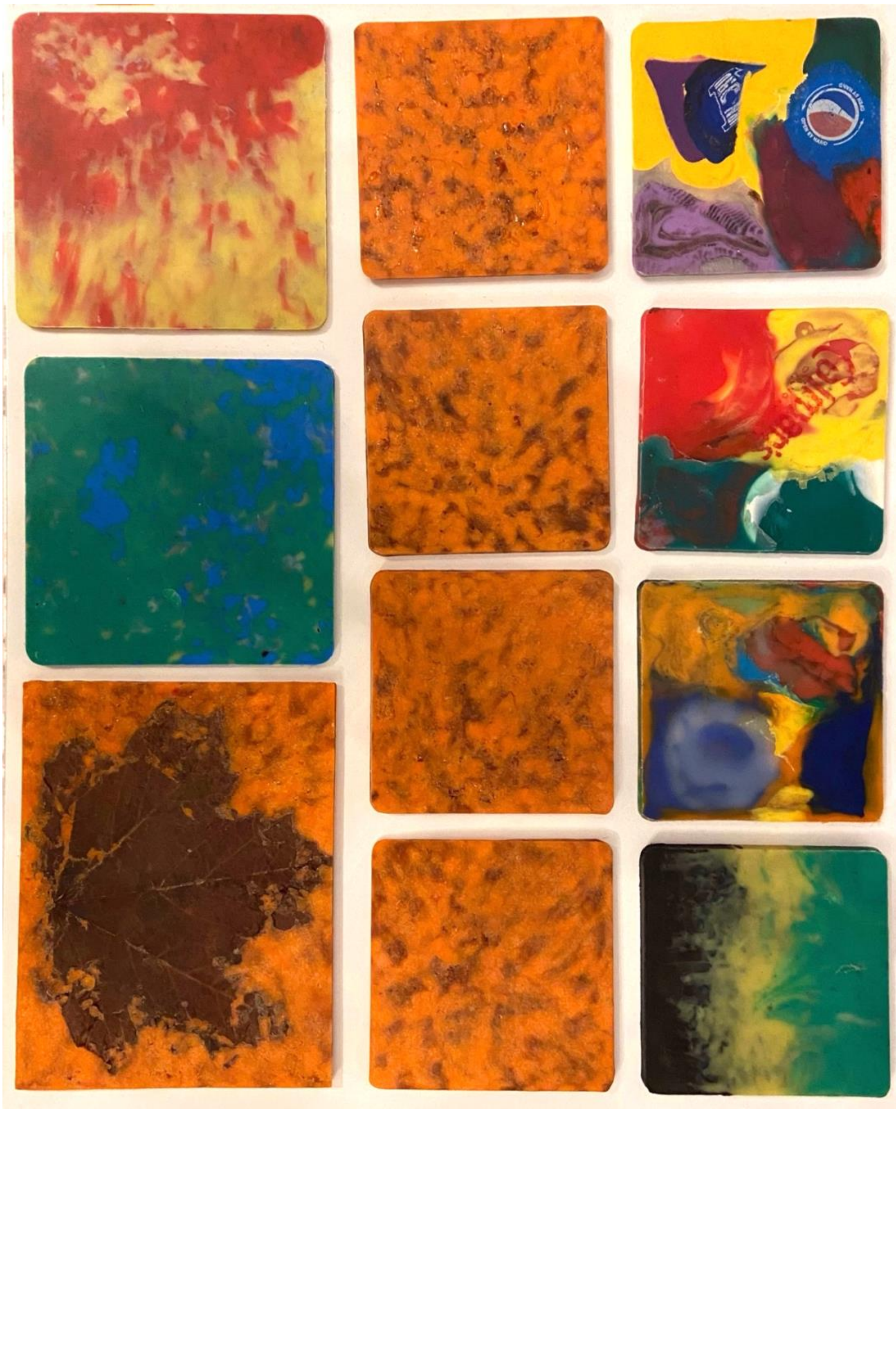




Compressed facemask sheet



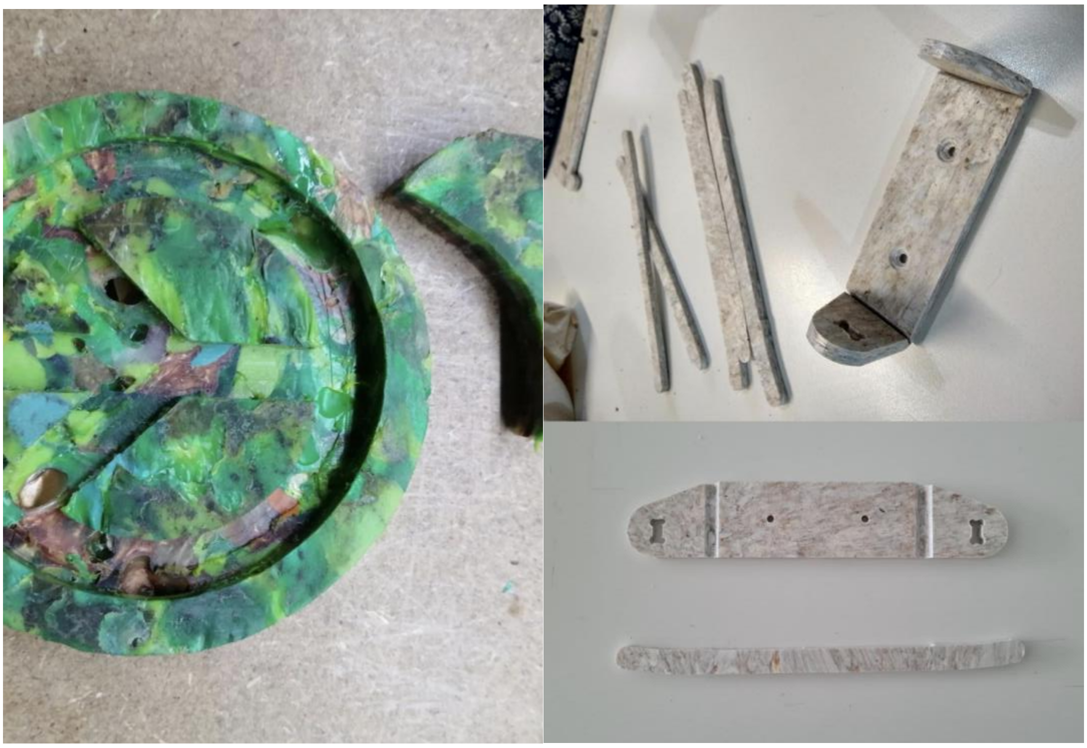
*Laser cutting results*



Facemask butterflies

*Molten edges*

*CNC-milling examples from the Precious Plastic Community*



https://community.preciousplastic.com/how-to/

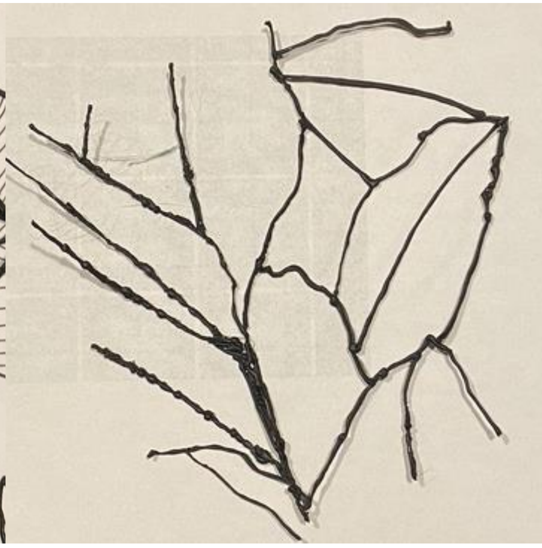
**Appendix 2.** Extrusion and 3D printing results

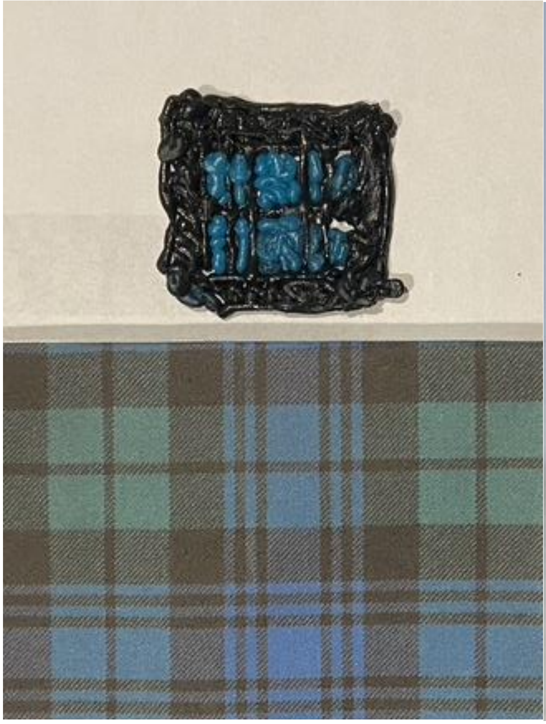
*Extrusion*


Extruding and extruded PET


Extruded PET
Blended PLA and PE


*3D printing pen*

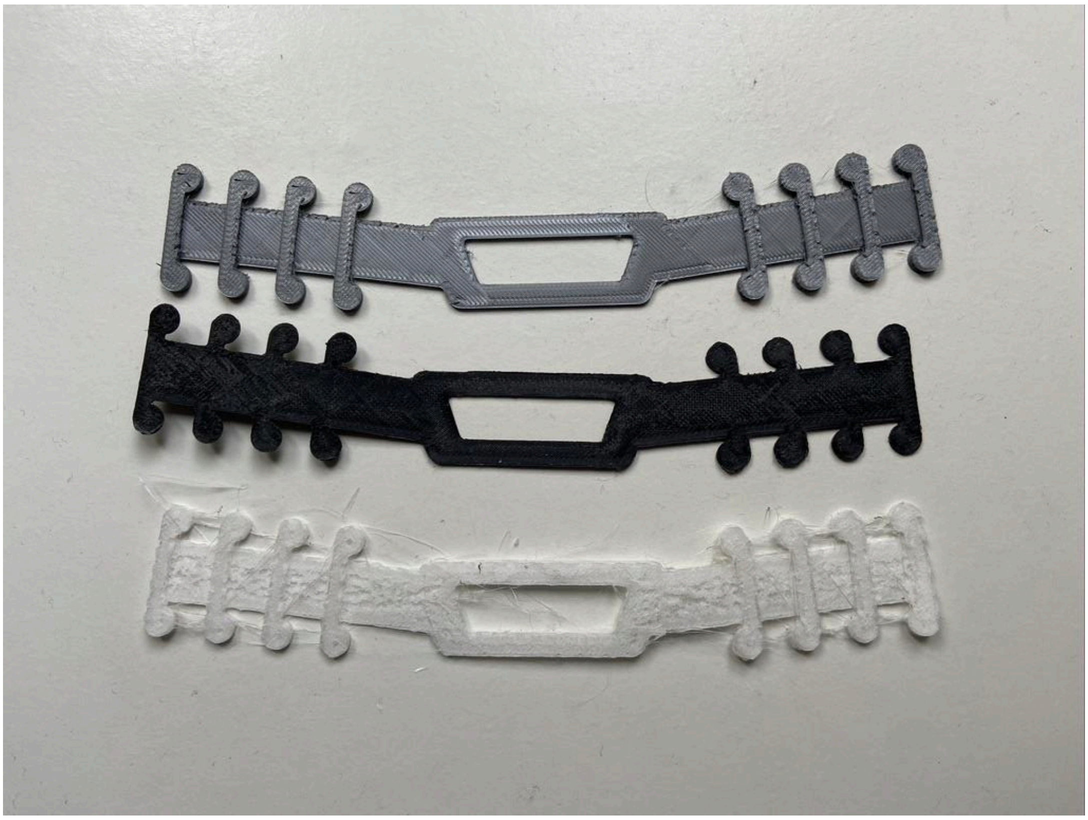





*3D printer*

Printed blob
Fixed print

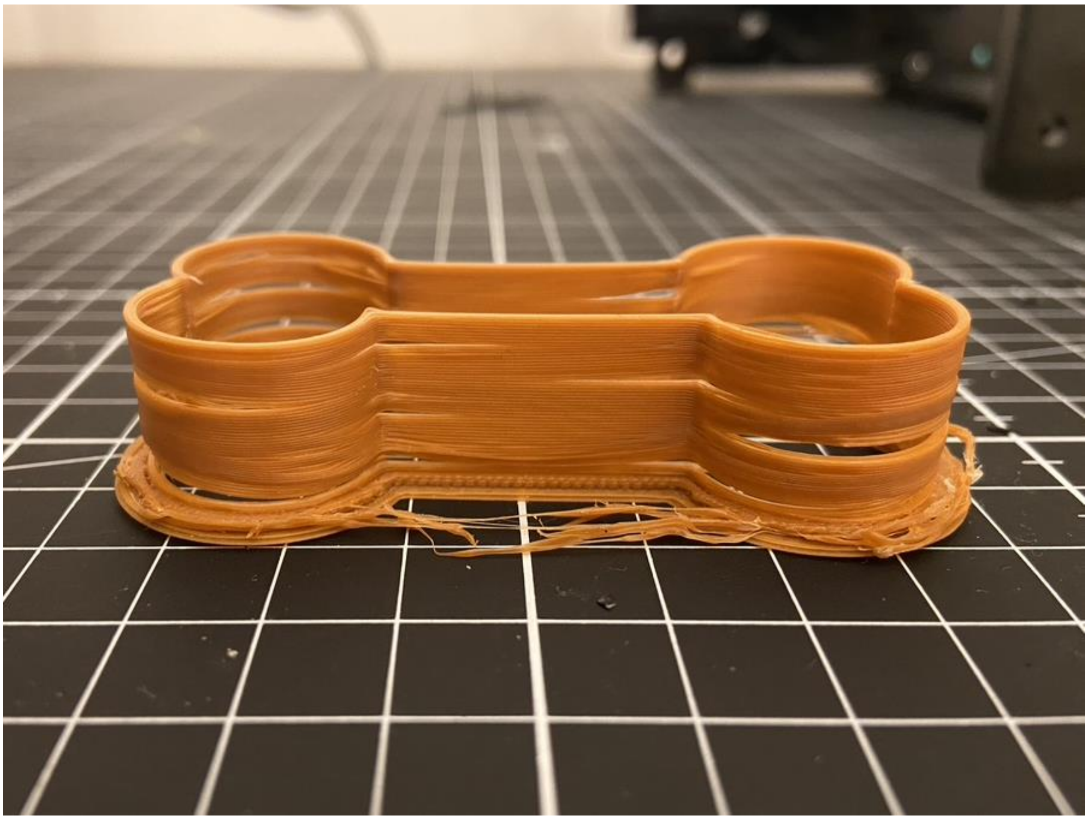
Lucky money cat printed from 50% PE filament
Smiley face cookie cutter



Facemask strap
PLA
50% PE
50% PP

First layer of print – 50% PP

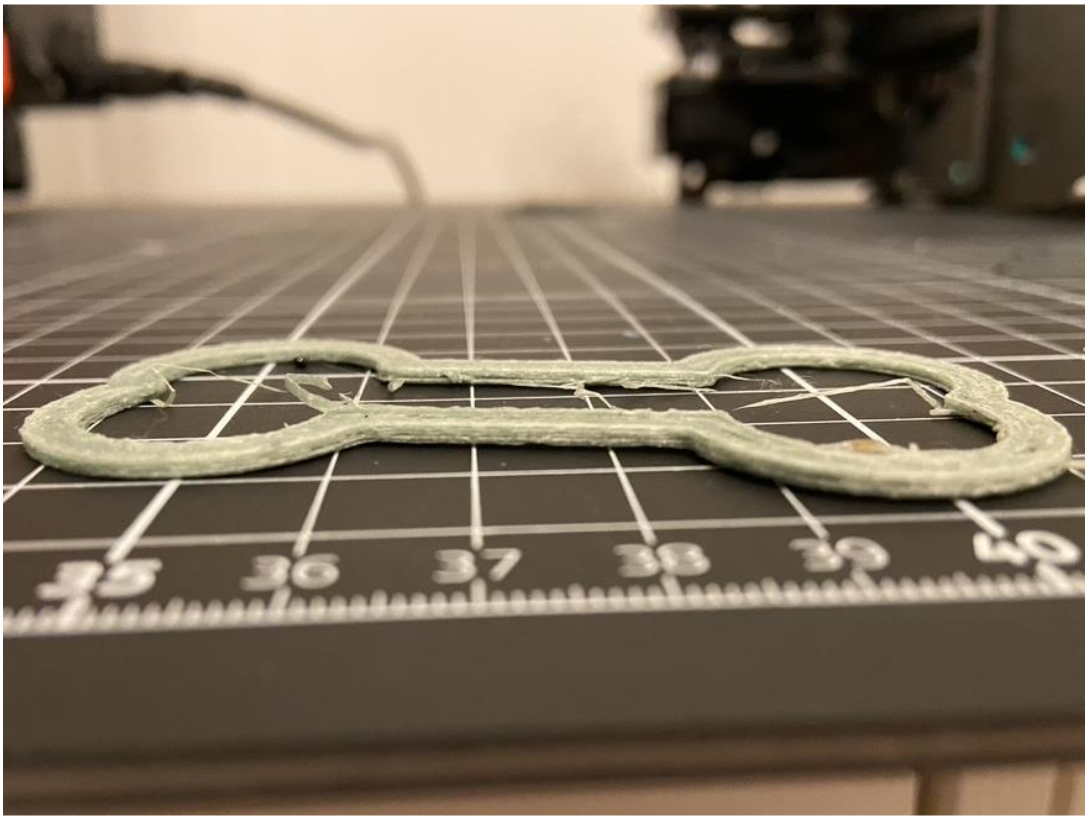
PET filament’s end after taking out of the printer
PET print



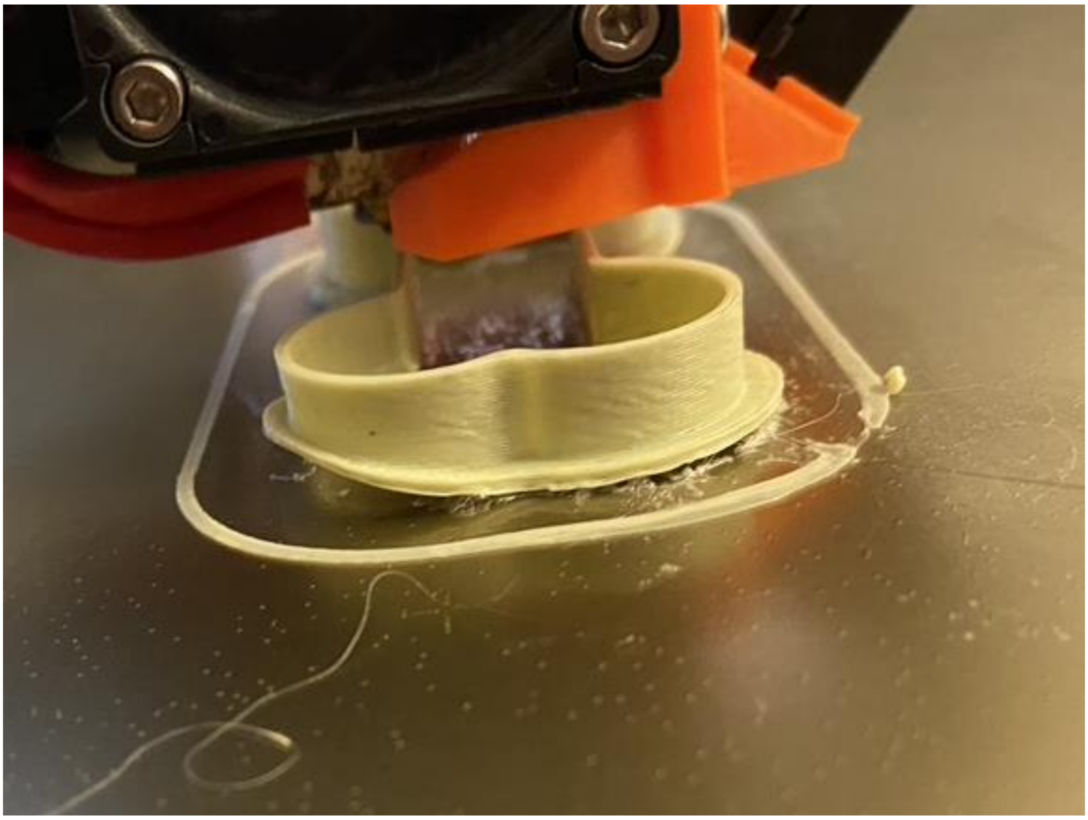
50% PS print
100% PS print

40% PE print
50% PE print

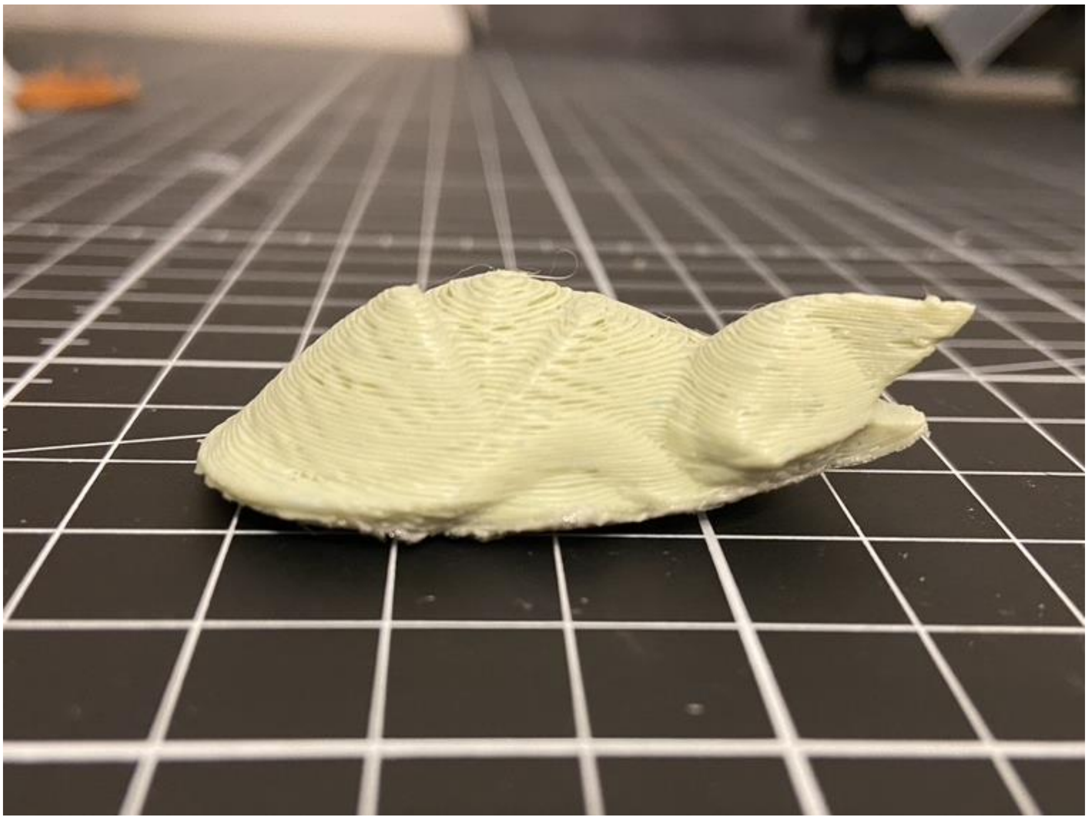
100% PP print
40% PP print



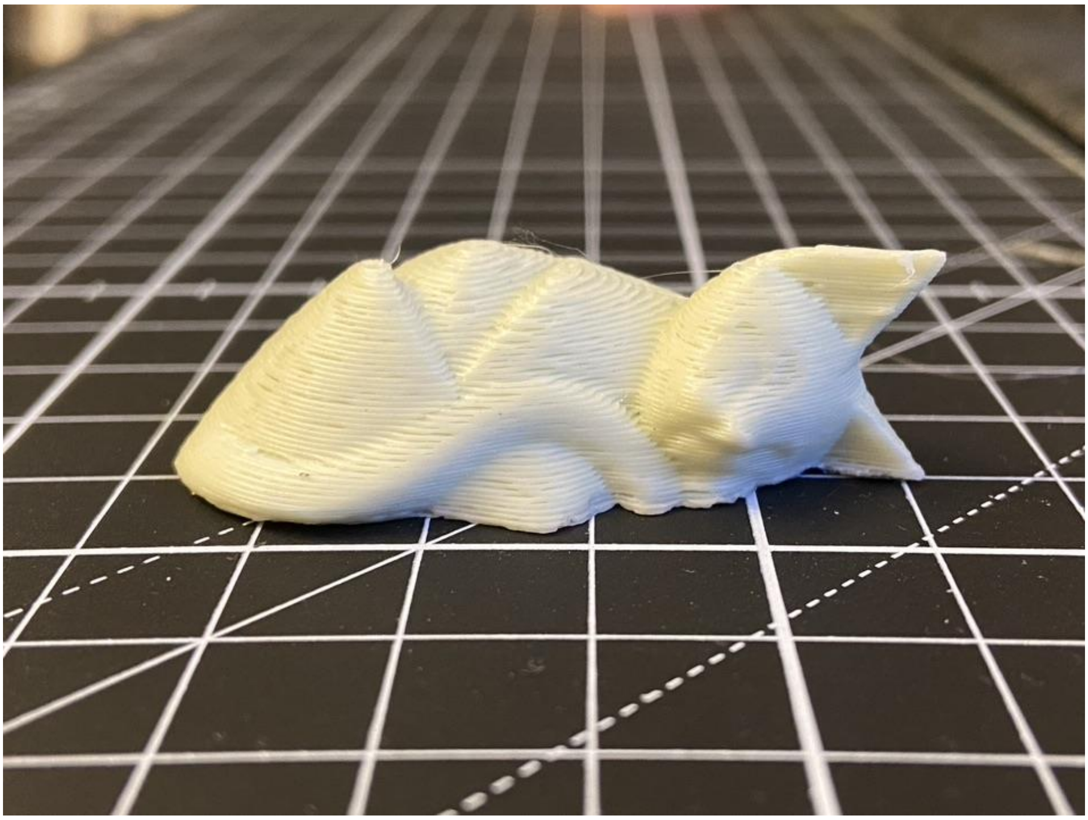

50% PP print
100% PET print

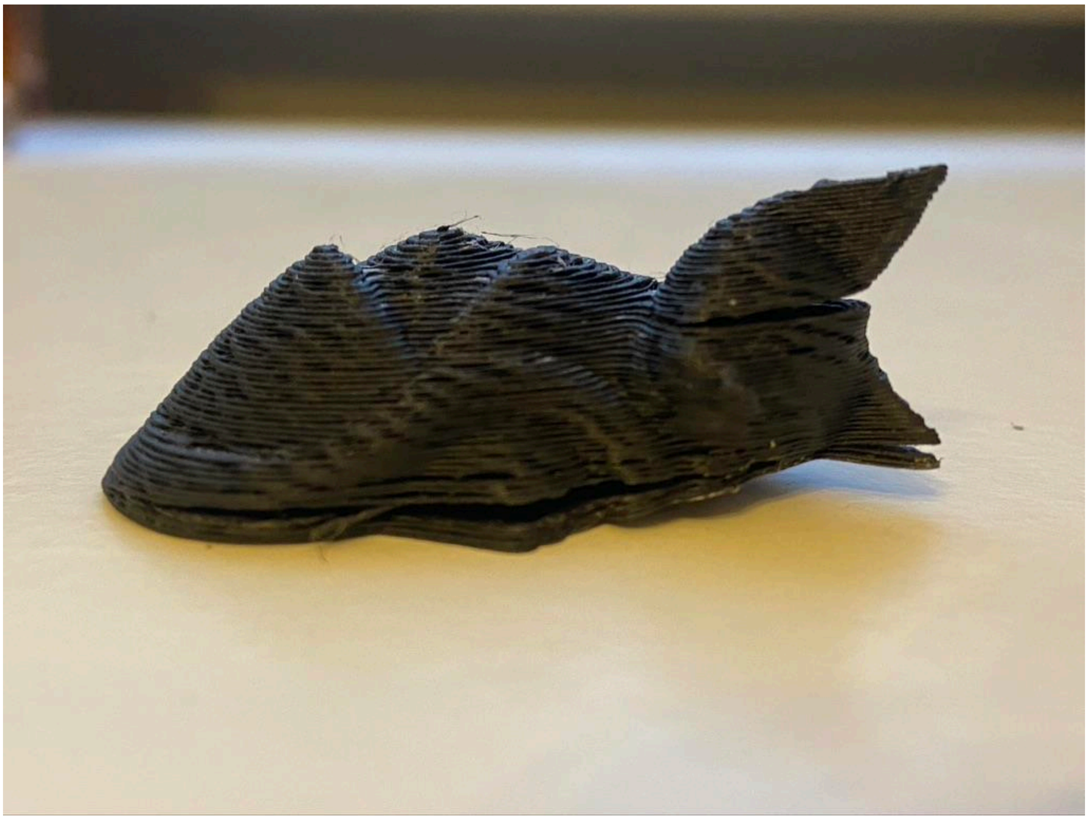


100% facemask PP print
100% PP print on the printing bed



100% PP print
50% PP print





40% PP print
40% PE print

50% PE print
50% PS print

100% PS print

## **Appendix 3.** Interview and conference transcript

*WRAP - Laura Copsey at GRIPS, March 2021*

*Q How does WRAP assess changes in citizens' behaviour after all the actions you have taken to engage the public? What are the effective ways to lead to behaviour change based on your experience?*

A: We are learning from our campaigns, also we do behaviour change interventions, so that is where we actually carry on something on the ground to see how citizens respond to it. And generally, get a really good snapshot of something being scaled up and something we need be doing more, how we could communicate more. Through each of those, we have seen various changes in behaviours so as I mentioned in my slides, something we have been seeing much more of people saying they are recycling more, saying they are trying to recycle more plastic items. It is perceived behaviours and whether they are doing the right things or the wrong things, we cannot quite dig into it unless we do those interventions and get it into the nitty-gritty. We definitely know that there are intentions in there, and citizens are trying to do what they can. We are also getting a really good response from our campaigns as well, so we can see that people are doing more, they are behaving differently. There are also anecdotally from what we can see our campaigns deliver quite well as well. So for example, by anecdotally I mean comments underneath things we are putting on our social media saying "I have not actually realised that" or "now you said that I get it and I am gonna act this way slightly differently" so we are definitely seeing the swing to be more sustainable. But like what we were saying those resources we got at WRAP are very useful so we can all amplify those messages. I think something that is very key for citizens is that we are all talking very clear in a consistent way. We are not mudding the water by talking about things in a slightly different way, making it too confusing. Refer to the science, we got the position statements that are useful as well if you do want to use those. But absolutely we are thinking positively, and I think citizens genuinely want industry to get as far ahead as possible to make advance before it is necessarily. Even possible to do, we know at WRAP there are the steps you need to take to get there. Part of what we are trying to do is educating about that as well saying change does not happen overnight. So absolutely citizens are trying to make changes. It is about sedimenting your audience and trying to understand who is doing the right things and how we can improve them, and who is not doing the right things and how we can get them there as well.

*DOBA – Bartek Urbanski, April 2021*

*Q Tell me about yourself and the studio.*

A: I came across the idea, Precious Plastic, in 2018, in Warsaw. I met with the studio. They are struggling right now - they don't have the permission actually to do it because Poland is very strict, and it is actually illegal to melt any amount of plastic by themselves. They were doing it then they realised that they could be fined so they stopped. And right now, they are fighting to change the law in Poland. I started doing it back there and I was trying to help them using the machines, the injector, the shredder and the extruder. Everything just began when my girlfriend was going to graduate from her studies, and she came up with the idea making something out of recycled materials, and she came up with making a waist watch out of plastic waste. She just approached them and let them know what they know, and they let her use the machine, the injection machine. When she told me about it, I helped her design the mould. I reached to some people around – some engineers they help us with the mould, and when the product, the watch was released, she graduated. We both wanted to make a business out of it, and we decided to move to Britain, because when in Poland it is illegal, we decided to move over here. So after one year working in a grocery store, I rent a studio which I have right now, in September 2020, and it was just a desk and an injection machine, very basic and we brought with us the mould for the watch, and another one for the hexagonal tiles. And currently the only thing we are doing are the hexagonal tiles that become products. The watch is under the stage of developing. I am currently waiting for another mould from Poland because it's cheaper over there and the quality is quite nice. I hope it will come up soon. And I'm developing the connection between the communities, you know I'm trying to reach as many people as I can, I'm reaching to businesses, shops, restaurants, asking them to collect not money but plastic for me, plastic waste.

*Q Have you had people worked in your studio yet?*

A: No, I didn't organise any workshop, because it was totally impossible. The restriction was so tight, so I only invited my friends here. People arrive to bring plastic to me, but I couldn't let them come inside. I am willing to do such workshop, and I would like people to know about it.

*Q Can you tell me more about Precious Plastic and the studio in Poland that inspired you?*

A: The studio in Warsaw is called plastic revolution in English. They found out what Precious Plastic was, they found all the blueprints, the video instructions on YouTube. So, they decided that's a very good idea and they were scouts as well as I was, so we are very keen, you know, active and volunteering. So, they didn't even think to make a profit out of it. They built machines, and they actually won grant from a company that makes water plastic bottles. I know it's a bit controversial, but they accepted the money, and with the money they were able to build the machines. They were in Precious Plastic headquarter in the Netherlands. They organise things that way you don't have to actually stay in contact with them because everything is already published. And from time to time they just share your photos of your creations because the whole Community around the world is so big, it's very hard to keep everyone in touch. So that's how it works right now.

*Q Does plastic revolution studio only work alone or engage the community?*

A: In Warsaw, it's very small and it's based in a basement. It's a workshop. They put the machines in the van, and they organise workshops in schools and festival outside.

*Q Do you mainly work with everyday plastic waste?*

A: Yeah, it's mainly everyday plastic waste. And because there are different types of plastic waste, that's quite obvious, and the main difference is the melting points and the fume it creates. Because the main types of plastic are 1-7, there are number 1-7, you can find them on the bottom of plastic. So, the number 1 is the most popular, all the plastic bottles are made out of it, and it's the most toxic one, PET. When I take it from someone, I just put it in the recycling bin - I don't even know how to deal with it. It's the most popular plastic and I can't afford to recycle. The second one is no.2 and no.5, they are on the same level to melt, not together, they have different melting points. HDPE and PP, also no.4, LDPE. So those three are my favourites. HDPE is my favourite because milk bottles are made of it. So right now, I'm working with HDPE mostly, and I'm planning to only work with HDPE and PP as materials. I will shred them. You know you will need to clean all the machines when you want to switch to other materials so it's quite hard.

*Q What do you think of plastic and plastic waste as a material? Do you think plastic is evil or should we make peace with it?*

A: When it comes to make more plastic, that's not a good idea. So that's why I'm using the plastic that was already created, which is not used anymore by anyone. So, I prefer to make something else out of the waste rather than put it in a very deep hole and forget about it, maybe in the future it will pollute and damage the environment. So, for me making more plastic and you know out if fossils and fuels, this is evil, this is a very bad idea. But working with plastic waste is great. I think it's precious, we should definitely not burry it under the ground and use it for other ways.

*Q Your work is very aesthetic, where did you get the artistic mind from?*

A: Precious Plastic. They are creating marble like tiles and I really like it. And it's encouraging people to buy them because they look nice. You know I can just recycle it myself; I need to find people who would pay for them. So, it's encouraging and convincing for people that they look good. It is actually not hard to make those; I'd say it's hard to make a consistent colour rather than making each product unique and with different pattern.

*Q So, when you make a product or creating a different pattern, is there any emotion between you and the plastic waste once you see the product is made or when you have the interaction with the plastic, is there any emotional connection?*

A: There is. I don't know if you see our website, every single tile, you can buy a set of tiles, or individual ones that are more unique, I choose them to be sold to be unique, so I named them, every single one is named differently. So, the moment I'm choosing the name for it, it is emotional.

*Q Do you think your plastic-related behaviour totally changed after working with plastic waste?*

A: I'm plastic free right now. If I buy anything made of plastic, it has to last at least two months. So yeah, my behaviour totally changed after I realised how much plastic is wasting. So, I'm like not totally but 98% plastic free now.

*Q Do you think you are influencing your friends and family to do similar or same things with plastic?*

A: When I tried to say anything to influence them, it wasn't a good idea. But right now, I'm influencing them without saying anything but just showing me as an example, like you can buy better food when you go plastic free, so that's the way I'm influencing my family. When it comes to plastic, we need time to understand that plastic is bad. Because for everyone it is convenient, you know, they can't really understand. It's like meat you know, 30 years ago no one was thinking going meat free but right now a lot more younger people decided to go vegan. It will be the same with plastic. We need more people like me and others to go plastic free or at least limit the use.

*Q Have you had any comments from people who bring you the plastic waste after knowing what you are doing with it?*

A: People who bring the plastic to me are helpful and cheering, they are very motivating. And they can spread the positive words. They are waiting for the watch to be released. But they are haters online saying, "there are bigger companies doing recycling, this is useless, senseless, you should not do it".

*Q Have you thought about using ocean plastic in your work, you know there is a huge amount of it lying there?*

A: I know there's a lot of it and it's over there and needs to be taken out of there. I know in the future if I need a lot of material, I will need to rescue some of it but right now it is difficult as it needs a good washing equipment and I'm not really into the technology of washing the plastics. When I see fishing nets, I don't know what to do with it, there are plants growing on them, just so hard. The problem is huge and overwhelming. I respect people who are doing it.

It's so cool to see that people are actually interested in this kind of topic. Because even when people are keen into recycling and environmental studies, they see the Precious Plastic movement as something very powerful. But I think that kind of thing will teach people how to behave and will change people's minds. I know it's very hard to do so and it's very easy to say.

*Still Life Glasgow, May 2021*

*Q Can we begin from introducing yourselves and the studio?*

A: I'm Aaron, and this is Will. We both studied art in our universities. Will did Fine art and I did illustration. We started making furniture together six years ago or something, wooden furniture. And we were trying to come up with a way using stubs of waste material basically. And I guess we just stumbled across Precious Plastic videos on YouTube, and they made it seem really easy on there, seems so simple. About that same time, we moved up to Scotland from London. So, we got a studio space and started experiment. We started from building the shredder. I think it took us six months to build that because we've never built any machines before. We built everything and just learning through going, and kind of I guess learning about the materials as well and all its problems. We started integrating the plastic and the wooden furniture after about a year of experimenting. We got a residency in house of the art and love, in Bellahouston park. There was residency program there, and we got a bit of funding and some space to test it out a bit further, combining the wood and the plastic. So that was three years ago, from then we just kind of developed from there. We try to just keep it simple; we just concentrate on the compression technique of recycling the plastic. We just try to keep it as simple as possible because there are many possibilities. It's easier to just concentrate on the small part. Now we got the place where we are selling quite a bit of furniture, we are trying to do about four online shops a year, and we take commissions between that as well. With coronavirus happening, it's kind of hard. About half of the stuff we sell online is to locals, locals picking them up, people in Glasgow, in Edinburgh. And then the other half, quite a lot to London, around London, mainly Europe. I think we've done about eight online shopping updates now. The products sell out very quickly every time, and it's like a reward when you see products sold out, you are like oh my god people do actually like it.

*Q How did you get support from Precious Plastic?*

A: It's all open source. They put the design for the machines up, you can download it, which includes part of it you have to get laser cut, all included. It's got a lot better now from when we started. When we started, it was like a forum. Other people around the world put up their discoveries. It's all very nice. Everyone tries to help each other out, most of the time. 95% of the people are really good at sharing and helping each other. There were a few people kind of take information and develop it and keep that secret. We try to help people out as much as possible. It's not our strong point doing videos, things like that. We try to focus on making things, that's where our passion is. Other people are much better doing videos and kind of how-tos, things like that.

*Q What is the plastic waste you work with coming from?*

A: There is this organic supermarket around the corner from our workshop. When everything is more normal, they have a collection point there for people to drop off bottle tops. So, bottle tops are our main source of the plastic, and the other things are, I guess one of those supermarkets you can refill things, like washing up liquid or shampoo, so all those big barrels, we can collect them from there as well. I mean that's more than enough, more than what we can deal with, just from one shop. People are donating them as well. They get in touch via Instagram or email, or our mums, our friends' mums. We just sometimes get some random little packages in the post of bottle tops. It's nice for people like to send bits of their plastic. It's more like, people bought things from us or planning to buy things off us, it's nice they can be included a bit, making it more circular.

*Q So, there is people donating their plastic also buying products from you?*

A: Yes, we've done it quite a few times. We have a design kit, so if people want to design their own top, drawing a little. Yeah, it's like a card we send out, quite a few times people send that and also collect lids and send along those as well. But it's quite hard for one household to collect enough bottle tops. You know one and half thousands of bottle tops are in a stool. But we get way more than that every week.

*Q How did you land on Still Life this name?*

A: There are a few reasons behind it. Because of our art background and we were doing painting and stuff, so we like still life painting. Also, we think of it is kind of still life in the plastic, we try to give it a new life I'd say. It's where we are from and what we are trying to achieve, making the plastic more of a scene and more valuable.

*Q What do you think of plastic? We should make a war with it, or make peace?*

A: Plastic is a good material. That's part of the problem. It can be used for so many things, and it's so cheap. You know, it's a battle. There just need more laws around, like the labelling of it, and where it goes after, you know. There needs to be more accountability.

*Q What products have you made so far from the beginning?*

A: We've made some benches, and plant hangers, we used to make loads of plant hangers, coasters, dough scrapers. We've got a collaboration at the minute with this guy makes kitchen knives. We started making handles for him, well, helping him make handles. He's called clement knives. He recycles plastic himself. He wanted us to help try to be able to increase the number of knives he could make. So that's kind of things you know, helping people out the way we've done. We are gonna do some baking equipment with him, and we designed some moulds for him for free, and kind of in return he's gonna help us as well. So, you know it's nice to have that kind of exchange. When the first things were made, the dough scraper, we worked with a local bakery, who has a very big Instagram following. So, we kind of made one for him and he posted about it and that's kind of how we took off. So, we made a lot of those and this new designed scraper, he's going to open a new bakery down the road, so we are gonna collaborate with him again, which is quite nice to have the loop again.

*Q So, when you see the products you've made from plastic waste to be the very nice-looking plastic products, is there any emotional connection between you and the products you've made out of the plastic waste?*

A: I think we got attached to the stools. We definitely have favourites. It's almost like, because of the way that you melt the plastic into the mould, it's almost a bit like painting. We kind of treat it like that making each one. That's the really fun part. It's kind of figuring out, we don't make the same every time. We've got rough ideas of how things will look when they come out of the oven, but there is always the element of chance, kind of like ceramics. You've got an idea, but you never know exactly. Part of it is up to the kiln, but it's the oven in our case. Yeah, but that's part of the fun. It's always exciting opening up the mould.

*Q What kind of impact do you want your studio to have?*

A: In terms of the amount of plastic we can actually recycle, it's just such a drop in the ocean, such a small amount. But I guess our aim is more to trying to show people what you could make with it and how it could be used in a bit of a way to make something that will last for 100 years or longer even. Because it's a robust material that can last that long, it's being used to make things just used once. We want to try to make things will last people's lifetimes and can be passed down. Kind of like people buy furniture or ceramics, they pass it down to their kids. We also want people to question what the stools are made of, just by looking at them without actually know what they are made of. Kind of just see it and then start thinking what it is and tell them that kind of dialogue with them, which is what we want to do. When they got it in their house, people see it, it has hopefully a bit impact, maybe make other people start to think about how they use plastic. We know we can't change the world, but every small bit helps.

*Q Every time you see people who buy your products and post stories and tag you, your stools, trays in their home settings, do you feel satisfied and have feel emotional change?*

A: It's nice to see other people getting excited about it and appreciating it.

*Q In most cases, when your clients buy products from you, is it because you use recycled plastic or it's more for the artistic reason, or both?*

A: That's interesting actually. I think it's a mixture definitely. Because I think you can definitely tell there are some people that message us regularly or comment who are obviously really into the plastic recycling idea and really investing that. Then there are other people that liking the design. I'd say we sell quite a lot of the stuff to kind of designers and artists, creative people. But there is also a fair amount of people that are just interested in the impact. There is a cross over. I'd say there is different kinds of people.

*Q After staring the business and studio, have you observed any your plastic-related behaviour change?*

A: I think so yeah. Just when you see the amount of plastic just in one shop. Because when you hear all the numbers, say the amount of plastic in the sea or going to the landfill, it's so hard to comprehend, for the person who is not involved in the recycling industry. But we've kind of seen, had a bit more of the insight into that, so we try to not use it as much as possible basically. But it's also funny when we walking around and you see a bit of, some sorts of colours and things that are quite rare, when we see a pink bottle cap on the floor, we were like woo, that's a rare bit, we should collect that. It's funny where you end up; we look at it differently now.

*Q Do you know if there's any customer who takes plastic more seriously after buying your products?*

A: A lot of people do end up collecting for us after they buy something. So, I guess that's some changing. Also, we get people commenting, saying "oh I don't know this is possible". People don't realise that it is plastic. So that's nice. I think we do change people's perceptions.

*Q  Are you considering doing open workshops for people who are interested in the process?*

A: We used to have people visiting use quite often, just to look at how we do it, and we still get a lot of emails. We helped quite a few other places, start-ups as well, more kind of community interest places are doing it for the workshop side. We've always wanted to do workshops where we get people in and make something, but we haven't figured out the right product to do it with because of the time it takes. We want to make bigger things that's where our real passion is, to try to use as much as material per object. If it's bigger and more robust, it's gonna last longer. Hopefully we will do workshops sometime, but we don't know what it is yet. We like having people coming in and chatting, more chilled out. I think it's easier for people to understand when they can physically see and touch it. Because a lot of machines and processes from a picture is a bit like, what is a shredder? And when they see it, they are like "oh!" "Right!"

<u>Recycle Rebuild Rory Dickens, May 2021</u>

*Q  Tell me about yourself and Recycle Rebuild?*

A: I'm an architect, and I used to work on disaster response for a while, from 2015 to 2018. Before that I did sustainable kind of training and building with bamboo and these kinds of things, so I always have sustainability at the back of my mind. And I was looking up to gather funding and when I get kind of frustrated with the way the charity set tool was working. It didn't seem to be any charity that had really dealt with waste management. So, because of my disaster response background and my understanding of working with charity set tool, I created Recycle Rebuild to try to address this problem in the post disaster context that I was in at the time. And I have found a donor and the idea of the concept and I created the Recycle Rebuild the brand and we invented our first project to try to create a business of some kind of social entrepreneur shape idea. It focuses on taking waste and converting it into something that people can use. That's the value of Recycle Rebuild. And I've done newer bits of work since and we continue to grow. That's my main background.

*Q  Apart from finding funding and donors, what's the biggest challenge you encountered founding the organisation?*

A: One thing I've always wanted to do is to make sure that as much as the money from the donor would get to the project. You know we talk to a lot of charities and we hear that 95% makes it, which means 5% doesn't. That's kind of the thing I want to challenge. Also, to make it sustainable, I heard the fact that most charities spell within the first two years, which is what I want to avoid happening with Recycle Rebuild. So, we made a very early decision that everything would be volunteer-based, so all the people involved are volunteer-based. It creates the entire challenge, because the reason we feel our aspect of how we help is different from the people are creating a business so there is a financial incentive. But when we talk about our own, people involved in our charity, there is no financial incentive to keep it going. So, it's kind of interesting that we have the same problem that every charity has, but it's actually internal. And that's also for me a big problem. We get a lot of interest, we get a lot of people who are like "I want to help, I want to get involved". And then you got them involved, and they disappeared after eight weeks, ten weeks because people move on and with Covid, we have this massive surge of people being like "I want to change the world, I want to volunteer" but Covid stopped everything, we stopped. You know we slowed down because we couldn't use donor's money in an effective way so that's probably the biggest challenge.

*Q  What role do you think designers play in addressing waste and climate change?*

A: I think designers actually hold the key. I don't think the solution truly exists, and I don't think people until now actually spent a lot of time thinking about it. So, there are a lot of thoughts that can go into designers' practices. I mean I am a designer depending on ideas. That is kind of interesting because it's kind of my career as well. So, Recycle Rebuild is my passion project where I utilise donor funds to recreate change. But at the same time, you can approach a similar task from a different aspect, and I think more people understood that and more designers kind of create more clever ways of thinking about it. I mean art, fashion, all these kinds of things help think about the problem, and whether or not designers are creating the next machines that solve these problems. I mean like Tesla, it's the idea, with the right amount of funding, the commercial venture that uses design to solve the problem.

*Q How do you view plastic or plastic waste as a material? War or peace?*

A: I think, inherently saw some purposes. You know plastic is a material like we should imagine gold or stone or whatever, it's part of how we do things. But I think the pandemic would be very different if we didn't have plastic. If you look at the NHS, you instantly realise that plastic is irreplaceable in that sector. The part of what we do wrong is we design badly with it. You know I think a lot of people have this concept that I've got the plastic bottle and I'm gonna use it for a minute and it's gone. The reason that plastic is not a problem is because it does its job very well. And we've got the designers using plastic in the wrong places. Now utilise it better and make sure we recycle it. There is a little bit of blame on the designer for sure, but there is also the blame on the systematic, the society that we live in now the idea of the infrastructure for us to deal with the plastic is probably ingrain in the society, which is outside of the role of the designer. And Precious Plastic inherently had that problem, you know they are trying to solve the back end of the problem, and you know that is how the world is weighted right now. Coca Cola blamed us for the problem of the waste that we must deal with it and that's the designers' response, we are dealing with it, as much as we can. But at the same time, we should get the start better. There are some evil designers for coca cola for sure.

*Q Have you observed a lot of changes in people's attitude before and after the project in Dominica?*

A: That's an interesting question because when we arrive, when we were there, I guess it's just gone through a natural disaster, a lot of people were much more open to change and new methods. One thing I would say is if you want people to change, after the natural disaster is the best time, because you basically reset their world. But the solution must align with hierarchy of their necessary need. And a lot of the time is about financial rebuilding, getting security back. In terms of Dominica as a context, they had no recycling before, and after the hurricane they wanted to rebrand their tourist industry and they were transitioning to Dominica the nature isle, their branding. So, nature was very much in the media, in the tension. However, the education was not there, there has not been any education or culture of sustainability, so you have the government of mind shift happening, but you also had a country where everyone's mind was in a different place. So, in the tourist sector sustainability is very important, but outside of the tourist sector, it might not be so important. Because it affects business, I mean what was also interesting is you had a lot of aligning with other NGOs. For example, the red cross is not an environmental charity, but they had to clean up the waste and the street trash to reduce dengue because the increase of the mosquitos. So, then you could also use sustainability message hidden in a package about health that is going to kill your family which makes it more adoptable. So, the transition is super slow. You slowly interact with the children in school that would make a change, but I didn't see a cultural shift. But what was quite interesting perhaps was there were some people on this island, I mean 6,000 people, there were people on this island who wanted an outlet that how they can be sustainable. But because no infrastructure existed on this island, they couldn't do it. When we gave them that option, it was easily adopted by those one or two percent.

*Q What's the difference between people in developed countries and developing countries about plastic waste and why is that?*

A: It's kind of interesting. One of my research I went to Bangladesh with Precious Plastic. I think the only one thing is they think it's a poor man's job. You think about the trash collector in the UK, I assume they are probably not a master or something, they are not highly educated, they take the job because that's the only job they could get. We as a designer can posh it up. We are designers so we can work with it to create some amazing piece of work. If I created some work with 100 pieces of waste plastic, people would be like "oh my god this is so classy and cool". The lower class is dealing with waste everywhere. In Bangladesh, the lowest of the low class picks up the trash off the street, and then they gave it to the second lowest low to sort it. But the products don't necessarily have value all the time. It's fashionable for us to have a product, an outcome. And the reason that the lowest low would do that job is because they are happy to work all day for £1, because that's the only way or they see a small step of the ladder. And yeah wherever you go people see that. And when it comes to places like here, for example the Netherlands of Denmark, they have these schemes, where a lot of people be like I don't need to put this in the recycling bin because someone would come and pick it up for me and they will cash the donation scheme, and that's kind of interesting. Some countries have adopted, you know in Denmark, by the side of the bin there is litter holders for cans so when someone walk past, they can just pick it out and do it. So that's kind of amazing, instead of having a separated bin for recyclables, they just have little holders attached to the bins so someone else could do that job. I think it's always about money.

*Q What do you think plastic waste should do to have an impact here (developed countries)?*

A: We don't build our own houses, it's very unlikely we would build our own house, but for something moving into a new house, or on government scheme, incentive. To deal with the waste which needs to be done in a very large scale, and I guess you can see some examples of it happening in developing countries, the cheapest thing in the market that I would build my house out of it. But here we need the government; we need the right incentive to have it installed or put it in the new houses. So, we were talking about design, you know in a very small scale we can say furniture, ok furniture going in to place in our houses and we are going to add that later. And we are talking about building new houses, there is no reason all the insolation come in your house couldn't be waste materials. And I think especially with this drive to be more sustainable, and to have a lower CO2 emitting household, you are gonna need more insolation. This is something that you don't see. And I think if I had a really nice house that didn't look like a house here, people would be like I don't want it, this looks too designer-ish and geeky or whatever, but if it's hidden in every single house and no one knows it was there, then fine. And I think one of the interesting facts is a lot of houses in the UK are brick covered, and in Norway is wood. And Norway is much older than here, the reason we have bricks here is because we think it's safer, we think it's better, purely cultural. And the houses in Norway are better and they are made of wood which is more sustainable. And because we want our house to look like a brick house.

*Q Have you observed any plastic-related behaviour change in people in any of your projects?*

A: Whenever you do a training and activity, there is that immediate that people going "ah, cool", and there is that certain level of catching. The one thing is quite tricky is, I was never there long enough to truly get a very strong understanding of seeing a shift. And from all of these habits we tend to build around sustainability of buyer habits, might be the items that you purchase, is it a consumable item? Sometime it's guilt, you know we all develop this kind of social anxiety or guilt towards buying that really unsustainable product, and they are very hard to measure because one you might not see it, so we do see a lot of time is when you do show them something, they are like proud of it that they made, but a lot of time I often work with companies or charities where you educating the team, and they will make comments at the bar when you have a drink with them later, they are like, "no straw! See I learnt something". That's the closest I could get to the true adoptions. And you might see some proudly way around their plastic, recycled objects they made, but yeah, it's quite hard to see that true change.

*Q What do you think of using recycled waste plastic in educational tourism setting?*

A: Tourism is normally the first thing I always ask people when they want to set up a workspace. "What's your tourism like?" Because it's very easy to sell to westerners, the products. It's much harder to sell it to someone who is not a Westerner. That's kind of the true reason because somehow, we recently kind of understood that with Precious Plastic we can never create something as cheap as the mass-produced products. So therefore first, residents understand the entire value and then realise it's worth more because all the statement it's going to make. And then it becomes fashion. And we all know that clothes all cost the same price to make, but a Gucci bag is way more expensive than you can get from Primark. And that's the same message. You are using that kind of buyer attitude that definitely works. And having something customised through your trip, I think a number of times as a kid I convinced my family to put a penny in the machine that crushed it into a shape that reminds me of Edinburgh castle, the little copper thing. I mean it's pointless, you are actually crushing your money in making something that is not valuable, but we all did it because of that memory. And now that machine is everywhere. So same concept but with plastic, a part of the journey they pick up five bottle caps and you put those five bottle caps into a machine then you get back Edinburgh castle, you know that's kind of cool. Think, imagine you have to clean up the city, to exchange those little thing, local material. People feel good about cleaning up our city, so it's a good idea. And particularly as well in Dominica there are a lot of source for the cruise ships that have the same imported stuff. There is probably like 50 companies in the world that create tourist souvenirs and they all basically the same with different flags on them. And tourists find them, you know I went to Dominica, I went to the French islands wherever, they are the same things just different pictures, but they want something really unique, you know, and that's how art and crafts kind of get the ability to be sold, like this basket made by this woman. In front of everyone "I was like oh my god I want to buy this for Kevin because Kevin loves basket." And that uniqueness is what important in the tourist setting that stands out, you get an edge because of that. And yeah, I like the 3d printing idea. Have you seen my giant 3d printer?

It's a sneak peak, but this is way too big for tourism. It can print waste. I'm definitely interested in your 3d printing, which is my next venture. I did this vase, this is polystyrene. The reason that I use polystyrene is because PP and HDPE in large scale warp. I work with Precious Plastic and what is missing in Precious Plastic ecosystem is a giant 3d printer, and I know that people have done it, but they just kept it secret. I want to make it my own, so I built this 3d printer. I'm building the second version, version no.2, yeah it is my next big venture. I've only printed PLA and polycarbonate. So, my printer will be metre by metre by metre and the nozzle will be 2-6 mm. It prints directly from granules; the nozzle is the Precious Plastic extruder. My dream is to somehow convince Ikea or whatever, saying "looking we created this brand-new, really designer furniture, from ocean plastic." I think it would be quite interesting in a few months' time to have you to look at the machine and come up with a product.

_Bambú Simona Zhou and Michael Mangus, May 2021_

*Q Tell me more about yourselves and your business.*

A: (S) As you know, I came from research background, so I worked for the university of Edinburgh after doing my PhD in clinic research. I worked there as a post-doc. And then I was transitioning to work in the industry. After a kind of stressful time at the job, I decided to kind of change my path, that's where eventually landed me to setting up the business Bambú living sustainably. At the time after leaving the job I had more time in my hand, so I started reading a lot more and finding a lot more about plastic pollution, and zero-waste as well. I think once you get into the field, then you find out a lot more information and aspects as well. I've always been interested in trying to improve healthcare, also from my research background as well. All the research I've done up until then was focused on medical research, on the topic towards helping, toward curing diseases, or improving healthcare. So, for example zero-waste is never completely waste or plastic free, it's an easy term to put people into the lifestyle. So for the research side of things, I know plastic pollution is impacting not just on the environmental side of things but also people's health and eventually we are all kind of connected, so it's going to affect our own health as well, not just living creatures on the planet but also human's health. So, I thought from that aspect it would be good for me to try to do my part in raising awareness and get more people to learn about the problem and do something about it to change and improve hopefully. So yeah that's kind of my story.

(M) I'm Mike, Simona's husband. I'm sort of the support along the ride. When Simona mentioned about what she was deciding to do, I thought that we had been together for quite a long time, and through the years of the ups and downs of I questioned whether I wanted to continue doing what I was doing, so I'm a computer animator, I work for video games. I'm still working at my job, I'm still working as a computer animator, but I do this in my free time. So, I'm switching between my job, Bambú employee and being a father for our child. Long before we started this journey, we were doing things like recycling and reducing our waste. We were doing progressively more each year, and kind of heading down this path anyways. And I think with the start of Simona's business it just accelerated things and got us thinking more about things we could do locally to help do what we do. Long before we started this, we never have been horrible but like I said, just thinking consciously about things are going. That's what really let us down this way, one day Simona said, "hey I want to save the planet", and I said "sure, let's go for a ride".

*Q Have you witnessed any change in your business throughout these years? For example, people are more aware of the problem?*

A: Yeah absolutely. I mean back in 2018 when we first started, there weren't any zero-waste shops in Edinburgh. At the time it was the Newleaf, the shop in Marchmont. They didn't really call themselves a zero-waste shop. But they were probably the first shop to start in Edinburgh where they provided some sort of refill. But they also sold other products that are not necessarily all plastic free. So you know at the time when I decided to go on the journey, I did research as well, as a scientist should do, I surveyed over 300 people, to ask the question whether people were interested in plastic free shops or zero-waste shops. And the majority were interested. Some didn't know what it was. There is a little bit mixture but what I found was the majority were women who were more keen to kind of be interested in shopping or going to a zero-waste shop. So that was the main thing. So, at the time when we first started, we started kind of basic. Actually, the first thing we did was participating local community fair to raise awareness so any profit we made we donated towards the community fair that supported different local based charities. So, we started where essentially a handful of plastic free snacks, healthy snacks, like dry fruit and nuts. We had soap bars, obviously without the plastic bottles. And at one point we also had the washing up refills so in my mind I thought ok this might be very lowkey, very small, but it kind of created something for people to see and to talk about. And I feel like people would feel related to it a bit more, you know when they can see rather than me handing out the leaflets, because of the chances that people take the leaflet then put in the bin. If you have a physical something to show to people and say, "look, this soap bar is equivalent to three plastic bottles." So, by making the simple switch to the soap bar, you are already saving three bottles of plastics. And the same way with the washing up liquid that something every household uses, and making the simple switch, people can be reducing tens of hundreds of bottles ever year. So that's kind of our start of Bambú popup. We call it popups because we used to pop up everywhere with every opportunity we got. We popped up at a local cafe that opened at the time, we also did weekend market, so we got a stall there and we started selling products there and handing out leaflets. For us it's not only just selling things that are plastic free, but also trying to connect and starting conversation with the public, the community, so yeah we actually decide, one of the volunteers at the time created these leaflets with simple plastic tips which you probably find it on our website as well, to give it to people or for them to look, to see what the simple steps they can take in order to reduce their plastic consumption. We started from pretty much people we met along the way telling us them not knowing anything about what zero-waste shop is, what plastic free is or why would you go plastic free, we could get a lot of times so to now that there are several shops that opened in Edinburgh, and we had the chance to open our own shop. We are still enjoying doing the market and popup, and now we are mainly in Leith area which is down at the shore. There is an actual following, even the market is quite regular, they are pushing it to be more like a zero-waste market so actually encouraging other venders to reduce their packaging. So, there is a lot more of this mentality. We've also met with other brands who are very conscious about reducing waste and circular economy. One brand they only do printing when they need it, they don't do it ahead of time, they are not generating any excess waste other than what is needed at the time. Just cutting off a lot of the problems like things going off or having things in stock so you could have a smaller space as well which pass on savings which in turn does give you more leverage to get more clients which also impacts a movement. Because that's also a big part for us, at the moment we are probably much closer to zero-waste, but still quite far from completely zero-waste, which most people are, I think with every steps, with every change, we as a community become closer to each individual being zero-waste, then we as providers and most other people we speak to in the same sort of field or industry, like we are able to turn to what people provide us product and go we prefer to receive our product in this certain fashion. It leverages the whole industry which they can in turn with them receiving their content, a chain with several people. When they receive their content, they could also say the same thing, it's like, we are having to do some certain things at our end to leave the plastic so can you just avoid sending it at the first place? It's just a whole market kind of idea. It comes a long way even we just started three years ago.

*Q Which way do you think is more effective? Having conversation with people at the market or having the information on your website?*

A: I suppose you work in different level. Because when you speak to someone directly, like face to face at the market, it's a bit more engaging, because you are talking directly to them and they ask for advice, they want some tips they can ask you directly, you can give direct recommendation, it's a lot more tailored. (M) It's very specific, so people ask some recommendations and you can ask the details they have. We have a lot of people they come up and ask like, sensitive skin, certain people ask like where the products come from because they want to look at the carbon footprint things like that. And stuff like that you can have on the website, but you get the answer so much quicker than having to read paragraph and paragraph of your ethos, the product information things like that. (S) I think on the website, it's good because it's there for people to have a browse, to have a look. And also, you know they can take the time whenever they have time. It's useful to be there. Face to face is always more engaging I feel. And you get to meet people from all walks of life, which is quite nice. That's what I quite miss because since we had our son who's now just a year old, I have to step back a bit more from the front face of the business to look after our son. We also did a popup at the university, they were organising events to also try to raise awareness of plastic and circular economy, and less waste in general. So, me being there and being able to talk about it, for people to ask me questions, providing them with the alternative ways that are more ethical, more eco-friendly with less waste and less packaging. I think that's a good way, if you make it easier for people to transition, to buy things that are not just for you but also for the planet, then it's a win-win game. Because it's easy, why not right? If it's difficult, it's the extra steps and extra obstacle that people feel like "I can't be bothered". So yeah, I think the trick is we try to make it as easy as possible, and inform people why it is a better product, why it is the best for the environment and why better for your own health. (M) Yeah, living up to the pandemic, pretty much the website became a booster, with the pandemic and not being able to trade during lockdown, the difficulty of much what we were doing before is meeting people in person and popping up at these locations, to markets, it's very easy to be forward facing, just meeting people, passing what you are doing is worth well, just driving people in and getting people to talk to us to ask question and picking up products on the go and kind of bringing the product to people. Then we ran into a point where we were thinking we will have to make the shift with the pandemic everything is changing, more online so we were pushing a lot online, trying to get people to buy on the online shop but luckily we were able to continue to trade.

*Q So, a lot of your online customers they actually know you in person before from the market?*

A: Yeah people passing on information. Simona is very vocal locally on Facebook and Instagram and other kinds of social media. She's giving information, she's telling people where we are gonna be, what we are doing, mentioning "hey, check out the website". So, she's always active in a way to say that "here we are", "we are here to help" because part of what we want to do is to get as much people as possible to get involved. You know people always say it's expensive to get into zero waste. We try to make it as affordable as possible by offering a range of products that people can afford to get as many people to shifting their ideas.

*Q Do you think it will be cheaper for these local businesses to be cheaper for the vast public to afford or it will still be a long way?*

A: First look, it appears to be more expensive, but in reality, if you switch your lifestyle, and if you take it into account, the whole picture, it's not actually more expensive because for example, a tin of deodorant from a zero-waste pack is £6 from our stall, we do returns so when people bring back, they actually get money off from bring back the tin because then we can send it back to be reused to complete this circular economy and reduce the waste as well and save people money. So, £6 is quite expensive for a tin but if you think about it a tin … with the benefits that you are not producing any plastic waste, you are reducing the waste. It's trendier to have a zero-waste lifestyle. It encourages younger people who may care more about the trend seeing the possibility. Some people who wouldn't be excited about saving the planet or zero-waste, I think any way that could help people or push them is good.

Q: Conversation is more important, but with Covid happening, it is very difficult.

A: Yeah, it's difficult when you have to be isolated and work remotely. I think what helps is building a community online, that's step one. You can start to say online community or talk group, you can have a website. That's why we are building online, Instagram, social media, and online groups that follow her to look for pictures and look for the information, are excited to reach back. (S) I think it does help a lot to have that kind of direct communication, it's a lot more impactful. When you have a conversation with someone, they are gonna remember you. When you give a good tip and why it is a good thing, they are going to remember, and from there they will be "I will have a look on their website to see what else what other changes I can make", and you know step by step they are transitioning to a more sustainable lifestyle.

*Q Have you had feedback from your returning customers that this lifestyle really had impact on them, and they spread the information?*

A: I can say honestly, we get pure divide, same as when we first started. We get a lot of people who are very attracted to us for specific reasons. They don't really care about the ethos around it, the zero waste or saving the planet. They just like the particular products that worked really well for them. They like the idea that they can shop local, so they come to us. Then we get the complete opposite the other half and in fact I would say the other half overshadow the first half even though it's a split. They shout from the rooftops, they tell their family, and every gift they buy is like I want to buy eco-friendly, we got a lot of people coming and they are like I'm buying a gift for my mum because I'm going home, or I'm going on holiday to see friends so I want to bring them a gift. And we get so many people tell us that they are trying to switch their mum to be more eco. I spoke to people saying that "I'm here buying things for my mum and trying to get her to be more eco-friendly". (S) Now when Mike mentions these things actually, a lot of memories. I mean a lot of people came to us buying whether it's gifts, I suppose a lot of times gifts because we have a lot of locally made things. It's a nice way for people to say, like they buy this as a present and give it to someone whether friend or family. So it's not just a gift, it's also kind of a way to say "this is actually a zero-waste product, it's plastic free", so in that way it's very nice to, it's almost like butterfly effect where our customers are impacting their friends and families by making them aware of the products are available, they are nice and they make a nice gift as well. (M) Being at the stall, I get customers coming by and they said "oh a friend of mine mentioned that you were here" or "I spoke to Simona online through Instagram" and we get so many people that come to the stall saying "I heard about you from this, through that". Hearing the story of how people are attracted to us and we do get a lot of people coming back over and over again. (S) And the fact that they are returning customers obviously because they are happy. I remember one specific customer, she met us at one of the indoor markets, and she bought something for the parents who are slightly older generation than us. So, they were kind of saving the soap or shampoo bars for holiday. Then eventually because of Covid lockdown they started using the bar and they really liked it and then they went back to the daughter asking her where she got it. They ended up buying things online from us. They also wanted to buy a beeswax food wrap, but it was out of stock at the moment. I even went to other shops to see whether I could find the wrap, and I emailed them to keep it for them. They were really impressed by the very intimate customer service. The daughter wrote a very nice review saying they were so happy with the service and the products. These are the things that make me think I'm doing something helpful, touching, positively on people in the community. (M) This is the whole principle we have that we are not just here to make a buck from you, we need the money to survive the business, but we want to give information, be friendly, develop a community of other people who want to move into the same direction. We are trying to encourage people to make smaller changes along the way instead of not making any change. Once it becomes a habit, it's not that difficult. Our life is much simpler now than before. It's getting people to shift slightly little by little. It's only through the process of telling people of all the things I did, it's also part of the question of what you do to reduce waste, I've actually come a long way since the beginning.

(S)I think ultimately, it's better to turn off the tap as people say not using plastic in the first place, until then we also need to find some solutions of using and reusing that has already been generated.

# Have you thought about using ocean plastic in your design? Ideas? Does this lecture have any impact on you about ocean plastic?

Mentimeter

I've looked into the Texas-sizes plastic islands in the Pacific Ocean and it scares the life out of me

Since the lecture and the new knowledge learned, I didn't realise how reusable ocean plastic can be. Also how the plastic can be reshaped and melted down into a souvenir. I also really like the uniqueness of a tourist having a souvenir.

I have never thought of using ocean plastic in my designs Befoure. But from looking at your outcomes, they look gorgeous. This is like an art form. I will be thinking about this material going forward with my own design process.

One garbage truck of waste into the oceans every minute is astonishing... 150 million tonnes of plastic in the ocean is very depressing

I liked the connection made with plastic and nature with your use of leaves - it creates a very strong statement. The exploration of colour has inspired me to consider the use of plastic and upcycling it into my work

It's a really interesting idea and I really love it. Have you thought about jewellery? It seems to be a very popular thing to do to raise money for conservation of the ocean, but I've never seen jewellery made from ocean plastic. Magnets maybe too?

There is far more plastic in the ocean than I realised

That fact u made it all in in the work shop showed how easy it is to work with the ocean Plastics

I found it really interesting, as a product designer, the thought of the type of plastic code wears off after time in the ocean making it very difficult to recycle

15

# Have you thought about using ocean plastic in your design? Ideas? Does this lecture have any impact on you about ocean plastic?

Mentimeter

Thought about recycling plastic before for designs but oceon plastic is hard to work with. Definitely consider using it as a sustainable material in the future

It makes me consider the nationwide effect leaving litter on a beach in Scotland may end up so far away

I'm very interested about ocean plastic and how such rubbish resource can be created to be something new. I wish I had resources myself to edit plastic and have the workshop opportunities for it

Very impactful to show where the plastic goes if you throw it away.

I haven't thought of using ocean plastic before for my projects, however, I will be considering it from now on. I believe that this is a great project you are working on and I hope more individuals as well as me will be involved to save the ocean.

Might be good to consider making an item which is usable rather than decorative. I know many people that will throw out tourist tat after a couple of years during house clear outs. If they use it they are more likely to keep it

15

# Have you thought about using ocean plastic in your design? Ideas? Does this lecture have any impact on you about ocean plastic?

Mentimeter

There needs to be a major change in how we use plastic and what effect it has on marine life. We need to use alternatives to plastic in our designs

I love the idea of using oven plastic as a resource, but it's the fear of creating more waste than before and starting the whole waste cycle again.

It would be nice if you could "punch" the amount onto it that you collected and where about, so should how you contributed, and to show that it carried real value

Of course we don't want plastic in the ocean, it's killing the animals and the environment. But we also don't want plastic collecting in landfill. We can clean up every beach in the world of rubbish, but once it clean where do we put it?

The research and presentation was very detailed and informative. Moving forward with plastic we need to ensure that we look to reuse existing plastic to ensure that it does not go into the ocean. Or a bio solution where bacteria can break down.

I think in graphic design it is harder to incorporate ocean plastic in our designs but we can be just as active in trying to recycle and save plastics from the ocean

I think it would appeal to people who visit seaside towns to have their souvenirs made from ocean plastics as it protects the ocean of the place they visited

SMELLS LIKE THE OCEAN

Seeing how far the plastic travels on the map over a period of time was very eye opening.

10

# Have you thought about using ocean plastic in your design? Ideas? Does this lecture have any impact on you about ocean plastic?

Mentimeter

I loved this idea of making the ocean plastic into tourist gifts, I feel like sticking with basic tourist gifts like keychains or magnets would work really well as long it's been marketed loads as recycled ocean plastic. I definitely would buy!

10

# Have you thought about using ocean plastic in your design? Ideas? Does this lecture have any impact on you about ocean plastic?

Mentimeter

i didn't realise how much of a problem and the extent plastic in the ocean is. Great Job !

Great presentation and extensive research. Has made me realise that ocean plastic can be turned into something beautiful; it's not always a bad thing.

For my past projects I have researced about the use of plastic in general but not ocean one. Definetely I will keep your research and the research methods you used in mind for future projects.I love how you researched and experienced the topic

3

# What do you know about ocean plastic?

Mentimeter

Not an awful lot

It takes so many years to dissolve and it really damages the environment.

I know about all the micro plastics that end in the sea from shower gel and stuff, and general rubbish like plastics bags, and plastic from fishing nets, but I don't know if these count as 'ocean plastic'

floating plastic the size of France

there are more micro plastics in the ocean than stars in the sky (approx)

It harms wildlife?

It gets caught in marine life's stomachs

There's a lot of it

A lot of single use plastic, stuff that's been disposed off. Just far to much in the ocean. Don't know a lot just know its not good.

11

# What do you know about ocean plastic?

Mentimeter

Theres about 8 million tons of plastic in our ocean

Its easily spread around due to ocean currents

11

# What impacts do you think ocean plastic has?

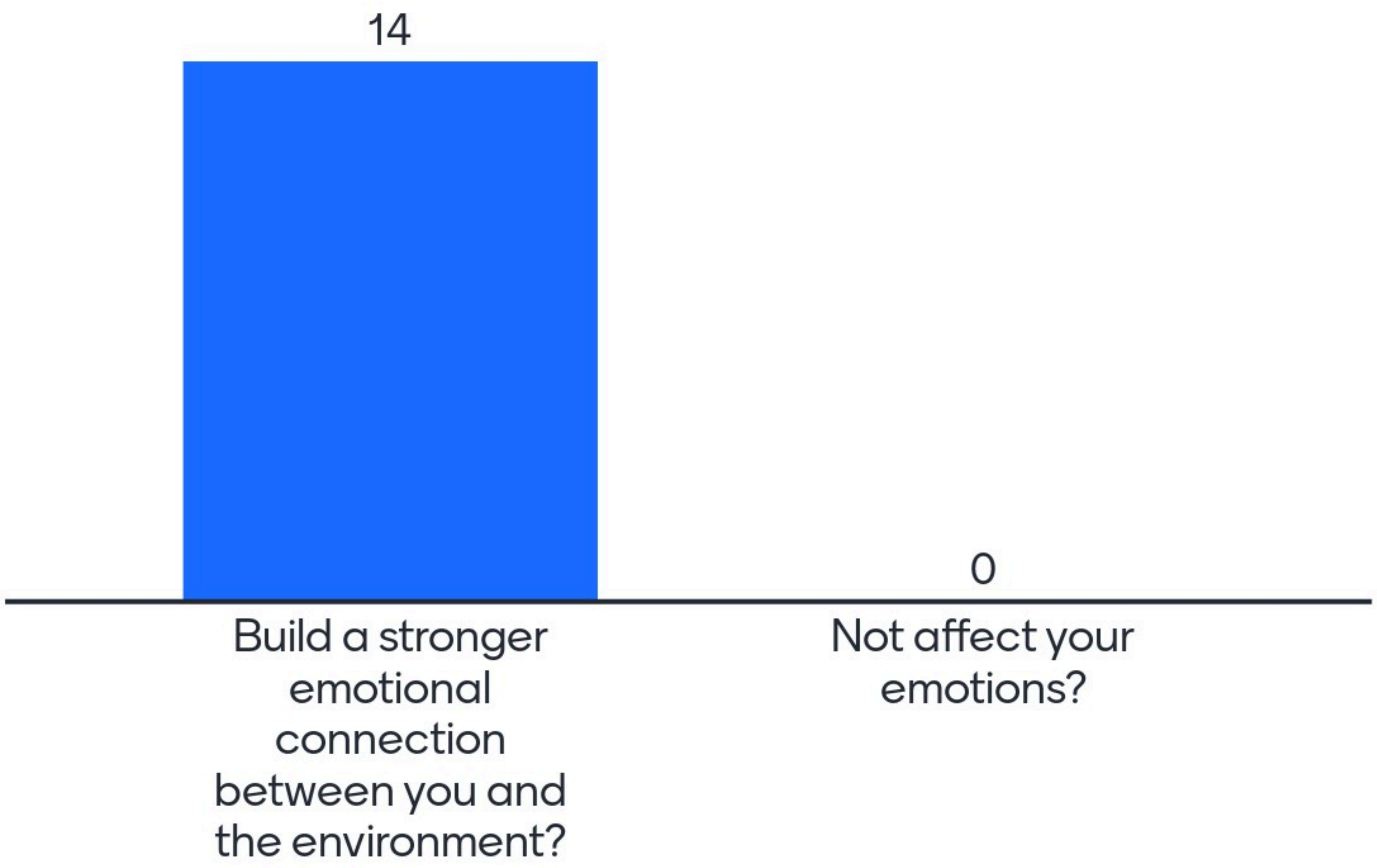
Mentimeter

Fishes eat plastic and e eat them so we also eat plastic...

1

# Will a visit to a plastic polluted beach and the participation in creative ocean plastic recycling activities

Mentimeter



# What do you feel about ocean plastic after this lecture?

Mentimeter

I feel more informed about the amount of plastics found on our beaches

Still think it's bad but might have some potential uses.

I have a more positive view on how it can be used in the future

I know more about ways that they can be reused

before, plastic was all evil but it can actually be used to make something quite lovely

its so sad seeing all those pictures of the poor animals with the plastic around them

this shows that more plastics can be recycled rather and just chucked away

I think what you did is amazing x

8

# What do you know about ocean plastic? And what impacts do you think ocean plastic has?

Mentimeter

They hurt turtles!

They hurt turtles!

environmental hazard

Marine animals suffer.

Animal and environmental issues (even down to a miniscule level), microplastics, I remember hearing once that about 4% of hawaiian beach sand is microplastics now.

affect drinking water and create microplastics

I known at least a few million tons of plastic end up in our oceans every year and he disrupt our marine Eco system

Ocean plastic kills fish, which leads to no food for phytoplankton. Phytoplankton absorb largest amounts of CO2 of the world. Hence, global warming

I know there is a lot of it that ends up on the beaches and stays swirling in the ocean - I think it has a lot of negative impacts on the ocean ecosystems and the animals that live within the ocean as they are consuming microplastics

13

# What do you know about ocean plastic? And what impacts do you think ocean plastic has?

Mentimeter

I know a little. 1. increased awareness of the problem, but may not have shifted consumer behaviour yet. We have a long way to go.

Ocean plastics are hard to collect, degrade into smaller finite pieces, washes up to shores, is gathered by currents to form plastic islands, and more. Because plastics can break down into microplastics, they can harm wildlife ecoystems.

they*

Saw Seaspiracy on Netflix, very well explained

13

# What do you feel about ocean plastic after this lecture? Has your perception of plastic changed after seeing the transformation?

Mentimeter

I think it has a lot of potential to be used in products and start conversations - I especially love those samples that mimic the ocean water!

It still is just as shocking as it was, but gives a glimmer of hope that maybe one day we can figure out how to make with it.

I still feel negative about ocean plastics. Seems like a hard material to work with when there are many types of plastics as well as sediment that can contaminate plastics for a second-generation use.

Yes! Wonderful lecture. There is a lot of potential for repurposing the materials. Do you know the work of Vinu Daniel ? Wallmakers.org

I would say plastics have definitely transformed our society and I have hope that we can finding more meaningful ways to digress the use of virgin plastic

After seeing the range of possibilities, maybe this scary problem can be turned into a beautiful solution.

I'm not sure if it did. There was a little bit of information overload to be honest. So I got a little distracted.

7

# Why did you choose this project?

Mentimeter

Seems lit

To learn more about sustainability and how to apply this

hearing about it from Chloe and its something I have been interested in doing and it is about making things better, a change

want to learn more about sustainability cause i don't know a lot about it

I would like to see how many everyday things we use would be able to be made out of recycled plastic

interesting brief

I wanted to know more about how sustainability can impact interior design and the way we do it

The way the world is heading, plastic needs to be understood and changed out for other materials. Was interested to learn more about sustainability

I'm interested in sustainability in design and how we can make more use of it

18

# Why did you choose this project?

Mentimeter

I grew up in a very beach area, sometimes when I walk around now I see loads of litter or plastic bits washed up and it's gross and sparked my interest towards this project

I liked the idea of thinking outside the box on ways to use recycled plastic

It will be very applicable in design in the very near future for us as designers

I think sustainability will play a big part in our futures, therefore it is important to learn about.

i hate plastic, it the reason of problems

this is the most familiar one

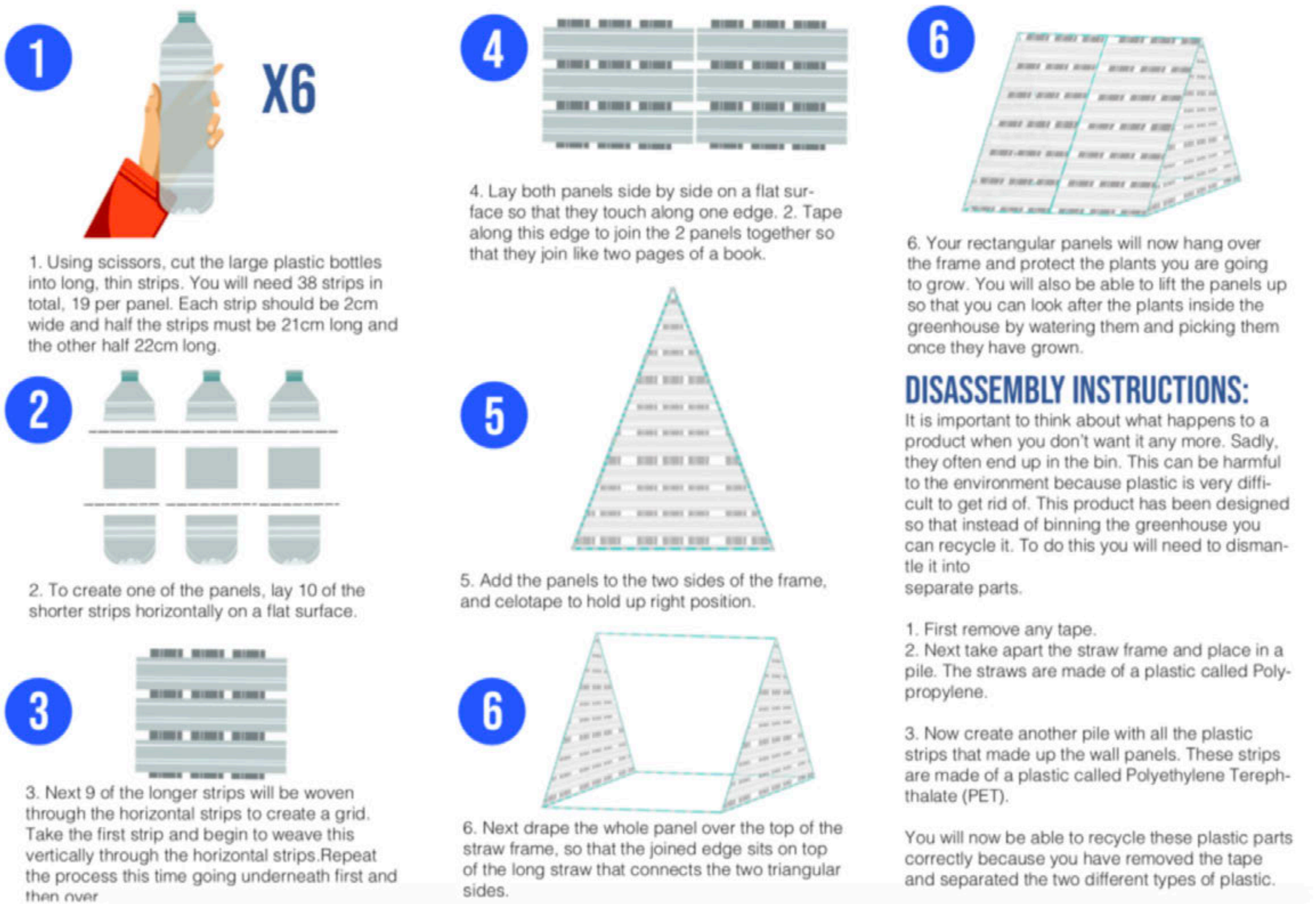
it seemed interesting and I want to learn more about sustainability and recycling. how we can incorporate that in our designs.

Interested to see what can be made from plastic

Relevant

18

# Group 1. Plastic Greenhouse



1. Using scissors, cut the large plastic bottles into long, thin strips. You will need 38 strips in total, 19 per panel. Each strip should be 2cm wide and half the strips must be 21cm long and the other half 22cm long.

2. To create one of the panels, lay 10 of the shorter strips horizontally on a flat surface.

3. Next 9 of the longer strips will be woven through the horizontal strips to create a grid. Take the first strip and begin to weave this vertically through the horizontal strips.Repeat the process this time going underneath first and then over

4. Lay both panels side by side on a flat surface so that they touch along one edge. 2. Tape along this edge to join the 2 panels together so that they join like two pages of a book.

5. Add the panels to the two sides of the frame, and celotape to hold up right position.

6. Next drape the whole panel over the top of the straw frame, so that the joined edge sits on top of the long straw that connects the two triangular sides.

6. Your rectangular panels will now hang over the frame and protect the plants you are going to grow. You will also be able to lift the panels up so that you can look after the plants inside the greenhouse by watering them and picking them once they have grown.

## DISASSEMBLY INSTRUCTIONS:

It is important to think about what happens to a product when you don't want it any more. Sadly, they often end up in the bin. This can be harmful to the environment because plastic is very difficult to get rid of. This product has been designed so that instead of binning the greenhouse you can recycle it. To do this you will need to dismantle it into
separate parts.

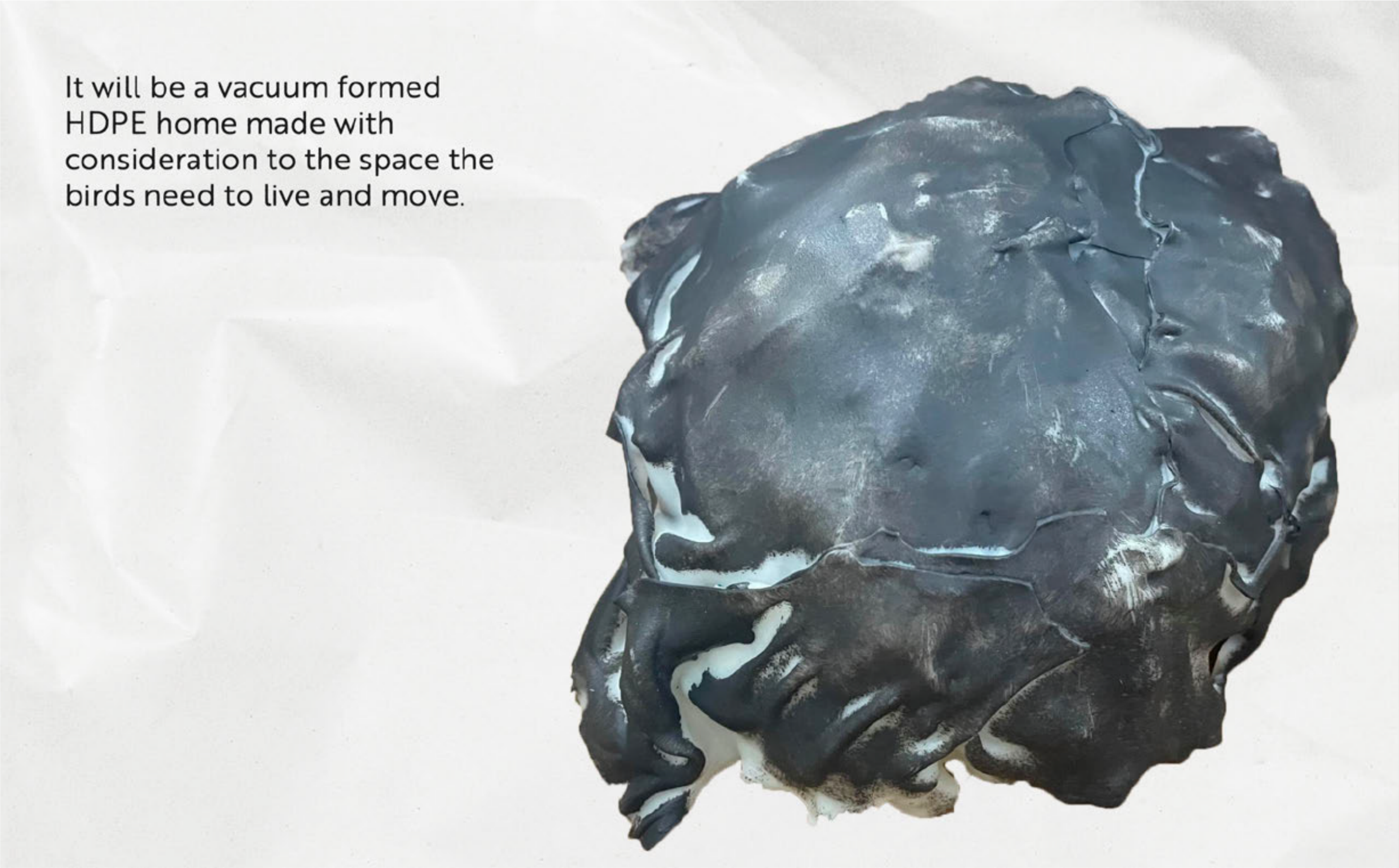
1. First remove any tape.
2. Next take apart the straw frame and place in a pile. The straws are made of a plastic called Polypropylene.

3. Now create another pile with all the plastic strips that made up the wall panels. These strips are made of a plastic called Polyethylene Terephthalate (PET).

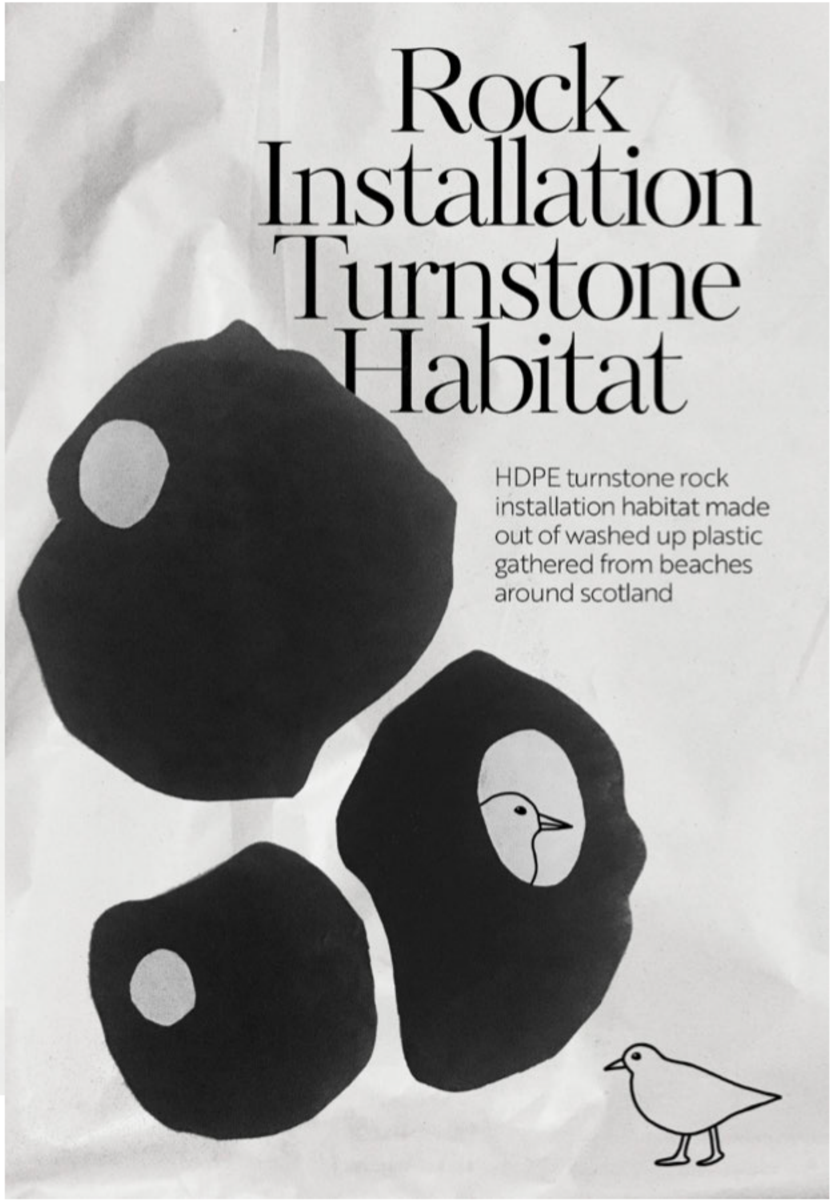
You will now be able to recycle these plastic parts correctly because you have removed the tape and separated the two different types of plastic.

Prototype

# Group 2. Rock Installation Turnstone Habitat




Prototype

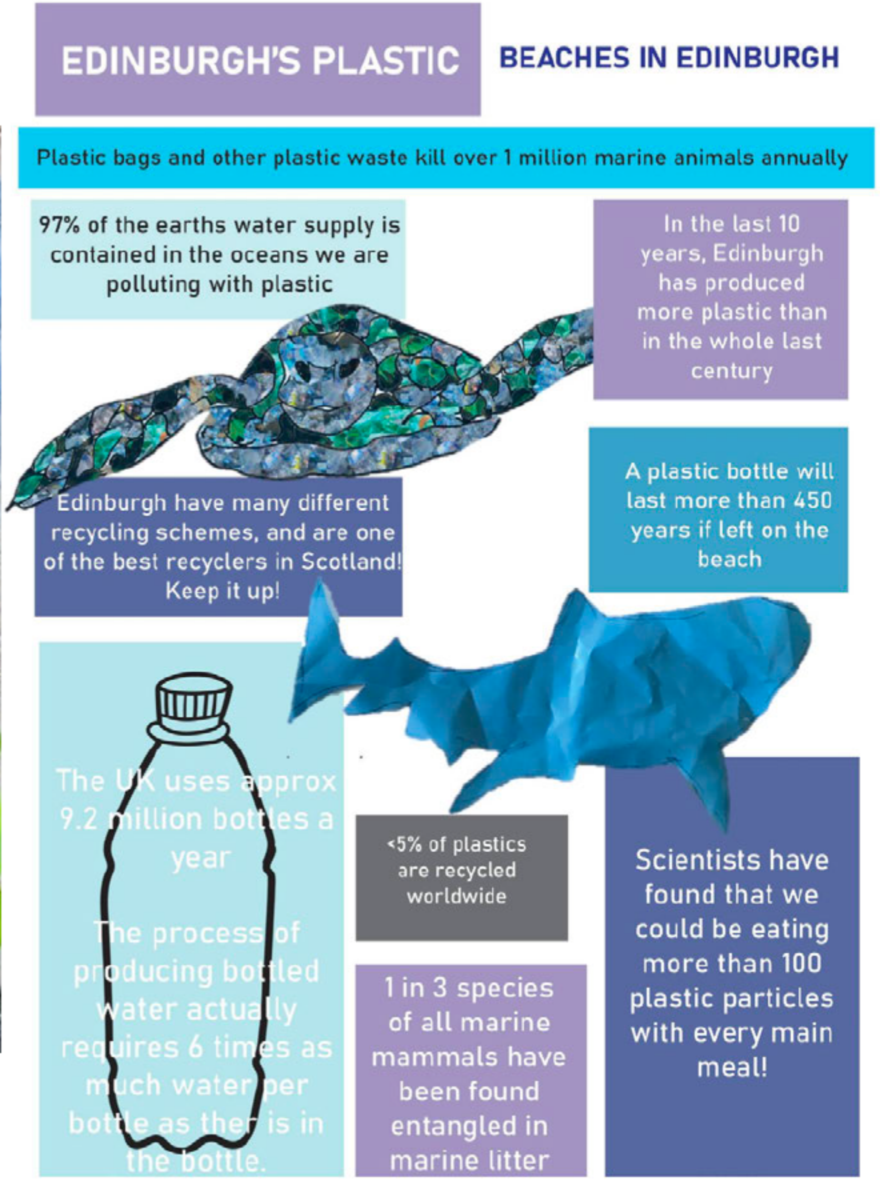


Group 3. The Litter Dock

Prototype

Group 4. Plastic Mural

Prototype



**Appendix 5.** Participatory workshop at Edinburgh Climate Festival – participation results




C


S
CASTLE



R
















I'M ON BOARD


EDINBURGH CASTLE




Forms(https://www.office.com/launch/forms?auth=2&from=FormsDomain) ? TX

# Post-participation survey

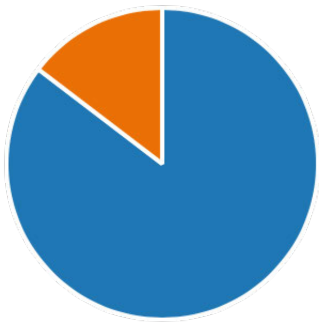
| 41 | 14:50 | Active |
|---|---|---|
| Responses | Average time to complete | Status |

1. Were you aware of ocean plastic before the workshop?

| | |
|---|---|
| Yes, very well | 27 |
| Yes, but just a little | 12 |
| No | 2 |

2. Have you encountered ocean plastic in your previous experiences (i.e. plastic packagings on the beach or sea)?

| | |
|---|---|
| Yes | 35 |
| No | 6 |



3. Do you take souvenirs home from holidays? What kinds? (This includes a stone from a beach)

41

Responses

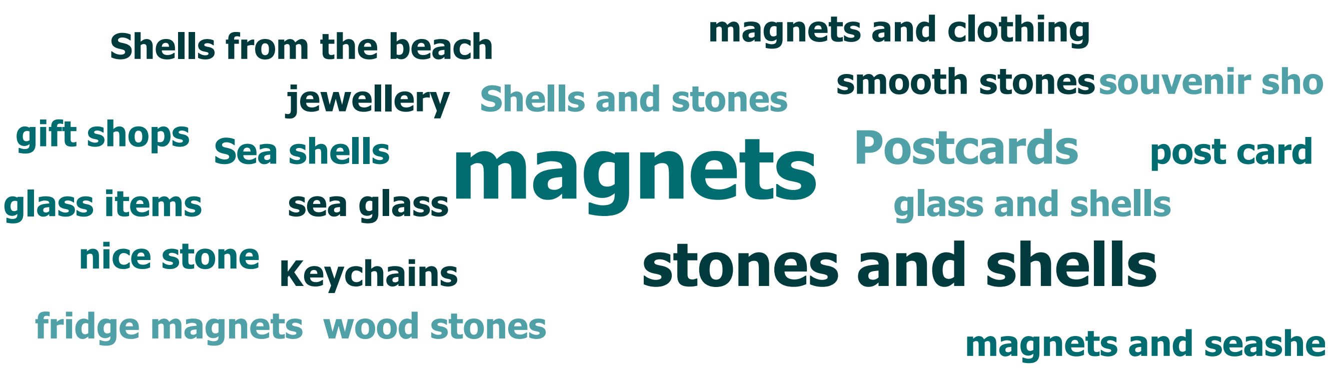
Latest Responses

*"keyring "*

*"postcard"*

*"stones"*

**7** respondents (**17**%) answered **magnets** for this question.



4. Have you purchased any souvenirs that are made of recycled materials? What kind of materials?

41
Responses

Latest Responses

*"recycled wooden keyring"*

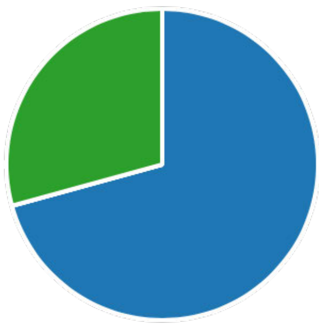
*"no"*

*"no"*

**4** respondents (**10**%) answered **plastic** for this question.


5. If you have a choice between recycled and raw materials, which one would you prefer for souvenirs?

| | |
|---|---|
| Recycled | 29 |
| Raw | 0 |
| I don't really mind as long as t... | 12 |



6. Have you personalised souvenirs? Or have you ever participated in tourist experience activities to make souvenirs? What did you make (e.g pottery, personalised photo keychains)?

41

Responses

Latest Responses

*"engraved my initials on a keyring"*

*"no"*

*"no"*

**26** respondents (**63**%) answered **No** for this question.


7. Do you think you will have more personal connection to a customised souvenir?

| | |
|---|---|
| Yes | 37 |
| No | 4 |

8. Would you participate in a tourist experience activity like this to make your own souvenirs in the future?

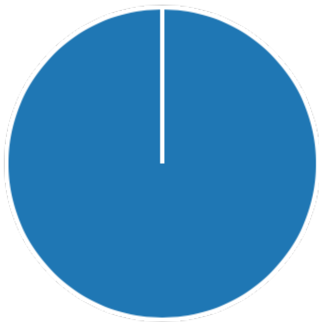
| | |
|---|---|
| Yes | 40 |
| No | 1 |

9. What would make you reluctant to participate in a tourist experience to make your own souvenir?

| | |
|---|---|
| It's time consuming. | 12 |
| I'm not artistic enough. | 11 |
| The souvenirs sold in the shop... | 5 |
| Other | 13 |

10. Would you participate in an educational workshop like this again in the future?

| | |
|---|---|
| Yes | 41 |
| No | 0 |



11. What's your opinion on making souvenirs from recycled ocean plastic?

41

Responses

Latest Responses

*"it's great to save raw materials"*

*"I'd like to make all the souvenirs from it"*

*"love it"*

**10** respondents (**24**%) answered **Great** for this question.

Excellent recycling
good use
awareness
fun
good initiative
Good thing
great way
Great plan
sure
littered plastic
better
Great
good
responsible way
ocean plastic
raw material
Great idea
way to get plastic
normal souvenirs
Great to repurpose

12. What's your opinion on using recycled materials in educational workshops like this?

41

Responses

Latest Responses

*"it's fun and unforgettable"*

*"it's fun and informative "*

*"fun, meaningful"*

**11** respondents (**27**%) answered **good** for this question.

fun and unforgettable
playful way
good thing
Great way
good way
fun and educational
public
fun
good
Great
fun and meaningful
difference
way
good idea
meaningful
educational
Great idea
Great choice
great for the environment
Educational workshops

## 13. Can you think of any other applications for ocean plastic?

41
Responses

Latest Responses

*"container "*

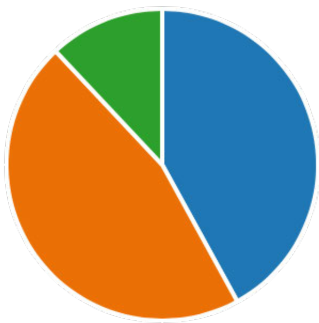
*"stool"*

*"plant pot"*

**5** respondents (**12**%) answered **plant pot** for this question.

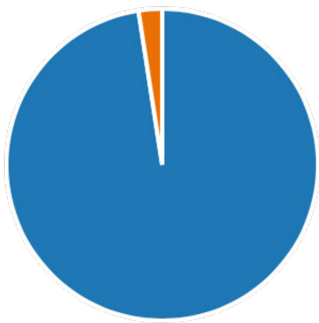

## 14. What did you make/experience today?

| | |
|---|---|
| Jewellery | 21 |
| Keychain | 23 |
| Using 3D printing pen | 6 |
| Other | 0 |



## 15. Will you use the item you made today to start a conversation about ocean plastic with your family and friends?

| | |
|---|---|
| Yes | 40 |
| No | 1 |



16. Do you think your attitude and behaviour towards plastic products and waste has changed or will change after attending today's workshop? State the details.

41

Responses

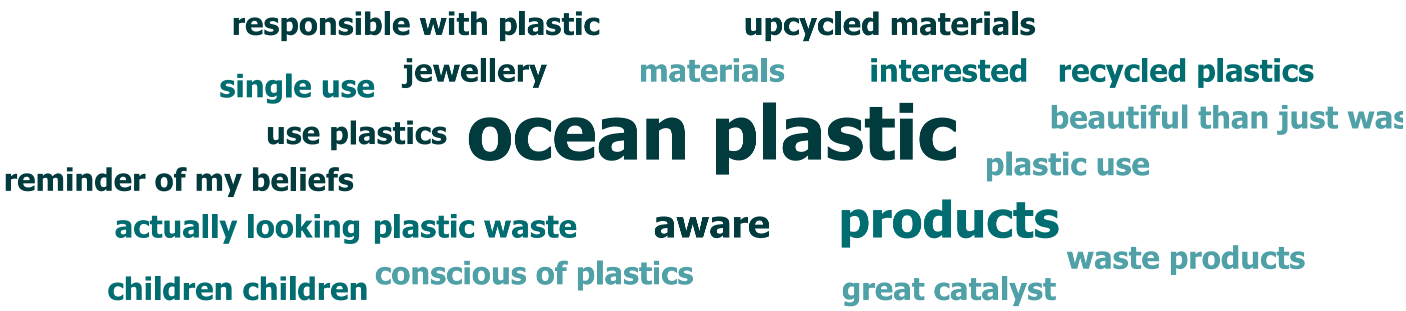
Latest Responses

*"yes"*

*"yes"*

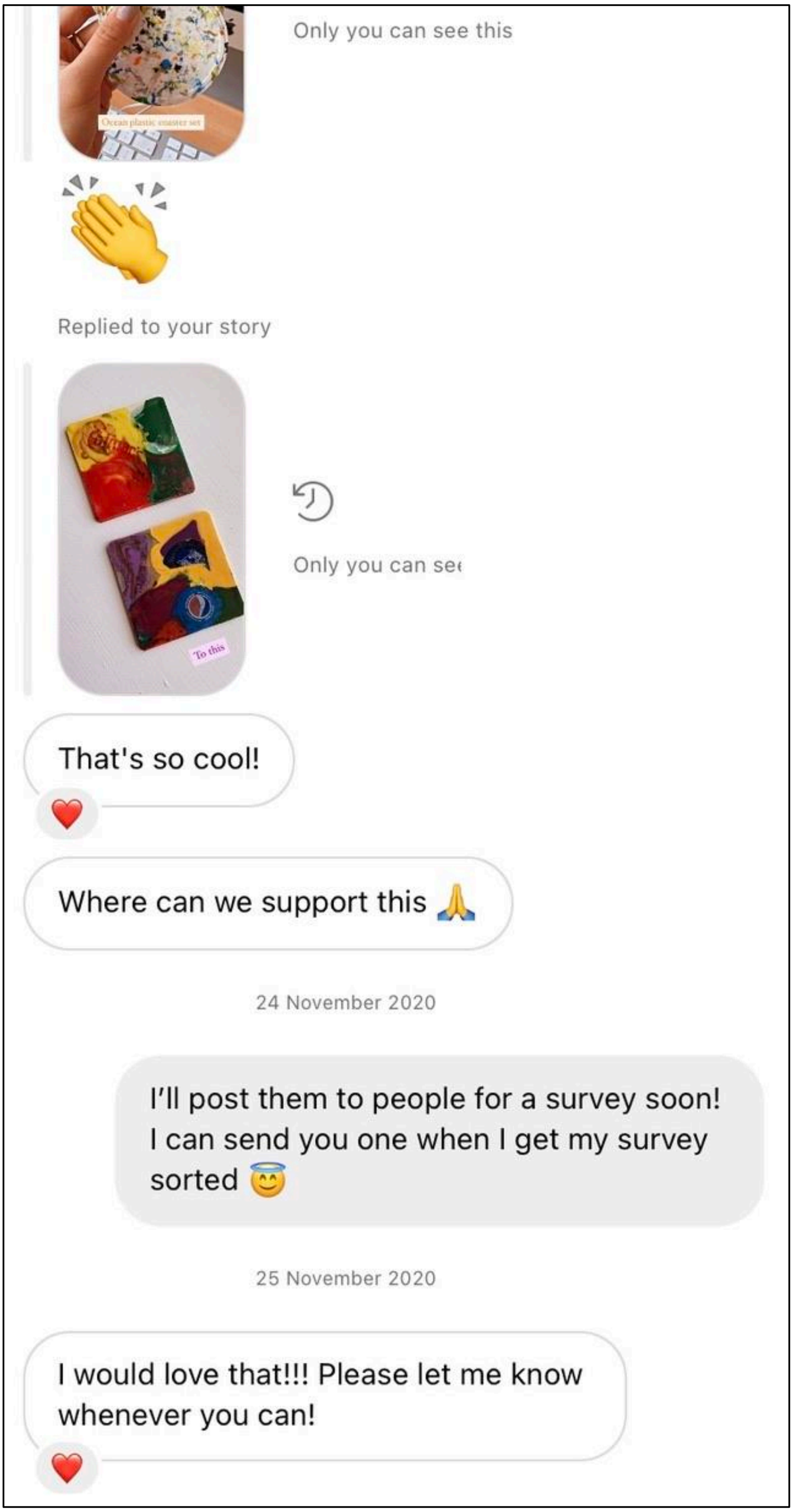
*"yes"*

**6** respondents (**15**%) answered **ocean plastic** for this question.




17. Thank you

**Appendix 7.** Social media reaction



12 August, 19:52

Reacted to your story

Only you can see

😍

❤️

Replied to your story

Only you can see this

Loooove this Chloe, so creative!!

❤️

Reacted to your story


Only you can see

23 November 2020

Reacted to your story


Only you can see

23 November 2020

Replied to your story


Only you can see

Cool!!!

❤️

12 August, 18:14

Replied to your story


Only you can see

Wooow

❤️

23 November 2020

Reacted to your story

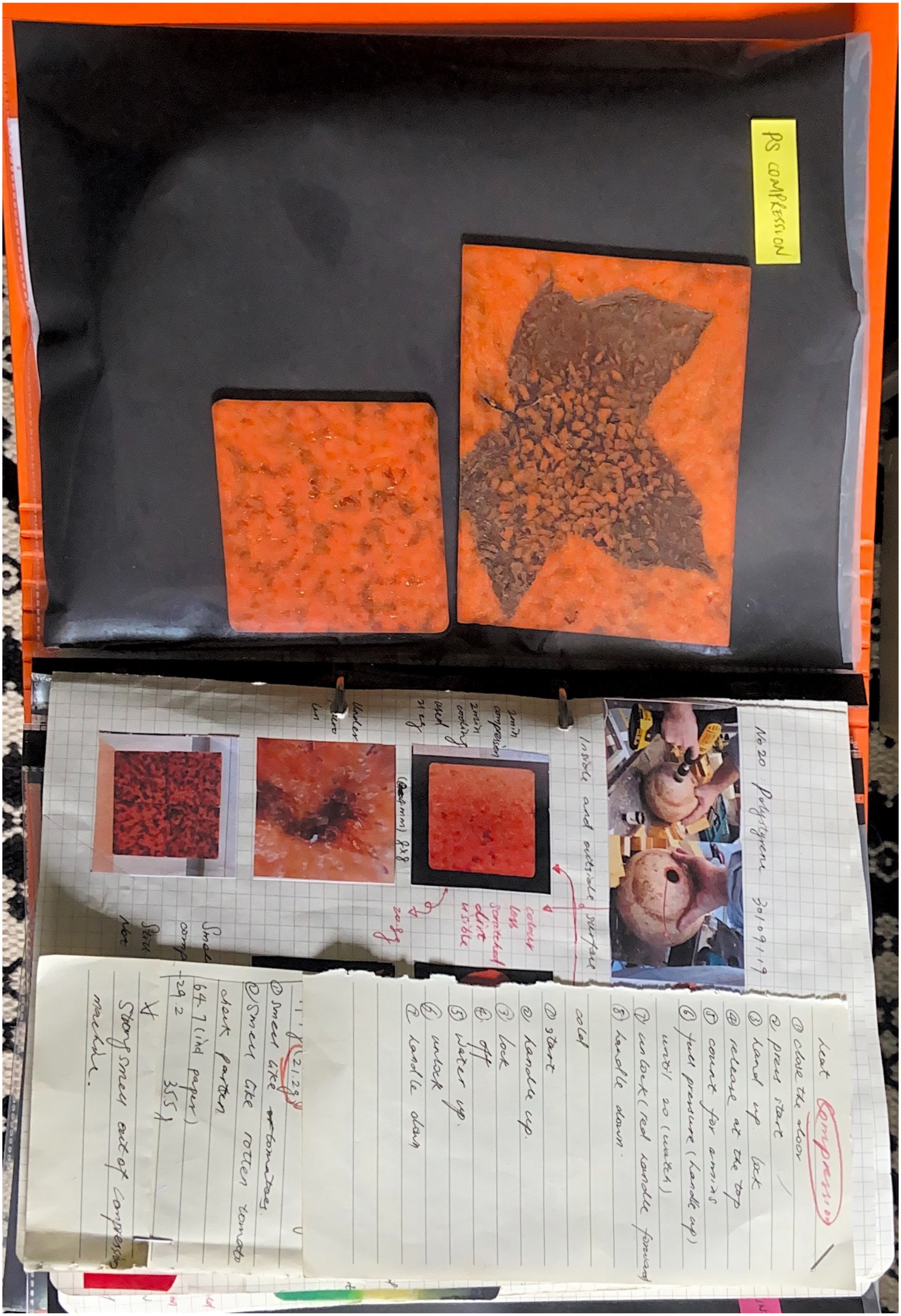

Only you can see

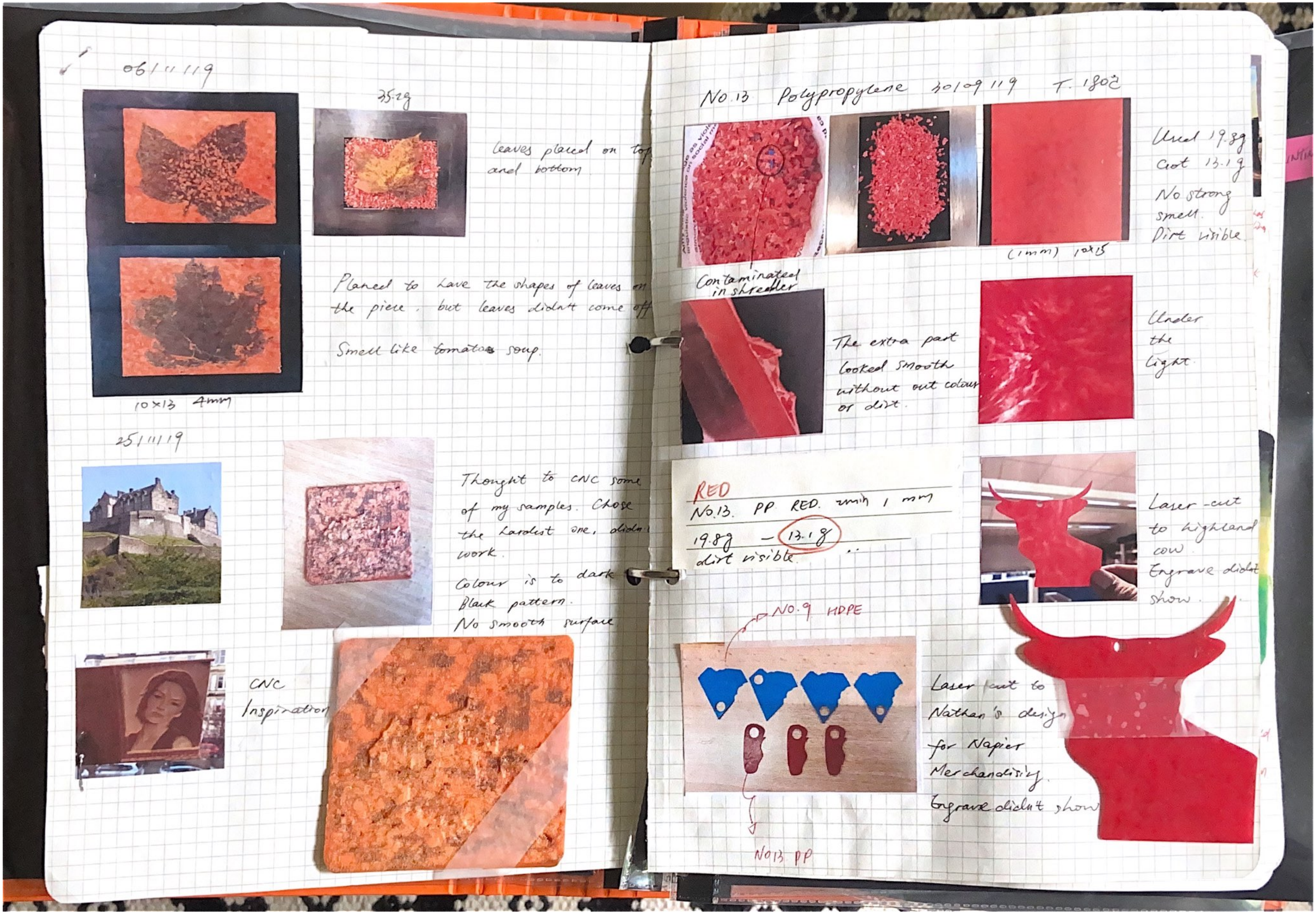
*Participatory workshop*

*Link to the consents*

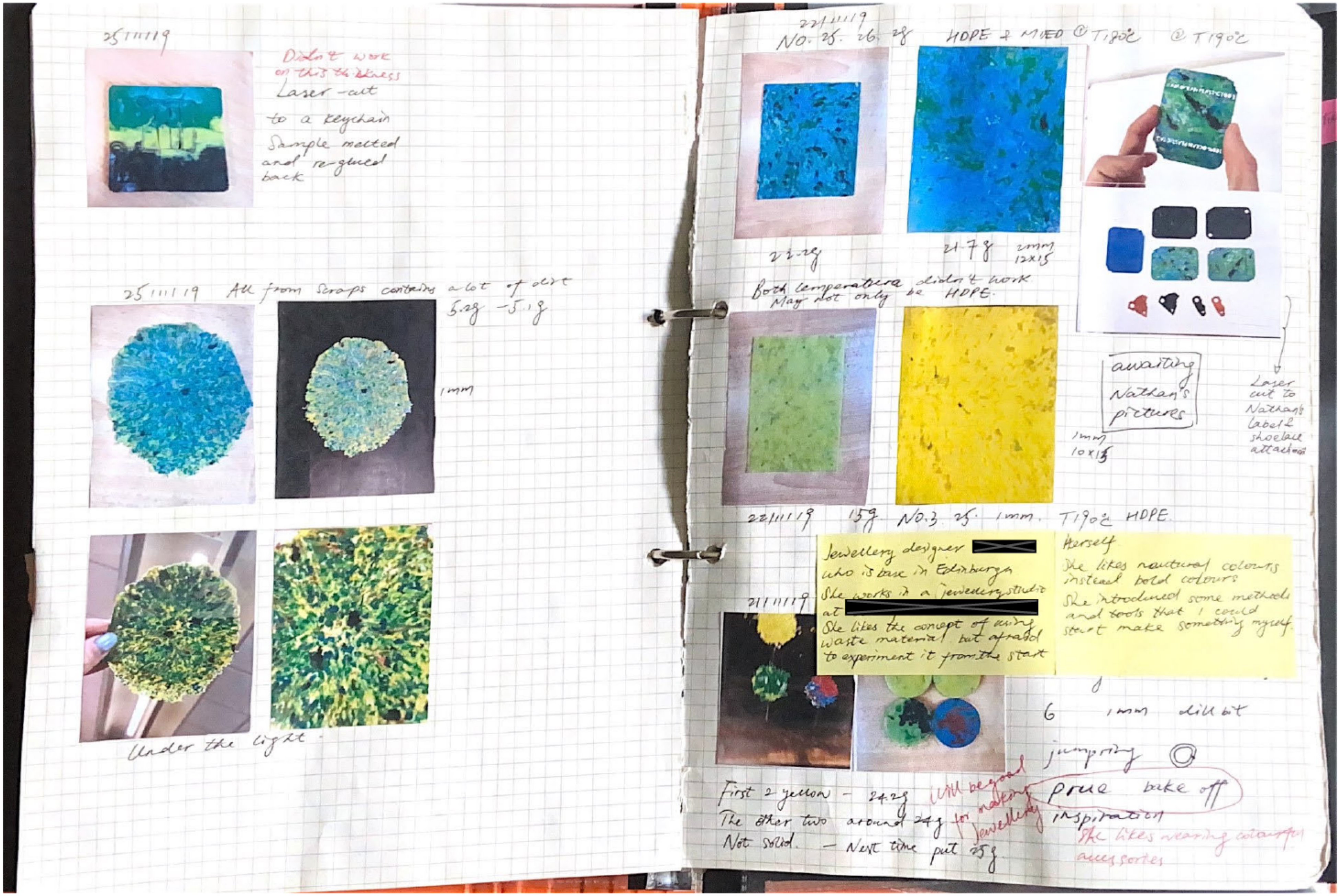
https://forms.office.com/Pages/AnalysisPage.aspx?id=WNzgmUucIEiGFwTDhsJUxtCbkGJ5xn9MkWzKxlshalZUNkY3OUpZUUVEMTJVT0sxNUVCSUU2TlA1Sy4u&AnalyzerToken=CLjwOhxds8Okm8lwvyJe5m8utRBCYuQS

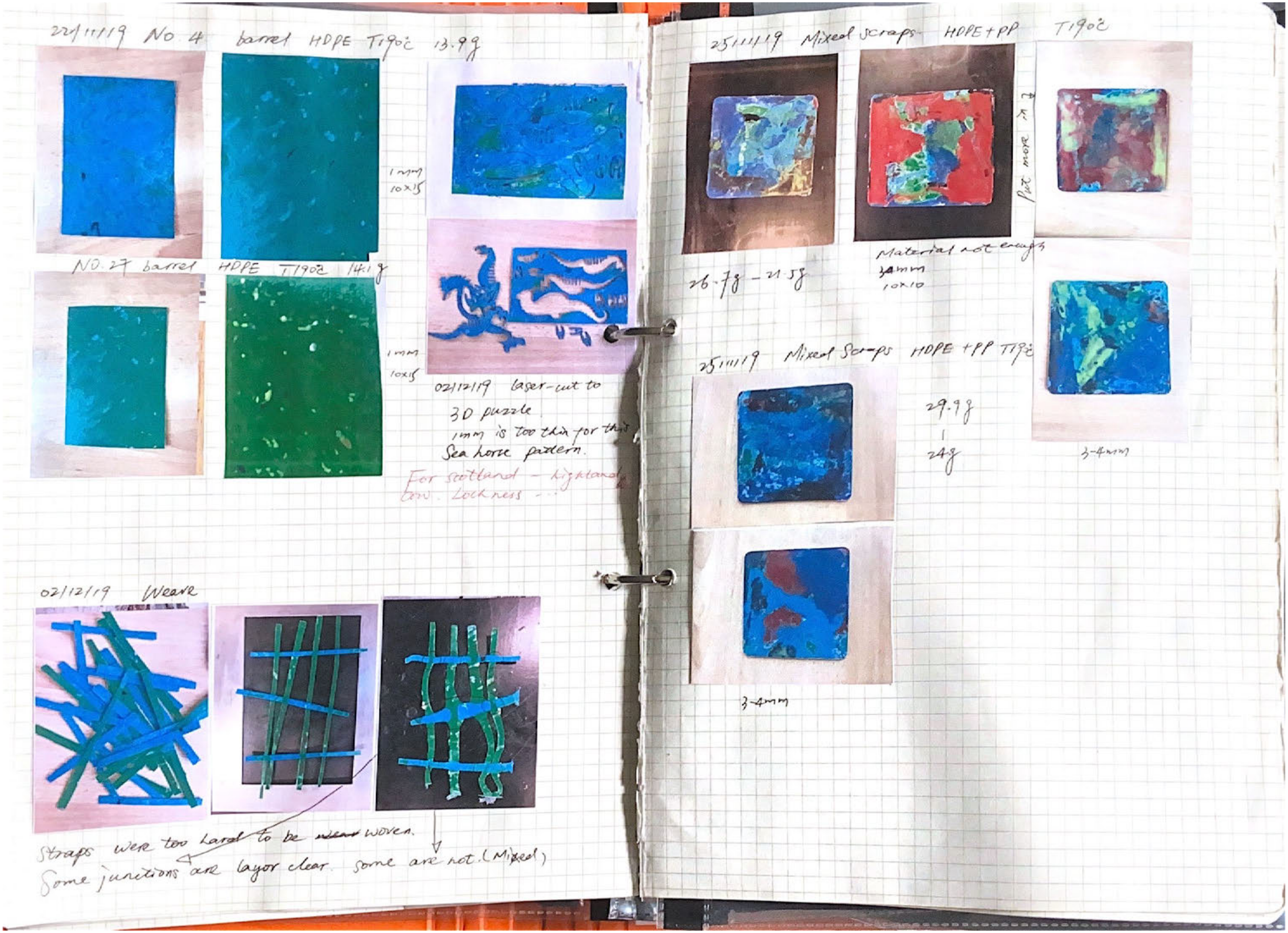

→ samples collected from Harris.
samples collected from other
English / Scottish areas
(Stevenston,
Queensferry
Devon)
25 HDPE
26 HDPE
27 HDPE
28 HDPE
11.03.2019 Field Trips
I couldn't believe my eyes
I couldn't believe what I wa
seeing. I know I saw it on
the internet and TV, but I ju
couldn't believe this was happen
in reality. But IT IS REAL!!
when I stood on the plastics a
saw them with my own eyes th
emotion kicked in harder. We
have to do something.
Ocean Plastic
Samples

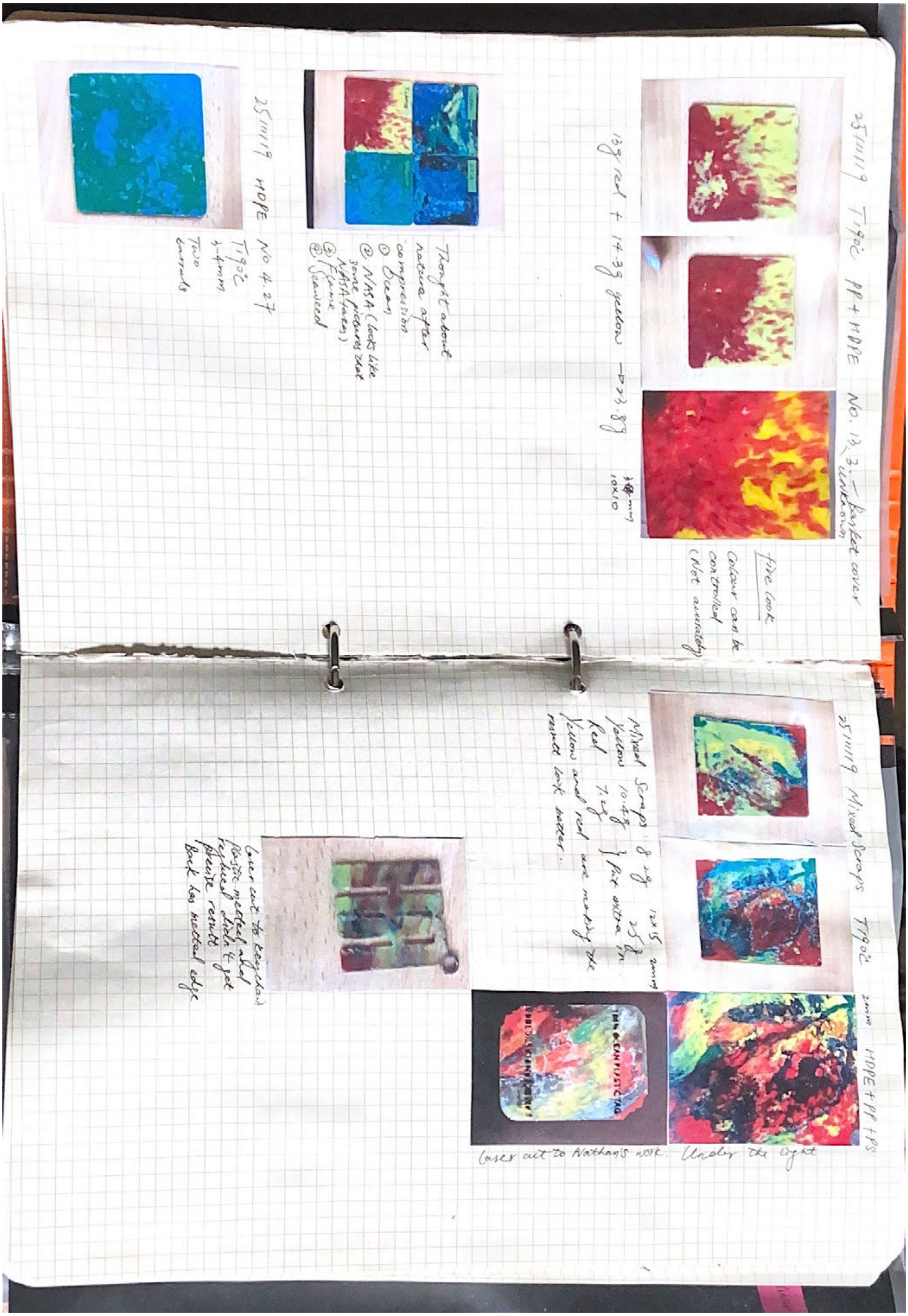

PS COMPRESSION
No 20 Polystyrene 30/09/19
Inside and outside surface
2min compression
2min cooling
used 21.2g
colour loss
scratched
dirt visible
20.8g
8x8
Under micro len
heat Compression
① close the door
② press start
③ hand up lock
④ release at the top
⑤ count for 2mins
⑥ full pressure (handle up) until 20 (watch)
⑦ unlock (red handle forward)
⑧ handle down.
cold
① start
② handle up.
③ lock
④ off
⑤ water up.
⑥ unlock
⑦ handle down
21.2g
① smell like ~~of~~ tomatoes
② smell like rotten tomato
check pattern
64.7 (ind paper)
-29.2
35.5
Strong smell out of compression machine.


06/11/19
35.2g
leaves placed on top and bottom
Planed to have the shapes of leaves on the piece, but leaves didn't come off
Smell like tomatos soup
10×13 4mm
25/11/19
Thought to CNC some of my samples. Chose the hardest one, didn't work.
Colour is to dark
Black pattern.
No smooth surface
CNC Inspiration
No.13 Polypropylene 20/09/19 T. 180℃
Used 19.8g
Got 13.1g
No strong smell.
Dirt visible
(1mm) 10×15
Contaminated in shredder
The extra part looked smooth without out colour or dirt.
Under the light.
RED
No.13. PP RED. 2min 1 mm
19.8g — 13.1g
dirt visible
Laser-cut to highland cow.
Engrave didn't show.
No.9 HDPE
Laser cut to Nathan's design for Napier Merchandising
Engrave didn't show
No13 PP

/ UNKNOWN
NO.21 & 24 HDPE
NO9 HDPE ICECUBE BOX 05/11/19 T180°C
white & black
dirt visible slightly smell
(1mm) 10x15
Used 14.3g got 14.3g smell.
used 13.7g got 12.7g
Scratched surface before shredding
lines not as neat as before but still clear.
BLUE
NO 9 HDPE 2min
23.2g − 7.0 = 16.2g − 2.5 = 13.7
12.7g smell
dirt visible
cut to straps
place on the hot plate one by one
15/10/19 NO.21 & 24 T180°C UNKNOWN PIECES
10x10 3mm
Did shred. Left as cubes
Trying to creat a check pattern
result
Not standard regular size / shape
might influence the result
When testing Melting Point the black samples showed slightly lower temperature
Might be mixed PE
blue green black
No.9 22 21&24
05/11/19 HDPE T180°C 13.5g
(1mm) 10x15
Not enough to make a single sheet
Black spreads better than other colours
Melted edge on the back
Laser cut to a leaf
Engraving didn't work
05/11/19 HDPE + PP + PS
PS didn't bond with the
Second time compression
First time
(1mm) 10x15
Under the light
Basket cover
21/11/19 HDPE NO3 . 27 .
6.4g
7.8g
7.4g
20.4g + 4g = 25.4g
First compression (4mm) 9x8
26/11/19
After the failure of laser-cut
Recompressed
Use Al sheet on one side
Result in one shiny surface and a normal matte one
20.2g + 4g new
Sample shrinks smaller than mould at 2nd compression


25/11/19
Didn't work on this thickness
Laser-cut to a keychain
Sample melted and re-glued back
25/11/19 All from Scraps contains a lot of dirt
5.2g - 5.1g
1mm
Under the light.
22/11/19
No. 25. 26. 28 HDPE & MIXED @ T180°C @ T190°C
22.2g
21.7g 2mm 12x15
Both temperatures didn't work
May not only be HDPE.
awaiting Nathan's pictures
1mm 10x15
Laser cut to Nathan's label & shoelace attached
22/11/19 15g No.3 25. 1mm. T190°C HDPE
21/11/19
Jewellery designer [redacted]
who is base in Edinburgh
She works in a jewellery studio at [redacted]
She likes the concept of using waste material but afraid to experiment it from the start
Herself
She likes neautural colours instead bold colours
She introduced some methods and tools that I could start make something myself.
6 1mm drill bit
jumpring
prue bake off
inspiration
She likes wearing colourful accessories
First 2 yellow - 24.2g
The other two around 24g
Not solid. - Next time put 25g
Will be good for making jewellery


22/11/19 No. 4 barrel HDPE T190c 13.9g
1mm
10x15
NO.27 barrel HDPE T190c 14.1g
1mm
10x15
02/12/19 laser-cut to
3D puzzle
1mm is too thin for this
Sea horse pattern.
For scotland - highland
cow. Lockness ...
02/12/19 Weave
Straps were too hard to be woven.
Some junctions are layor clear. Some are not. (Mixed)
25/11/19 Mixed Scraps HDPE+PP T190c
Put more in ?
26.7g - 21.5g
Material not enough
3-4mm
10x10
25/11/19 Mixed Scraps HDPE+PP T190c
29.9g
24g
3-4mm
3-4mm


25/11/19 T190°C PP+HDPE No. 13.3 – Basket cover
unknown
fire look
Colour can be controlled
(Not accurately)
13g red + 14.3g yellow → 23.8g
3mm
10x10
Thought about nature after compression
① Ocean
② NASA (looks like some pictures that NASA takes)
③ Flame
④ Seaweed
25/11/19 HDPE No. 4.27
T190°C
3-4mm
Two barrels
25/11/19 Mixed Scraps T190°C 2mm HDPE+PP+PS
Mixed Scraps 8.2g 12x15 2mm
Yellow 10.4g 25g
Red 7.2g } Put extra in
Yellow and red are making the result look better.
Laser cut to Nathan's work. Under the light
Laser cut to keychain
Plastic melted and reduced didn't get precise result
Back has melted edge

26/11/19 Scraps HDPE+PP+PS T190°C 2mm

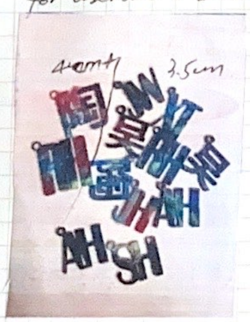
26.2g
↓
25.3g
12x5

black 1.7g
mixed scrap 3.3g
yellow 3.4g
red 2.8g
Total 26.5g → 24.3g

Too much black

① Volcano
② Magna

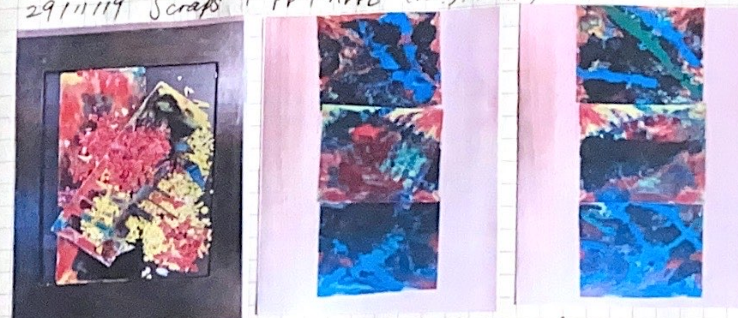
Sizes were too small for lasercut - didn't really work



4cm 3.5cm

~~4cm~~ 4cm will work better

29/11/19 Scraps + PP+HDPE (NO3. NO4)
red yellow



two sides.

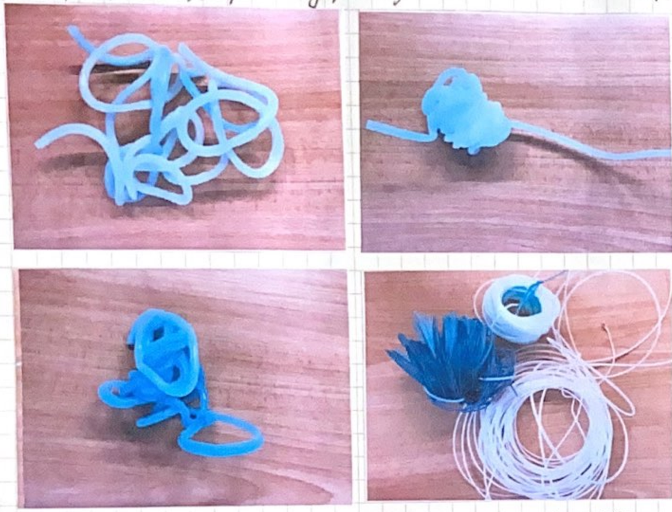
Under the light  under the light  Laser cut to keychains

The edge is still not perfect because the plastic re-glue back together after laser. PS should work better. See highland cow

Nathan's photographes for his project.

Concept - take ocean plastic back to ~~the~~ where it was from to take pictures.

02/12/19 3D printing pen filament N04. HDPE. T190°C



found first 2 pictures the shapes are interesting it was the end of producing the filament.

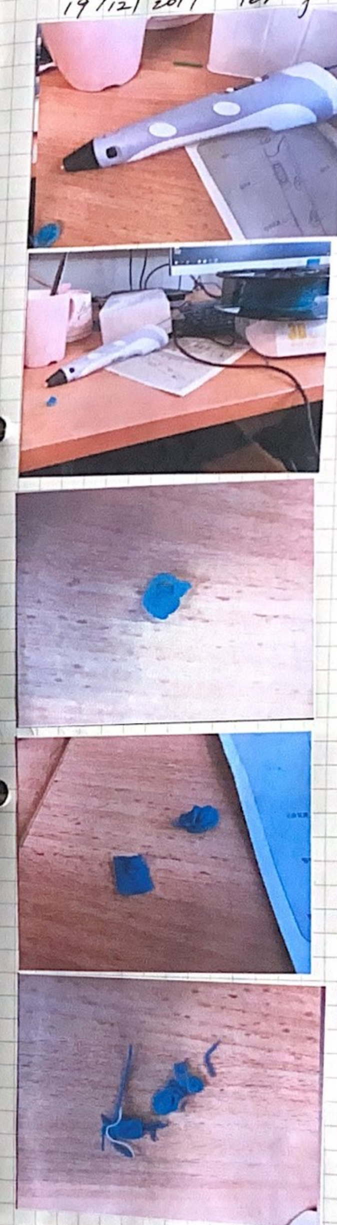
Ocean plastic HDPE (blue) + normal HDPE - white

It didn't work at the first try. recycled filament got struck in the pen.

~~It do~~ There isn't any information on its official website about what type of plastic the filament is.
Only says it's bioplastic.
Also no information about melting temperature of the pen.
Only says low temperature.

Watched YouTube videos about the 3D printing pen.
Reasons of failure
① HDPE is to easy to be melted - gears couldn't grip the filament out
② Filament's size ~~not~~ too small

19/12/2019 Testing Ocean Plastic with 3D printing pen (HDPE used)



The new 3D printing pen works better than the first one I tried

As it can adjust the temperature and speed.

It extrudes well, however, the material doesn't bond well.

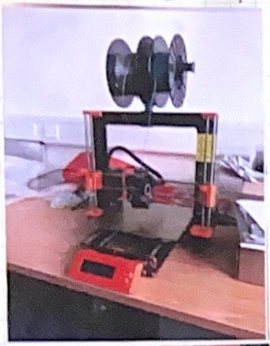
It just glue back together instead of layer up clearly.

Maybe because of the features of HDPE.

It started to extrude at around 180°C

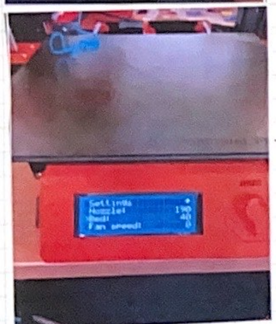
The slower the better.
(It has time to solid)

13/01/2020 Testing Prusa 3D printer



Set up

loading material

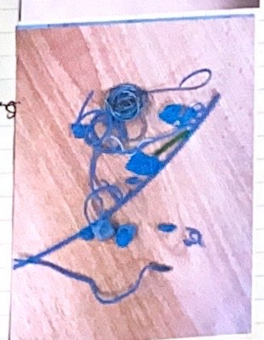


adjusted temperatures and speed

Tried to print a small simple square didn't work.

printed PLA

changed the temperature & speed.



Still no good results.

24/01/2020 NO. 21 PE(MIXED) + PLA 50/50

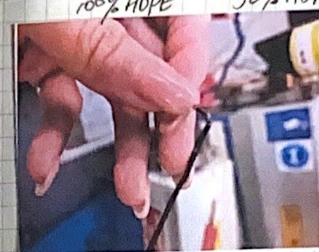
Yellow part (PP)

50/50 PE(MIXED) & PLA

More Fibrous

TEXTURE LOOKED DIFFERENT

100% HDPE 50% HDPE + 50% PLA



PLA & PE Not blended well Looks fibrous

changed settings

temperature: to higher (nozzles)

bed temperature to higher (stops it to shrink)

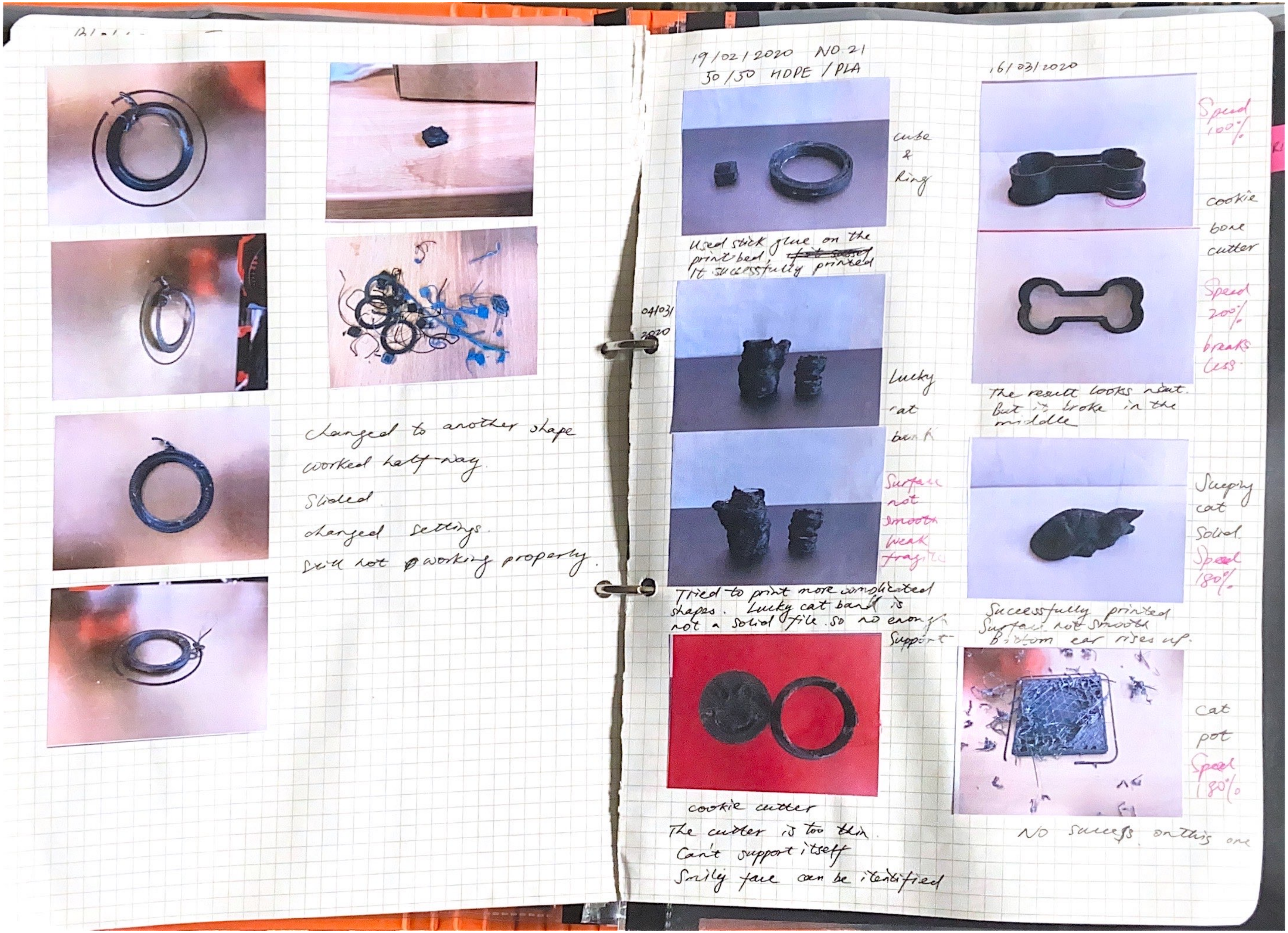
Speed to higher (stops it to cool down)

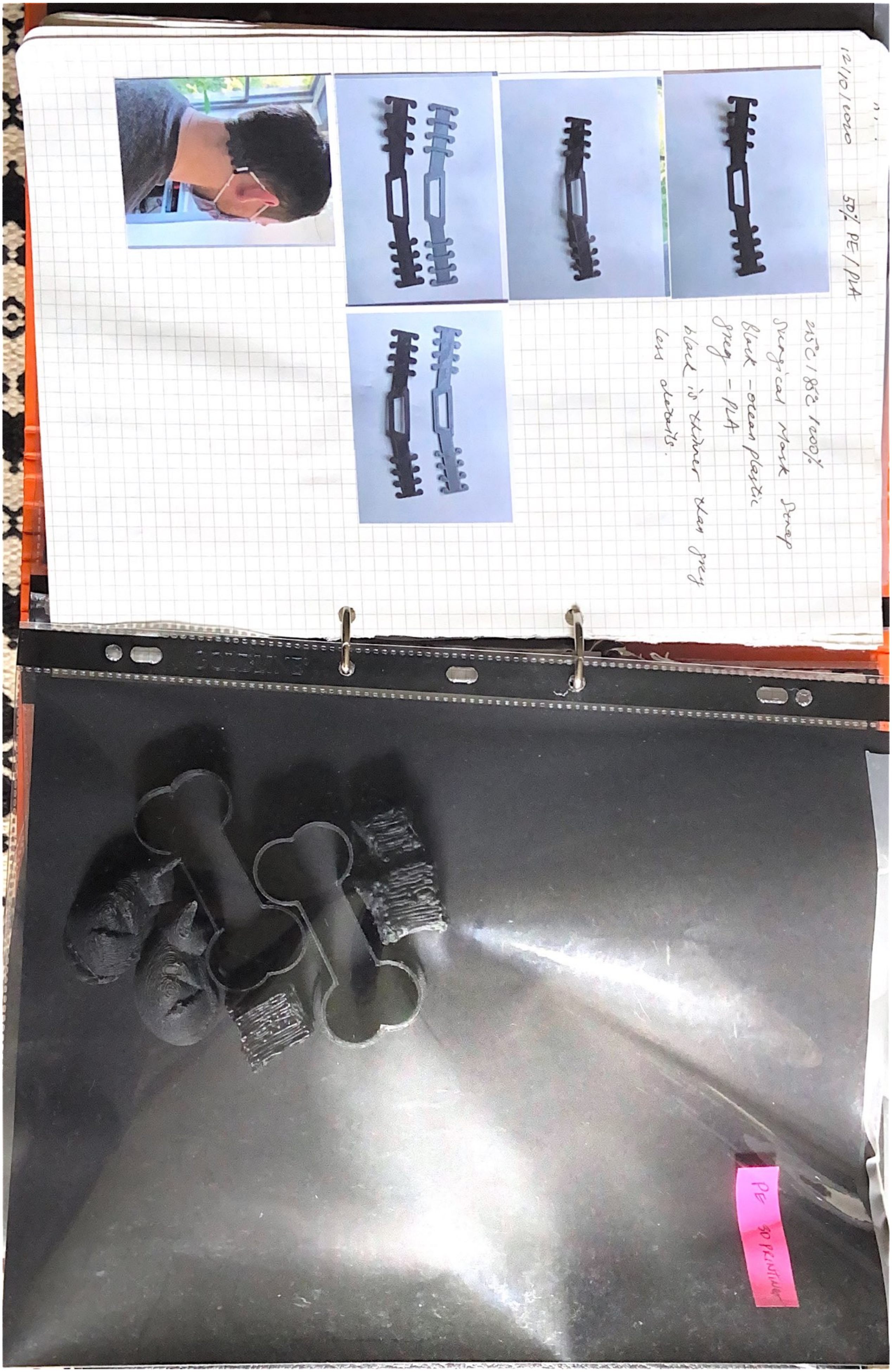
Loaded to 3D printer

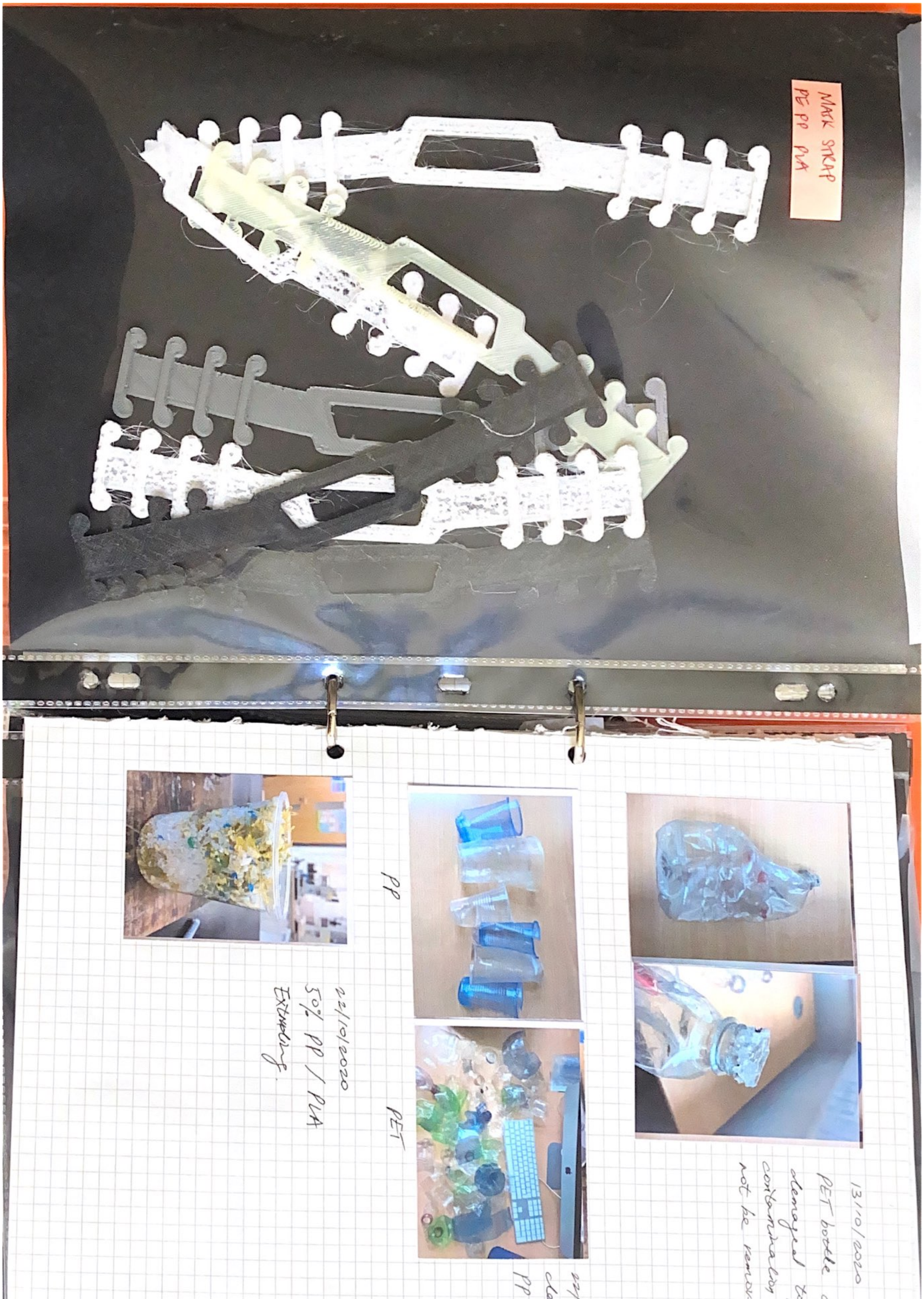
Started printing well

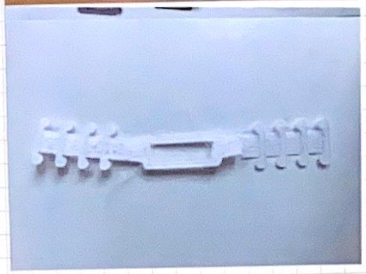
After 56% printing Started sliding and stopped working

Needed more experiments.

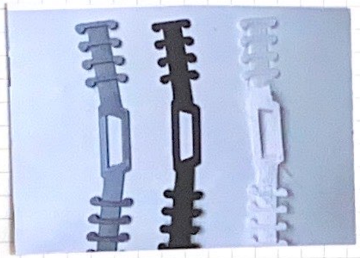

changed to another shape
worked half-way.
Stoled
changed settings.
Still not working properly.
19/02/2020 NO.21
50/50 HDPE / PLA
cube
&
Ring
Used stick glue on the print bed, It successfully printed
04/03/2020
Lucky
cat
bank
Surface
not
smooth
weak
fragile
Tried to print more complicated shapes. Lucky cat bank is not a solid file. so no enough support
cookie cutter
The cutter is too thin.
Can't support itself
Smily face can be identified
16/03/2020
Speed
100%
cookie
bone
cutter
Speed
200%
breaks
less
The result looks neat. But it broke in the middle
Sleeping
cat
Solid
Speed
180%
Successfully printed
Surface not smooth
Bottom ear rises up.
cat
pot
Speed
180%
No success on this one


12/10/2020
50% PE / PLA
215°C / 85°C 100%
Surgical Mask Strap
Black - ocean plastic
grey - PLA
black is thinner than grey
less details.
PE 3D PRINTING


MASK STRAP
PE PP PLA
13/10/2020
PET bottle details
damaged top
contamination could
not be removed.
22/10/2020
cleaning
PP / PET
PP
PET
22/10/2020
50% PP / PLA
Extruding.

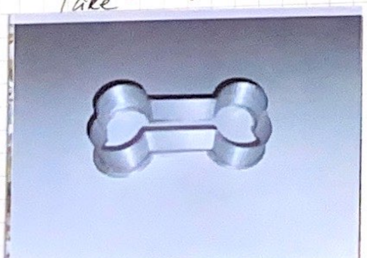
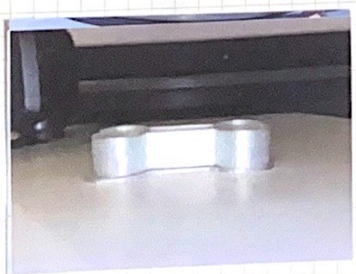
24/10/2020
50% PP/PLA
white: oceanplastic PP 50%
black: oceanplastic PE 50%
grey: PLA
Quality: grey > black > white



50%
PE/PLA
PP/PLA
filament

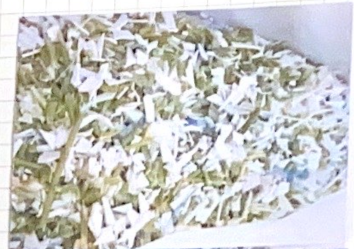

50% PP/PLA
printed cat

fabric shinier

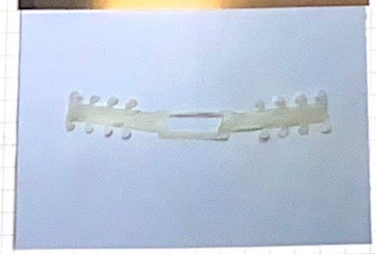



cookie cutter
break easy at the bottom.

27/10/2020 100% PP



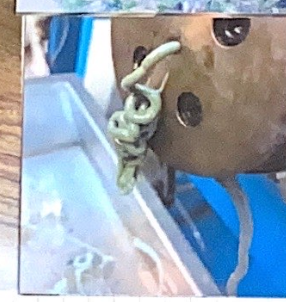
28/10/2020 surgical Mask strap

3D printing 100% PP
printable

30/10/2020 100% PET





The most difficult one to extrude.
very soft with other contamination in it.

02/11/2020 3D printing 100% PET

Extruded from printer

First attempt

Surface is not smooth (picture 1)

It's printable, but needs a lot of adjustments

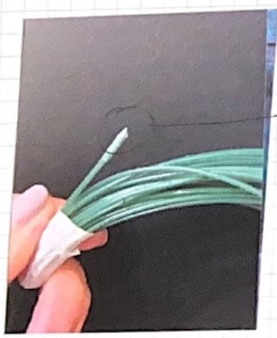
3D printer had broken down multiple times.

The filament becomes crispy in the printer and will not extrude properly most of the time.

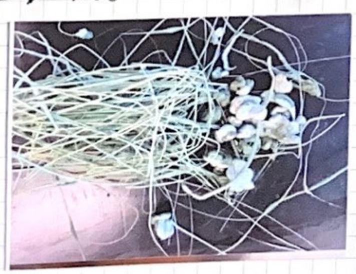
Top view

bottom view

Side view



powery / crispy
stuck in the printer.
not stable



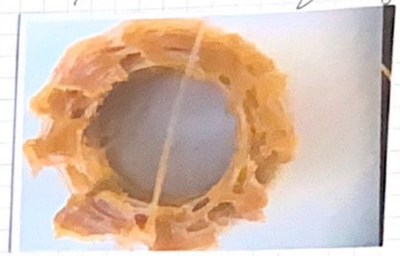
2/11/2020
Re-extruded
it won't get out the extruder properly
broken / blobs.

05/11/2020

50% PS/PLA 100% PS

printable with not precise results.

100% PS - printable, not good quality.



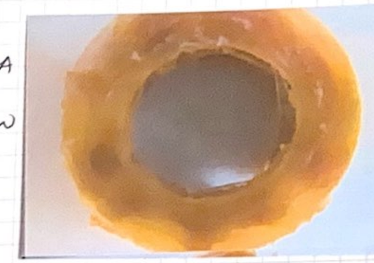
Top view

Bottom view

Side view

50% PS/PLA

Top view

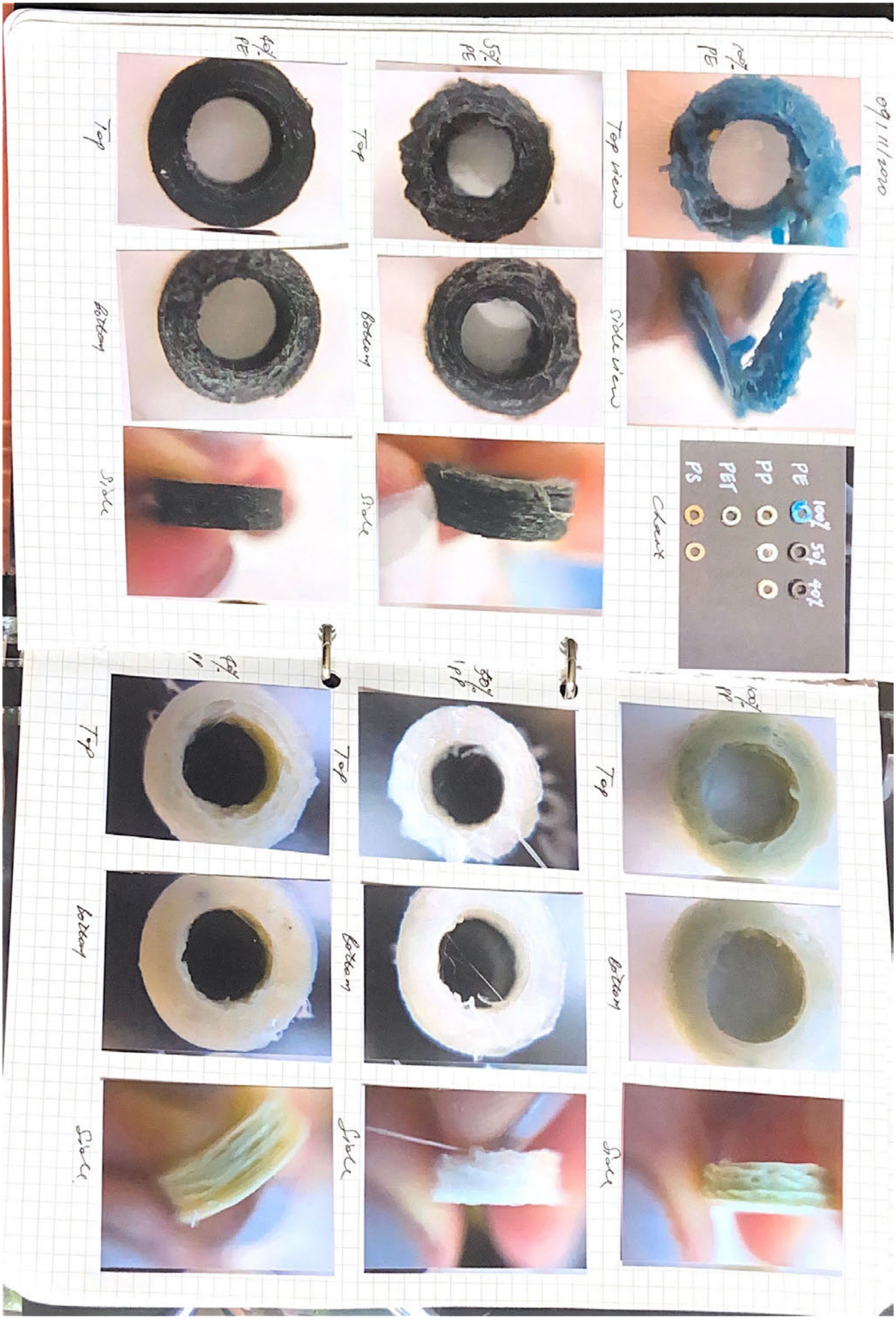


Bottom view

Side view

Side view

comparison
50% PS/PLA
&
50% PE/PLA



09/11/2020
100% PE
Top view
Side view
PE
PP
PET
PS
100%
50%
40%
Chart
50% PE
Top
Bottom
Side
40% PE
Top
Bottom
Side
100% PP
Top
Bottom
Side
50% PP
Top
Bottom
Side
Top
Bottom
Side

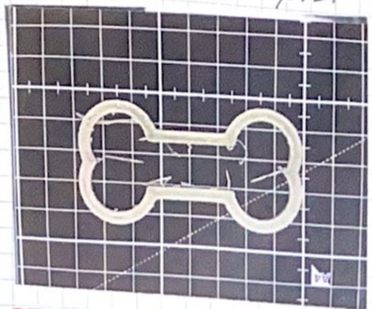

13/11/2020 100% PP
Bottom side curved up
50% PS
50% PS bone cookie cutter
Accurate shape
layers didn't bond.
easy to break.
02/12/2020 100% PS
100% PP Bone cookie cutter.
02/12/2020 40% PP
20/11/2020 compressing PET
coaster
breaks easily
compressing with PET cover
breaks easily
won't bond together
compressing
breaks easily
didn't compress well
breaks easily
PET degrades after processing
It becomes crispy / powdery
won't perform as well as other materials.

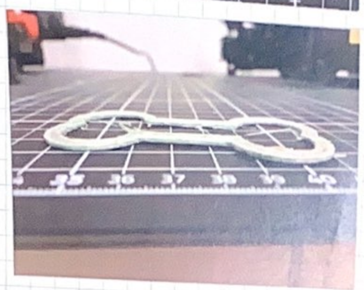

23/11/2020
PP/PE
compressing PP/PE & PE bottle tops
PE bottle caps
10mins to soften
logo & dirt visible


26/11/2020 compressing a small bowl
PP mixed with PE
26/11/2020 Baking paper compression
Baking paper on/under the mould to gain a textured surface
Result
Texture visible but the surface is not as flat as the one without the texture.
03/12/2020 3D printing keychain.
printing Scotland map keychain.
100% PP.
28/11/2020 Necklace
compression & laser cut necklace

02/~~12~~/2020 40% PE

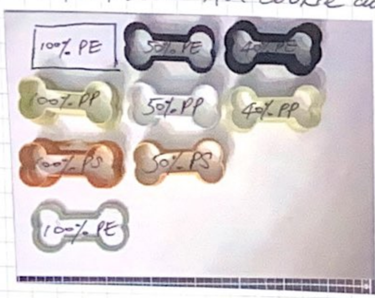
100% PET





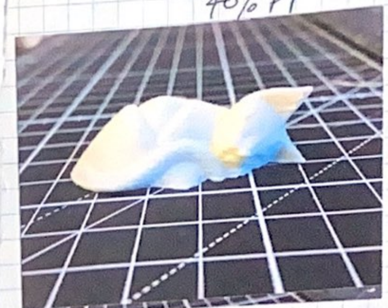
Didn't finish printing
3D printing PET isn't stable.
as the material is not
~~flex~~ fexible but powery

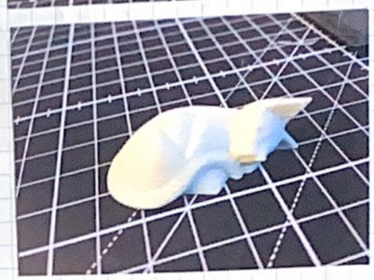
02/12/2020 All cookie cutters



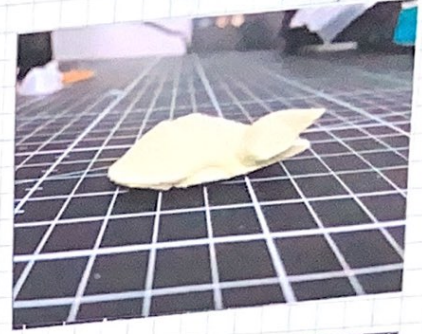

02/12/2020 3D printing cats

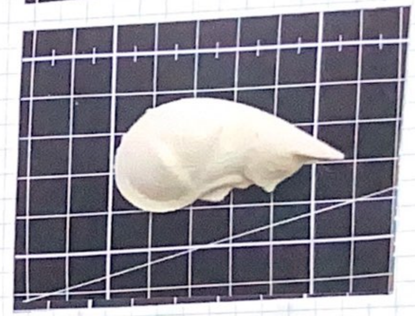
40% PP



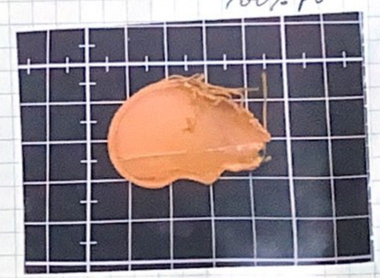


100% PP

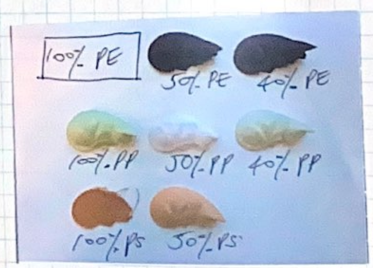




100% PS

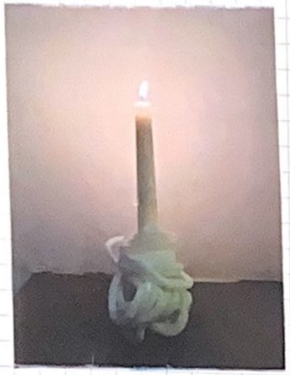


40% PE



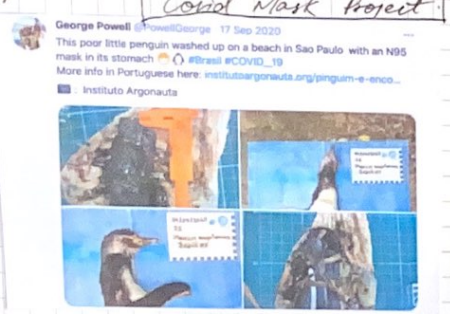

27/10/2020

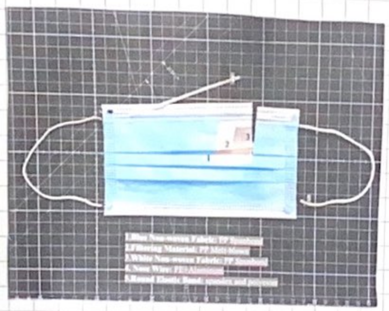
Extrusion candlestick.



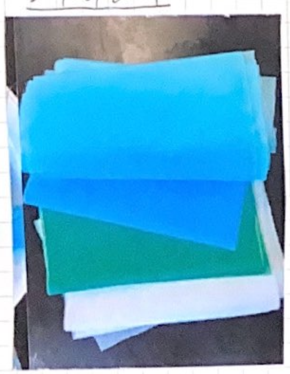
This is the leftover material from extrusion. Lyna would use HDPE to "wash" the extruder. I kept this one as it looks very unique. The inspiration to use it as a candle stick is from Studio Thier & van Daalen "the plastic mine" work. This will ~~dece~~ reduce the extrusion waste. It could also be "formed" into different shapes with different options.

Covid Mask Project



21/03/2021



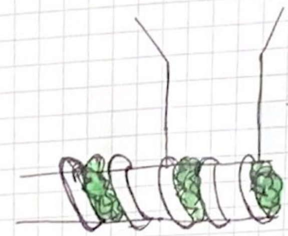
PP Meltblown Mask fabric. → cut into small pieces with scissors.

The reason why a shredder wasn't used.

- The fabrics are too lightweighted to feed through the shredder. Besides, the static electricity ~~will~~ would make the fabric stick to the inside wall.

21/03/2021

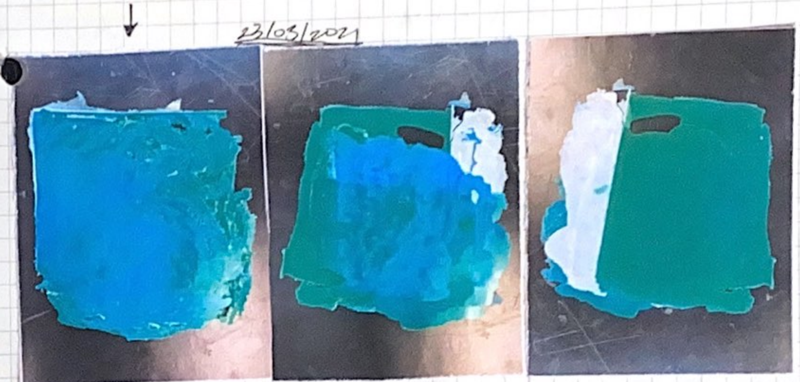
First attempt extrusion.



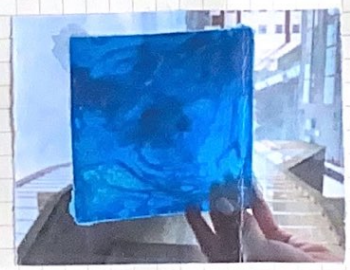

Because the fabrics were too soft, lightweighted and flexible, they would not feed in the spiral screw evenly. Therefore the extrusion wasn't stable. Shown in the picture: the diameter isn't even, partly thick, partly thin.

↓

23/03/2021



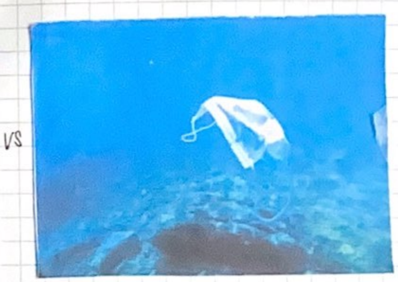
So I compressed the ~~extrusion~~ filament and all other fabrics together, then shredded the compressed ~~the~~ blocks.



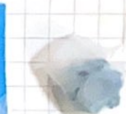
Masks to make an ocean pattern.

VS

or



Mask in the ocean?



23/03/2024
Compressing facemasks to a coaster.

The wrinkles are visible but not obvious.

Back

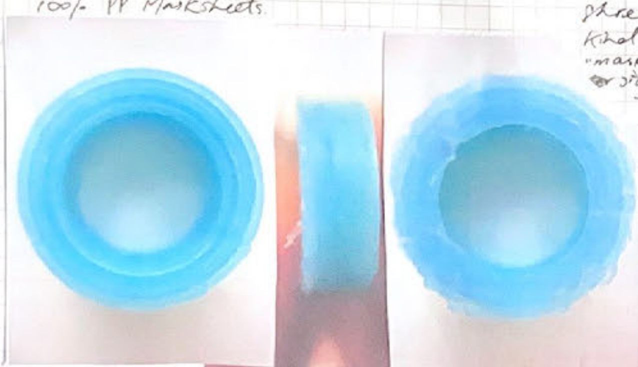
25/03/2024

Shredded from the blocks.

Extruded filament
This one is more even compared to the first one.

contamination from the shredder which kind of mimic the "masks being in the environment" situation.

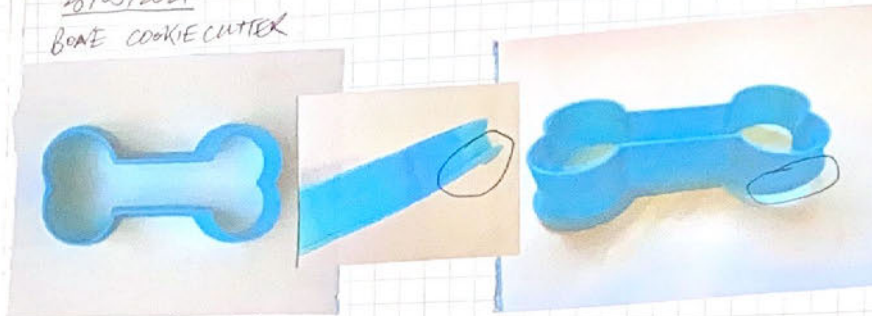
28/03/2024
100% PP Masksheets.



TOP SIDE BOTTOM

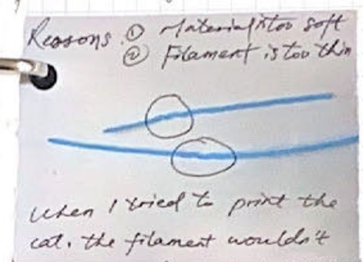
The printing process was smooth. The print was neat.
One layer wasn't adhesive enough
But the rest are good.

28/03/2024
BONE COOKIE CUTTER



completed print
warping on the bottom

One side is flat and the other side is warped.



load and it looked like this when it was unloaded.