3D-printing 'Ocean Plastic' – fostering childrens' engagement with sustainability

Introduction

Ocean plastic pollution has been described widely as one of the biggest environmental threats of our time. With approximately 5 to 13 million tonnes of plastic waste being deposited into the marine environment every year (Jambeck et al., 2015), oceanic plastic pollution is approaching catastrophic levels. As large islands of plastic waste such as the Pacific Gyre amass through the forces of intercontinental currents (Law et al., 2010) and miniscule plastic particles enter the food chain, serious consequences on the delicate ecosystems of marine life, and ultimately human health are becoming more apparent. Remote beaches in the pathway of oceanic currents, such as those on the West Coast of Scotland, become repositories for discarded ocean plastic (Barnes and Milner, 2005), with only a small percentage of the total amount being usefully repurposed by locals. The rest is left to photodegenerate, breaking into ever smaller parts and being washed back into the sea or ingested by local wildlife. Ocean plastic therefore represents an underused material resource freely available to local populations. It also represents an untapped material resource that is freely available in affected Scottish coastal areas. Applying a systemic approach to this circular process allows locals to experiment with materials and processes and discover novel ways to repair, repurpose and remake objects from ocean plastic, encouraging skill sharing and community education.

Conventional methods of recycling, such as industrial re-manufacturing or depolymerisation, are currently unviable both economically and from an environmental point of view, mostly due to the cost of collecting and transporting ocean plastic to centralised industrial facilities and quality issues connected to foreign particle contaminants having entered the plastic during its lifecycle. With the recent drive by the Scottish government to promote the circular economy model through proposing the establishment of a joint Centre of Excellence for Manufacturing and Skills Academy, where the research community, policy makers and local populations will come together to share skills, ideas and expertise, the need for a more comprehensive plastic waste strategy involving all levels of the populace becomes more pronounced (Shaxson, 2009). So far, the difficulties inherent in obtaining and working with ocean plastic have prevented a comprehensive engagement with this material in a larger context. Therefore, the concept of ocean plastic as a viable material for design, manufacturing, re-manufacturing and recycling has not been explored to its fullest degree. While companies such as Electrolux and G-Star (Howarth, 2015) have engaged with the issue on a commercial level, through utilising ocean plastic as a composite material in special editions of their products, these initiatives have proved to be economically unviable and were therefore short-lived. Individual designers such as Studio Swine (Studio Swine, 2017) have taken a more experimental approach, by focusing on the process of directly harvesting the raw material from the sea and then devising original in-situ manufacturing approaches to create thought-provoking objects that draw attention to the underlying ecological issues. In light of a growing environmental crisis, exploring alternative methods for using ocean plastic has become an imperative.

The objective of this research study is to develop a prototype model for public engagement that is based around visiting a number of beachside locations along the Scottish West Coast with small groups of school-aged children. Gathering plastic waste, in this case nylon and polypropylene rope, and taking it back to the digital fabrication workshop to clean, pelletize in combination with PLA, and extrude into plastic filament that is subsequently used to fabricate participants' own designs on an FDM 3D-printer will serve to share the material knowledge gathered in this process. This model will be both environmentally and socially sustainable. Through using flexible local collection mechanisms, with a particular focus on community involvement by including local high schools and mobile Makerspaces (places to create, invent and learn using a range of digital and manual fabrication tools) in the process, engagement at all levels of the remanufacturing process is fostered.
This study examines how field research based on the concept of participant observation could be utilized to evaluate the feasibility of conducting workshops with school-age children to use 3D-printing in an environmentally beneficial way, while also instilling passion and a sense of social and environmental responsibility within the participants. It is demonstrated how this can result in increased social capital and social trust.

Digital Craft and Learning

The idea that education should be more experiential and connected to real world objects is originally attributed to John Dewey. He asserts that:

"the conception of situation and of interaction are inseparable from each other. An experience is always what it is because of a transaction taking place between an individual and what, at the time, constitutes his environment [including the] materials of an experiment he is performing." (Dewey, 2007)

Digital making, particularly 3D-printing, engages the maker in a number of ways that differ from 'pure' hand craft or that which has been uniformly 'manufactured' by machine. According to Gershenfeld (2005:7), in their initial introduction of 3D-printing to students in 1998, "they were motivated by a desire to make things they'd always wanted to but didn't exist. The inspiration wasn't professional; it was personal. Rather, their motivation was their own pleasure in making and using their inventions". He goes on to say that "this process can be thought of as a 'just in time' educational model, teaching on demand, rather than the more traditional 'just-in-case' model that covers a curriculum fixed in advance in the hopes that it will include something that will later be useful." Gauntlett (2011:18) describes study around digital craft and 3D-printing as "primarily concern[ing] the values, applied intelligence and the feelings associated with making things by hand, as well as the need to understand how our material world works so that we can engage with it, fix it or transform it."

Creating 3D-printable Ocean Plastic Filament

For the purposes of this paper, elementary timelines and processes that happened in the *Advanced Material Labs* at Edinburgh Napier University will be summarised rather than a detailed quantitative dissemination of the results. To illustrate the environmental problem of ocean plastic to the children, some of those involved in this study were taken to two beaches on the west coast of Scotland to collect plastic that was washed up (**Fig. 1**). The plastic collected mainly constituted fishing rope (**Fig. 2**), made from polypropylene and nylon (Hunt et al. 2015). The children unwound the rope to reveal individual strands of plastic. These were pulverized before being made into new filament. The plastic strands were then laminated between sheets of PLA, turned into pellets then extruded into a filament. Two types of filament were produced; one using a regular transparent PLA compound (Ingeo Biopolymer 4032D) and another using a flexible PLA compound (Bio-Flex F2110). It was discovered that the regular PLA compound produced a filament that was more suitable for the FDM printing method, particularly when used with a Bowden-type extruder, as it produced more satisfactory printing outcomes in terms of finish and layer adherence. Experiments in the form of test prints were undertaken to gauge the optimal printing temperature of the filament.

Fig. 1: A researcher and participant retrieve some rope plastic waste on the shore near Ardrossan on the Scottish West Coast.

Fig. 2: Example of recovered rope plastic waste that was subsequently turned into Ocean Plastic PLA..

Developing a Prototype Model for Engaging Children

Once several batches of the new filament had been extruded, a workshop with a group of school-aged children was organised. The group involved included six boys between the ages of eight and eleven. The children who were not part of the previous beach combing were shown an audio-visual presentation containing pictures of the excursion as well as the process used to extrude the pulverised rope into filament. The workshop was recorded on film to capture the way in which children engaged with the material, what they thought of it, what ideas they had and to create a visual record of both what was made, as well as their behaviour when they made it. The children were given freedom to make what they wanted in response to the discussion, and were provided with a 3D-printer, a 3D-scanner, plasticine and 3D-printing pens.

When the children were told that the waste plastic collected on the beach could be turned into filament to be used in the 3D-printer, one of the children said: "So if I bring my rubbish, like old plastic bottles, can we use that to make new filament?" This question illustrates that being introduced to the idea that plastic collected on the beach could be reused to produce filament leads to further investigation to find out what else might be used. To instil the idea of vast possibilities and that what is perceived as waste in the present can be used as the raw material to create something else makes recycling seem more tangible.

In recent years, recycling has been widely adopted as a method of waste disposal, especially through council waste disposal systems (Halvorsen, 2012). However, though most people assume the role of an environmentally engaged citizen by separating their waste into different bins, their sense of moral obligation is generally limited, and so if their recycling bin is full, or if packaging requires a lot of effort to clean, waste will often be disposed of in the landfill bin (Abbott, 2017). To engage people, particularly children, on a deeper level with the concepts of repurposing and remanufacturing by providing them with a more accessible and involved experience, empowers them to gain greater insight into the transformative process of turning perceived material waste into a useable raw material. Demonstrating a clear link to environmental issues, provides a starting point for addressing these problems at their root by instilling children with an understanding of the preciousness of waste materials. This assumption is substantiated by appreciative remarks overheard during the course of the workshop: "This is so cool. We won't need bins anymore! We can use all our rubbish to make new material for the printer." This comment also conveys the excitement with which the children engaged with the possibility of creating 3D-printing filament from their rubbish. Additionally, the children who engaged with the project noted that they were more likely to both dispose of their rubbish responsibly in future as well as collect any they might find outside. This highlights the potential that this project has to inspire children to collectively take greater responsibility for the state of their immediate natural environment.

Workshop Outcomes

The workshop participants had many ideas for what they wanted to make with the remanufactured filament. These included; a Bermuda triangle, a sword, a fidget spinner, a Wall-e figurine, a toy car and a Batarang (batman's boomerang) (**Figs. 3&4**). While these items do not appear to be influenced by the process used to create the material, their choices do suggest that the material becomes irrelevant to children, as long as it fulfils a functional purpose in the way they need it to. The material becomes merely a medium with which to make objects. This is an interesting observation as it suggests that, once produced, the material plays the role of existing materials and does not assume a 'special' status. The participants used it in the same way they would use commercially produced PLA or ABS, which bodes well for its use as a longer term solution - its novelty does not hinder its appropriation.

Figs. 3&4: Examples of workshop participants engaging with sustainability through 3D-printing and displaying their outcomes.

Conclusion

The prototype model of public engagement outlined in this paper succeeded in creating a sense of meaningful engagement with the environmental issues surrounding ocean plastic in the children who participated in the beach visit and workshop. Being involved in the remanufacturing of ocean plastic literalizes the activity and removes it from being the abstraction that recycling as a broad and general term has become. Despite the process of creating the new filament being engaging and exciting for the children, it did not change the way they used it. They used it to create the same things they would make using any other commercially available 3D-printing material, which suggests its potential as a more widely-used material in future. Being involved in the process instilled a sense of responsibility in the children. As a result they are more considerate of what happens to their waste and understand that plastic waste in their environment is the responsibility of everyone and if possible they should dispose of it responsibly. As a next step, a collaborative project with a high school on the Scottish West Coast is planned, in order to explore how this prototype model could be meaningfully integrated into the national curriculum of subjects such as Craft, Design Technology, Biology, Physics or Fine Art.

Another outcome was a deeper engagement with all levels of the digital fabrication process, as well as an enhanced understanding of environmental issues generated by ocean plastic on local beaches and increased social responsibility of the participants. This prototype model can, therefore, be used widely in affected localities to create awareness and develop alternative strategies for dealing with the increasing proliferation of environmentally hazardous ocean plastic, while also actively engaging children in the remanufacturing process, which can lead to improved social capital across communities.

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